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Effect of Bus Rapid Transit System on a Modal Shift to Bus: The Case of Winget Area, Addis Ababa

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Declaration

I, Netsanet Kassahun, the under signed, declare that this research work titled "Effect of bus rapid transit system on a modal shift to bus – The Case of Winget area in Addis Ababa city" is my own original work. The work has not been presented elsewhere for assessment. This study has not been submitted for any degree or diploma program in this or any other institutions and that all sources of materials used for the thesis has been duly acknowledged.

Declared by

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Certificate Approval of Thesis

Addis Ababa University Institute of Technology

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This is to certify that the thesis prepared by Netsanet Kassahun, entitled **"Effect of bus rapid transit system on a modal shift to bus – The Case of Winget area in Addis Ababa city"** and submitted in partial fulfillment of the requirement for the Degree of Masters of science in Road and Transport Engineering complies with the regulation of the university and meets the accepted standards with respect to originality and quality.

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List of abbreviation

AACRA-Addis Ababa city road authority

BRT-Bus rapid transit

COXREG-Cox regression command

ETB-Ethiopian birr

HBE-Home based education

HBO-Home based others

HBW-Home based work t

HH-House hold

IIA-Independence of irrelevant alternatives

IID-Identically and independently distributed

ITS-Intelligent transport system

MBL-Managed bus lane

MNL-Multinomial logistic

NHBW-Non-home based work

RP-Revealed preference

SP-Stated preference

SPSS-Statistical package for the social science

TPM-Transit priority measure

TSM-Transit signal priority

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Abstract

Well-planned transportation system plays an important role in the development of the country. However, continuous increase in traffic congestion is resulted in longer travel times, increased accidents, more fuel consumption, and air pollution. Winget to Autobistera corridor is the most congested area in the city due to its proximity to shopping center and national transportation outlet. Integrating different transit priority measures Bus Rapid Transit transport system (BRT) is going to be applied in Addis Ababa. Practically, the designs of public transport systems in Addis Ababa are not based on the modal choice analysis of the target population. This research aims at estimation of the effect of BRT system on modal shift to bus, following Winget to Autobistera corridor, for the specific trip purposes.

Primary data was generated from the household survey through structured survey questionnaire. The secondary data was obtained from the concerning authorities of the Addis Ababa City Administration. Discrete choice model was used to predict and analyze travelers' mode choice for the specific trip purposes. The sample of 264 and 212 questionnaires were collected for work and education trip purposes respectively, in which 3/4th of the data were used for calibration and 1/4th for validation of the developed models. Systematic sampling technique was applied in this study. Conditional logistic regression model, special type of multinomial logit model, was used to analyze data and predict trip makers' modal shift applying statistical data processing software SPSS 21 and Microsoft excel tools.

The descriptive analysis indicates that 82.61%, 88.33%, 84.17% and 76.36% of travelers are interested to divert their choice to BRT for HBW, HBO, NHBW and HBE trips respectively. Estimation result proved time and cost related variables in addition to age-taxi interaction, income level-ride share interaction, marital status-taxi interaction, school type-lada interaction are statistically significant factors in mode choice. The developed models are validated with a predicting capacity of 88.37%, 90.56 %, 74% and 83.72 % of the preference of trip makers of HBE, HBO, NHBW and HBE trips, respectively. Applying developed models different remedial actions, scenarios, were determined to increase desirability of the bus. Stated preference model shows choice towards BRT bus decrease with the increase in travel cost, in vehicle travel time and waiting time. Moreover, household survey investigate traveler's concern towards BRT including sexual harassment, traffic accident and congestion, project delay and long bus waiting queue.

Key words: Modal shift, discrete choice model, BRT and Conditional logit model.

CHAPTER ONE: INTRODUCTION

1.1. Background

Transportation is a system in which peoples and goods are carried from one place to another. Well-planned transportation system plays an important role in the development of the country. Transportation facilities are a prerequisite for all day to day activities. At the same time, transportation causes a number of environmental problems and negative impacts on human health due to emissions, noise or vibrations. The rapid increase in auto ownership has caused several traffic congestion on the urban roads. Consequently; this resulted in social, economic, and environmental problems. Since it is challenging to prevent further growth of commuters travel policy makers are obliged to control auto trips through the implementation of proper transit priority strategies to effectively mitigate urban traffic congestion and as a result manage the environmental impact of transportation system.

In this regard, several policies and strategies have been introduced to persuade a portion of auto users to use transit services. The essence of the policies is to provide priorities for transit travel which results in modal shift from different mode of transport to buses. The Managed Bus Lane (MBL) in peak hours, providing discounts on transit tickets, increased parking fee, dedicated bus lanes and transit signal priority are a widely used transit priority strategies .Integrating different priority measures Bus Rapid Transit transport system is introduced in many cities of the world, which is going to be applied in our city Addis Ababa.

BRT is flexible rapid transit mode that combined stations, vehicles, services, running ways and intelligent transportation system (ITS) into an integrated system (TCRP, 2006). Transit priority measures are provided to improve transit travel characteristics. According to R Stewart (2013), maintaining exceptional transit services in the longer term can promote modal shifts from personal vehicles to transit. Regardless, the main idea of transit priority strategies is to either increase the cost of auto travel or reduce the cost of mass-transit travel.

This study is intended to estimate the probable mode choice shift to buses on introduction of BRT, in Addis Ababa City using an appropriate mode-choice modeling technique as assessment of the impact of the provision of BRT on roads carrying highly heterogeneous traffic flow. Modeling is a representation of the world or the representation of a system in another simplified form. Transport modeling is a simplified mathematical representation of a small part of the real world, aiming at describing and explaining travel behavior and visualizing the amount and patterns of transport (Ortuzar & Willumsen, 2004). Today transport model is serving for different purposes as: Providing traffic data for the future, analyzing the effect of alternative traffic plans/projects, providing traffic data for benefit-cost-analysis and providing traffic data for calculating the development of traffic accidents and environmental conditions.

The four step model briefly explained in (Ortuzar & Willumsen, 2004) has been widely used in transport demand modeling as a design framework. Ortuzar and Willumsen (2004) have argued that transport modeling is organized in to four basic stages (Four-stage modeling): Trip generation, Trip distribution, Mode choice and Traffic assignment. Here in this study mode choice model will be discussed further more. Mode choice models are one of tools that assist improved decision making and planning in the field of transportation (Ortuzar & Willumsen, 2011). One of the different ways to model modal split in transportation is function depends on attributes of the available modal options and the individuals. The basic concept behind this theory is that the individual selects the alternative with the highest utility value .According to this theory; the individual prefers the one modal option over all available alternatives if and only if its utility value exceeds the utility value of all the rest (Koppelman and Bhatt 2006).

Revealed Preference (RP) is based on the actual choice set of the data about actual or observed choices made by individuals. In this case the surveys involving questions regarding the current travelling attributes in a real environment (Omer Khan 2007).In Stated Preference (SP) the choice sets are situations constructed by the researcher. This technique becomes an attractive option in transportation modeling since it presents the decision- makers choice and behavioral pattern under different hypothetical scenarios. Previous studies show that total travel time, total income, ownership of means of transport, distance, age, and average family monthly income significantly affect the choice of transport modes. These factors are included in characteristics of the trip maker, characteristics of the journey or characteristics of the transport facility. Disaggregate /discrete choice modeling, which can be used to analyze and predict a decision maker's choice of one alternative from a finite set of alternatives (Kohlová & Markéta, 2008). The major factors for disaggregate modeling to be more applicable than the aggregate approach are its Predictability, reliability, transferability and their data requirement is less than for that required for aggregate one. The ultimate interest in disaggregate choice modeling is to enable to predict the decision making behavior of a group of individuals (Moshe & Michel, 1999).Logit model is a commonly used discrete choice model. Most models for travel demand forecasting are based on the assumption referred to as utility maximization theory. In utility maximization theory, utility function depends on attributes of the available modal options and the individuals. The basic concept behind this theory is that the individual selects the alternative with the highest utility value .According to this theory; the individual prefers the one modal option over all available alternatives if and only if its utility value exceeds the utility value of all the rest (Koppelman and Bhatt 2006).

1.2. Statement of the Problem

Addis Ababa is one of the cities with congested routes that result in longer travel times, lost productivity of travelers, increased accidents and worst air pollution (UNHAITAT, 2017). Almost all the residents of Adds Ababa city are suffering from transportation problem. This is because of a rapid increase of the city population and urbanization. The continuous increase in traffic congestion in the city is resulted in longer travel times, increased accidents, reduced productivity, more fuel consumption and air pollution. This problem gets a bad level in the specified study area of the city, Winget to Autobistera corridor, due to its' proximity to shopping center and national transportation outlet. The travel time of the route from Winget to Autobistera area was initially observed to be 15-25 minutes during off-peak periods and 60-90 minutes during peak periods. This makes the route one of the congested routes in the city.

This rapidly increasing transportation problem has pushed the city government concerning authority, Addis Ababa Transport Program management office, to set transit priority strategy, bus rapid transit, that cover 17.3 km all the way through Wingate-Pasteur-Autobistera-Teklehaimanot-Mexico-Kera-Jemo for improving the city transport system.However, practically, the designs of public transport systems in Addis Ababa are not based on the modal choice analysis of the target population. In transport planning mode choice analysis is a crucial issue to minimize problems related to traffic pattern, economy crises and right of way issues.

This research plans to carry out an all-inclusive participatory investigation to determine the effect of bus rapid transit system on a modal shift interest of trip makers towards the newly introducing transit system, BRT, by assessing modal choice preference of trip makers. In addition this study will be a model for the future planning of transport system as a target population mode choice analysis is not practical in the Addis Ababa city.

. Moreover, this study helps transport planner and transport service provider companies by providing real information about preference of the peoples in the study area and factors affects trip makers' modal choice in order to satisfy their transportation demand.

1.3. Research Question

The following are questions that are expected to be answered by this study.

1. What are the main factors that affect the mode choice of trip makers for each trip purposes?
2. What is the relationship between the above determined factors and available transport modes for the specified trip purposes?
3. What is the effect of BRT system on a traveler's modal shift to this newly introducing bus system?
4. What are the significant scenarios that can increase the modal shares of the public transport, bus, in the study area?
5. What are the concerns of trip makers towards the stated BRT bus service?

1.4. Objective of the study

1.4.1. General Objective

This study aims at estimation of the variation in the modal shift behavior trip makers. This is as a result on introduction of Bus Rapid Transit system, in the case of Addis Ababa city around Wingate to Autobistera corridor. Generally, the researcher aims to contribute for a better and sustainable public transportation system of the city.

1.4.2. Specific Objective

- To identify factors influencing trip makers mode choice for the specific trip purpose.
- To develop modal split model for home-based work, home-based others, Non-home-based work related and home-based education trips for available mode of transport in the study area.
- To examine the tendency to shift from current modes of transport to the stated mode of transport, BRT.
- To identify significant scenarios that can enhance the modal shares of the public transport systems in the study area.
- To investigate the trip makers concern towards BRT bus service.

1.5. Significance of the study

The bus rapid transit system is the first project in east Africa. As it is a new introduced expensive project this research is intended to estimate the probable modal shift from several available modes to stated BRT buses. Based on the finding of this research suggestion will be delivered for the city transport planners whether to extend the BRT project to other cities.

Another contribution of this research is to assess the current preference of the dwellers in the specified study area to the available transport modes. This let know public transport provider companies the actual preference of target population they providing service. As transport planner and transport service provider companies understand the preference of the resident it is one step to solve a rapidly increasing transportation problem of the study area.

1.6. Scope and Delimitation of the study

Transport planning is a four step modeling process. This process includes: Trip generation model, Trip distribution model, Modal split model and Trip assignment model. To do so transport planner should consider the traveler decision to travel, their choice of destination, their choice of mode, their choice of path or route .Modal split model is considered alone in this research. The input of the model will be generated from specific study area in Addis Ababa city planned only around Wingate to Autobistera corridor following the stated bus rapid transit system project. This study limited to home based work, home based others, non-home based work related and home based education trips. Even if earlier done researches does not consider non-home based trips as their contribution to transport modeling in lower it is included in this study.

1.7. Organization of the Paper

This research encloses five chapters. Chapter one is the introduction of the study including back ground, statement of the problem, research question, objective, significance of the study, scope and delimitation of the study. Chapter two is literature review which contains Transport planning and Modelling, Modal split model, Logit Model, Home-Based and Non-Home-based Trips, Transit Priority Measures, and also review of related studies.

Chapter three is research methodology. Chapter four is the result and discussion parts of the thesis. This contains conditional logit model for home-based work, home-based others, non-home-based work related and home-based education trips with selecting significant variable, model estimation, model calibration, model validation and also scenarios to enhance modal share of public transport. Descriptive statistics form the data of household survey is also included. Chapter five and the final part are conclusion and recommendation. This chapter presents the results of the study and finalized objective with recommendation.

CHAPTER TWO: REVIEW OF RELATED LITERATURE

2.1. Transport planning and Modeling

Transport Planning is a process of providing, operating and managing of facilities transport to achieve safer, faster, comfortable, economical and environment-friendly movement of people and goods. It involves problem definition, search for solutions and performance analysis as well as evaluation and choice of project. Transport problems have become more severe than ever in both developed and developing countries. Application of transport planning is the main gate to minimize these widely increasing transport problems. The general increase in population and transport demand has resulted in congestion, delays, accidents and environmental problems beyond what has been considered acceptable so far (Ortuzar Willumsen, 2011).These problems would go out of control unless efforts are not made in improving transportation system.

According to (FHWA, 2016), transportation congestion management is included in transport planning process. In Addis Ababa traffic congestion problem is rapidly increasing (Inhabitant, 2017), which indicate the need for transportation congestion management policies. Traffic congestion not only causes the travelers transportation problem but also adversely affects the environment and rising air pollution, (Eluru, et al., 2012.).As transit transportation system plays a leading role in minimizing transport problem and environmental impact our transport policy should enhance it.

Transport model is a simplified mathematical representation of a real transportation world. This helps at estimating the resulting traffic on the transport network together with an understanding of human behavior.

Model is used to predict changes in travel demand and utilization of the transportation system in reaction to changes in land-use, demographics and socio-economic conditions. (Koppelman and Bhatt 2006).One of the important aspects of transportation modeling is to predict the travel choice behavior. These choices include how many trips to make, where to, and what modes. Model provides a better understanding and interpreting of these complex transport systems, as it is a simplified representation. (Ortuzar Willumsen, 2004).

The rational four step model explained in (Ortuzar Willumsen, 2004) has been widely used in transport demand modeling .The approach starts by considering the study area as a network of various zones .The four models were created in the 1950s to determine the demand on the roadways.

The four step model briefly explained in (Ortuzar Willumsen, 2004) has been widely used in transport demand modeling as a design framework. According to Ortuzar Willumsen (2004), description transport modeling was organized in to four basic stages (Four-stage modeling):

- **Trip generation**: Models calculate the number of trip produced and attracted to each zone in the traffic analysis zone based on data for land use.
- **Trip distribution**: Models calculate the trip pattern connecting trip productions and attractions. Determine origin-destination matrix.
- **Mode split**: Models distribute trips from an origin to a destination to the different modes of transport.
- **Traffic assignment**: models that distribute trips to the different preferable road networks.

Here in this review mode choice model will be discussed further alone as it issue of our study.

2.2. Modal split model

Modal split models are used to analyze and forecast the choices that individuals or groups of individuals make in transportation. Typically, the goal is to predict the share or absolute number of trips made by mode. Mode choice is one of the most vital stages in transportation planning process and it has direct impact on the policy making decisions(Minal& Ch. Ravi , S., 2014).An important objective in mode choice modeling is to predict the share of trips attracted to public transportation, which is environmentally friendly.

Nowadays, mode choice modeling has a great political value to improve society's transportation demand and to introduce public transportation system. There will be no success in developing a sustainable transport policy, if the policy makers do not recognize the traveler's need for choice and demand (On Chiu Churn. et al, 2 014). However, identifying the factors that influence traveler choice towards available modes is the most challenging task. Mode choice models can be calibrated to aggregate or disaggregate zonal level data. However, According to (A. R. Mamdoohi.et al, 2014)

Transferability of aggregate model is not in acceptable range; whereas transferability of disaggregate models have relative proper response.

Since transportation planning studies are very costly, particularly due to high cost of data collection for modeling calibration and validation, model transferability could be a potential alternative [Ortuzar Willumsen, 2002]. The ability to transfer models from one city to another can help to save a precious time and money. Accordingly, Disaggregate choice model is widely used modal split model. The discrete choice models have commonly selected transport modeling for characterization of each traveller's behavior (J. Rich, et al, 2009).

The discrete model is represented by a utility maximization theory. This theory assumes that the higher the utility of choice, the greater the value and benefit which the consumer will get from it and the greater the possibility that this alternative will be preferred. Even though there are different types of discrete choice models, logit model is the most widely applicable discrete choice model as it is straight forward and simple to estimate and interpret.

2.2.1. Factors Influencing Mode choice

According to Yuanqing Wang *et. al.* (2013) travelers demographic, socioeconomic and trip related attributes were vital factors in influencing modal shift to BRTS in China and probability of modal shift to BRTS was found out. Also Ling Ding *et. al.* (2013) studied the effect of multiple transit priority strategy on modal shift of car commuters in China, the increment in parking fees and Managed Bus Lanes (MBL) had significant effect on the modal shift of car travelers. But discount in travel fare was unable to push car commuters shifting. According to utility theory modal shift occurs when one mode gains a comparative advantage over another in the various forms such as costs, comfort, time, flexibility or reliability. The relative importance of each of these factors varies depending on a kind of passengers , their socio-economic characteristics and purpose of trip etc.(Khaki*et al.* 2009).Traveler modal choice is generally a function of three basic factors: characteristics of the journey, characteristics of the traveler, and the modal attributes (Ashu S.

Kedia& B.K. Katti, 2014).Generally, previous studies investigated the relationship between the characteristics of travelers, trips, and transport facilities, with the individual's transport mode choice behavior. Researchers found that, there are three basic factors influencing individuals' mode choice behavior.

(1) Characteristics of Trip makers

- traveler's background,
- Household structure (age, number of employed, couple with children, singles, etc.)
- Income level
- vehicle ownership(0, 1, 2+),
- availability of vehicle choice;
- Possession of a driving license
- Need for car for something else (at work, take children to school, etc.)

(2) Characteristics of the trips

- purpose of the trip(frequent or rare work trips are often easier to undertake by public transport than other trips)
- Time of day(late trips are difficult to accommodate by public transport)
- trip distance;

(3) Characteristics of the transport facility

a) Quantitative factors

- Relative travel time;
- in-vehicle, waiting and walking time by mode
- Relative monetary costs (fare, fuel, parking ,toll/road pricing)

b) Qualitative factors

- Comfort and convenience
- Reliability and regularity
- Protection, security

These characteristics could be interrelated with each other directly or indirectly. However recent studies focus only on correlation between the individual choices of transport mode and these individual characteristics.

2.2.2. Revealed and Stated Preference

The **stated preference** discrete choice technique relies on respondents making choices over hypothetical scenarios. Conversely, **Revealed Preferences** techniques use observations on actual choices made by people to measure their preferences towards the present scenarios. These two approaches are able to provide data set for the development of disaggregate travel demand models. Revealed preference defines the current observed situations, which has limitations in expressing policies in terms of changes in attributes, in order to assess the feasibility of project (Ortuzar&Willumsen, 2011).The stated preference techniques over comes the non-hypothetical behavior of revealed approach. As a result it becomes attractive approach in transportation modeling since it presents a different hypothetical scenario that helps for policy makers. Conversely, stated preference approach sometimes leads to overestimation.

2.2.3. Aggregate and Disaggregate Modeling

Mode choice models can be calibrated to aggregate or disaggregate data. Aggregate models attempt to represent the average behavior of a group of travelers instead of a single individual (Minal& Ch. Ravi, 2014).Studies indicates that aggregate transport models are poor in flexibility, accuracy and transferability. Aggregate models are subjected to errors and overestimations due to its reliance on aggregated group data rather than individual records. Disaggregate model represents the Individual responses towards available modes as a function of the characteristics of the alternatives available and socio-demographic attributes of each individual.

As compared to aggregate which reflects and depends on zonal or group characteristics disaggregate approach captures individual characteristics. According to (Ortuzar&Willumsen, 2011) disaggregate models offer significant advantages over the aggregate models; however, they demand quite a high level of econometric and statistical skills for their use. Disaggregate models advantage over Aggregate models:-

Prediction ability: - Empirical evidence indicates that disaggregate mode choice models have the ability to simulate the phenomenon under study and to produce reliable forecasts for future planning purposes.

Efficiency: - Disaggregate models are based on the observable behavior of individual decision-makers. Therefore, statistically, they are efficient.

Reliability: -Disaggregate parameter estimates in model calibration process are more reliable than the aggregate estimates derived from the same data.

The transferability: - Based on the assumption that people with similar characteristics and under similar circumstances behave similarly, disaggregate models have potential for transferability. **Data requirements: -** Disaggregate data contain more information than aggregate data and are therefore more valuable for calibration purposes. Moreover disaggregate models can be developed by using data less than one tenth of the data required by aggregate models.

2.2.4. **Different types of Modal choice modeling**

Mode choice is one of the most fundamental stages in transportation modeling process and it has significant impact on the policy making decisions. According to,(Minal and Ravi ,2014) Mode choice analysis techniques are broadly classified into statistical mode choice models such as multinomial logit and probit models and soft computing techniques such as Artificial Neural Network models (ANN) and Fuzzy approach model .Modeling of mode choice is done by means of discrete choice model (Ben-Akiva and Lerman, 1985).

Discrete choice model is selecting from different available alternatives based on utility theory. Mode choice analysis help transportation planner and policy makers to know the existing state of transportation system and forecast the future needs of commuters in the course of insight their preferences.

Based on the assumption of random component the statistical mode choice method are categorized as; multinomial logit (MNL), nested logit (NL), multinomial Probit (MNP), and generalized extreme value (GEV) models. Multinomial logit model is the simplest discrete choice model developed under the assumptions; the random components of the utility function are extreme-value (or Gumbel distributed), the random components of the utility function are identically and independently distributed across alternatives, and the random components of the utility function are identically and independently distributed across observations/individuals (Koppleman& Chandra, 2006).

The nested logit model is based on the assumption that the random component is identically, non-independently distributed with type-1 extreme value distribution and it allows the estimation of probabilities among selected modes prior to the estimation of proportions between modes (Minal& Ch. Ravi , 2014). Generalized extreme value models relax the assumption that the error component is independently distributed across alternatives allowing the random components of the alternatives to be correlated. Models that belong to this class result in closed form expression of the choice probabilities which makes estimation possible without estimation (Chandra Rabat, 2000).

MNP Model makes its formulation on the flexibility of the probit model in handling correlations over alternatives and time is its main advantage.

Its only functional limitation arises from its reliance on the normal distribution. In some situations, unobserved factors may not be normally distributed (Kenneth, 2009). The most recent modeling techniques that researchers developed are with the use of soft computing techniques; artificial neural network (ANN), fuzzy logic and hybrid models which are the combinations of ANN and fuzzy logic. ANN is the essential component of intelligent technique which is prominent for its powerful information processing ability. Neural network provides the capability without the complication of having to formalize all the complex causal variables and relationships which other models (Juan Li, et al., 2010). Generally, the major constraints, drawbacks and levels of accuracy of the different modal choice modeling techniques are as summarized in the Table 2-1 below.

Table 2.1: Comparison of Various Mode Choice Models

Model Name	Basic Hypothesis	Major constraints	Major Drawbacks	Accuracy	Examples
Logit model	Extreme value distribution (Type I GEV).	Error term should be identically and independently distributed (IID).	Suffers from IIA assumption.	High	Al Ahmadi (2006); Mukala and Chunchu (2011)
Probit model	Normal distribution.	Error term is non-identically and non-independently distributed.	Difficult interpretation of results. Computational problems.	Low	Bhat and Sardesai (2006); Can (2013)
GEV model	Multivariate extreme value distribution.	Independent, but not identically distributed error terms.	Perceived utility of any alternative should not exceed an upper bound.	Low	Bhat (1995)
ANN model	Inspired by Human Neural system.	Performance depends on *Architecture, Training* and *Activation function*.	Difficult to interpret the result in terms of natural language.	High	Edara (2003); Cantarella and De Luca (2003); Xie and Parkany (2003); Ravi Sekhar (1999)
Fuzzy Set Theory	Based on underlying assumption of Commensurability.	Input Values should be fuzzy.	No learning ability and difficulty in deciding Membership function (*Tuning*).	High	Deb (1993); Kalic and Teodorovic (1999)
Neuro Fuzzy model	ANN and FIS models complement each other.	Pre-processing of input training data is required.	Lack of common framework, different NF models can't be compared.	High	Rao and Sikdar (1999); Yaldi et al. (2010)

Source: (Minal& Ch. Ravi , 2014)

Mode choice Modeling can be approached in two ways: aggregate modeling and disaggregate modeling. Disaggregate approach is widely used as it can capture the individual characteristics in a much better way compared to aggregate models that depend on zonal characteristics. Disaggregate mode choice models are of three types namely: Logit model, Probit model and General extreme value model (Minal& Ch. Ravi , 2014). Amongst all the three models, Logit models have found the most application in choice models because of simplicity and easy interpretation of results. It also has comparatively reasonable accuracy.

Estimation of parameters of model is done by two techniques, Maximum likelihood and Least squares methods. The maximum likelihood is the most common technique used in determining the estimators for simple and nested logit model. The data required for modeling is collected through surveys like household survey, workplace survey, destination survey, and intercept survey. Sampling from the data set is also a crucial step and should be done carefully. The model specification for mode choice should be done on case specific basis. Suitability of the model selected should be decided first so that the entire process starting right from data collection to analysis and interpretation can be carried out in a very planned and streamlined manner.

2.2.5. **Discrete mode choice model**

Disaggregate mode choice models are of three types namely: Logit model, probit model and General extreme value model. The major difference between these models basically is the distribution of the error term. Comparison of common mode choice models briefly explained in table 2.1 below.

Table 2.2: Comparison of common mode choice models

Model Name	Logit Models	Probit Models	General Extreme value
Basic Hypothesis	Extreme value Distribution	Normal distribution	Multivariate extreme value distribution
Major constraints	Error term should be Identically and Independently Distributed (IID)	Error term is non-identically and non-independently distributed	Independent, but not identically distributed error terms.
Model Formulation	Simple	Simple	Complex
Model Estimation	Simple	Simple	Complex
Introduction of Access modes	Model formulation and calibration becomes complex to a small degree	Model formulation and calibration becomes highly complex	Model formulation and calibration becomes highly complex
Application	High	High	Limited
Accuracy	High	Low	Low

Source: (Omer Khan 2007)

As mentioned earlier the logit models are derived from the assumption that the random parts of utility functions are independent and identically independently distributed. This assumption gives a great advantage in calculating the choice probability functions. It makes the calculation very simple and easy.

2.3. Logit Model

Logit models are based on the assumption that the random parts of utility functions are independent and identically independently distributed. This assumption gives advantage in calculating the choice probability functions over other models. It makes the calculation very simple and easy. However, this property is now professed as a disadvantage which makes the model fail in the presence of correlated alternatives (Ortuzar&Willumsen, 2011). Even though it has fail in the presence of correlated alternatives logit models have found the most application in choice models because of simplicity and easy interpretation of results. It also has comparatively reasonable accuracy (Omer Khan 2007) .Taking this into account logit model will be in use in this study.

According to (Koppelman and Bhatt 2006) ,the probability of an individual selecting a mode n, out of m number of total available modes is given as,

$$P_{in} = {exp\ (V_{in})}\Big/{\sum_{n \epsilon M} exp\ (V_{im})}$$

Where:

V_{in} is the utility function of mode n for individual i;

V_{im} is the utility function of any mode m in the choice set for an individual i;

P_{in} is the probability an individual i selecting mode n;

m is the total number of available travelling modes in the choice set for individual i. Depending on the available choice set logit models are classified as: Binary logit model (When the choice set contains only two alternatives and no hierarchal relation between modes),Nested logit model (allows a correlation between the utilities of the alternatives in common groups and hierarchal relation)and

Multinomial logit model (the number of alternatives available in the choice set which is more than two) (Minal et al,2014).

2.3.1. Utility Theory for Discrete Choice Model

Logit models are based on the theory of utility maximization. In a discrete choice, an individual chooses a single alternative, which maximizes his or her utility, from a choice set of finite number of mutually exclusive alternatives (Khan, 2007).The utility maximization theory states that, an alternative, 'i', is chosen, if and only if the utility of alternative, 'i', is greater than or equal to the utility of all alternatives, 'j', in the choice set, .According to (Minal& Ch. Ravi , 2014) Utility function has two components called deterministic and Probabilistic. Where deterministic component represents the portion of the utility observed by the analyst, and probabilistic or error component is the difference between the unknown utility used by the individual and the utility estimated by the analyst, represented by ε:

$$\boldsymbol{U_{it} = V_{it} + \varepsilon_{it}}$$

Where:-

U_{it} is the true utility of the alternative i to the decision maker t,

V_{it} is the deterministic or observable portion of the utility estimated by the analyst that affects choice, and

ε_{it} is the error or the portion of the utility unknown to the analyst that affect choice.

The random-error term ε is assumed to be independently and identically distributed as per the Gumbel distribution.

2.3.2. Method of testing and comparison of models

Checking signs of parameters

This is an informal test that is intended to examine the reasonableness of the signs of estimated parameters. The most common test includes test of the estimation results to assess the signs of the estimated parameters with theory, intuition and judgment based on the expected impact of the corresponding variables (Essam & Sadi , 2013). For example, it is logical for signs of time and cost related parameters to be negative because the utility of the alternative will decrease with an increase of travel time and cost.

Over all goodness of fit measures

The value of rho-squared measurements lies between 0 and 1. A value of zero implies that the model is no better than the base model; whereas, a value of one implies a best model, (Koppleman & Chandra, 2006).

i. $\rho 0\ 2 = 1 - \frac{\mathrm{LL}(\beta)}{(\mathrm{LL}(0)}$; measures explanatory power of the model relative to a model with all the parameters zero where LL(β) is the log likelihood of the estimated model or the model at convergence and LL(0) is the log likelihood when all the parameters are zero.

ii. $\rho c\ 2 = 1 - \frac{\mathrm{LL}(\beta)}{(\mathrm{LL}(c)}$; measures how the estimated model explains the preference of modes relative to the constants only or intercept model. LL(c) is the log likelihood of the constants only model.

Basically, this rho-squared value measures the explanatory power of the discrete choice model. Rho-squared even with small values can be significantly different from zero, implying that the model has statistically significant explanatory value.

The basic problem with these measures is that they improve no matter what variable is added to the model independent of its importance. Replacing the rho-squared measure with an adjusted measure which takes into account the degree of freedom of the model is one approach to such problem (Koppleman & Chandra, 2006).

iii. $\rho 0\ '2 = 1 - \frac{(\mathrm{LL}(\beta) - \mathrm{k})}{(\mathrm{LL}(0)}$; is the adjusted rho-squared measure with respect to the zero models where K is the degree of freedom or number of parameters in the estimated model.

iv. $\rho c\ '2 = 1 - \frac{(\mathrm{LL}(\beta) - \mathrm{k}\ )}{(\mathrm{LL}(c) - k')}$; is the adjusted rho-squared measure with respect to the constants only model where K’ is the degree of freedom or number of parameters for the constants only model (Koppleman & Chandra, 2006).

Tests for the individual parameters

The null hypothesis in most software packages is that the parameter is equal to zero. In cox regression, too, Wald statistics is used to test the null hypothesis that a parameter is zero by measuring the statistical significance of the parameter, with the following formula.

$$\text{Wald statistic } = \frac{\beta}{\text{S.E}}$$

Where;

β is the covariate regression coefficient (parameter) estimated value and

S.E is the standard error associated with the parameter.

SPSS results in a P-value for the null hypothesis that the parameter is zero. For 95% confidence level, if the P-value is less than 0.05, the null hypothesis is rejected which means that the estimated covariate significantly improves the fit model. P-values greater than 0.05, provided 95% of level of confidence, imply that the variable does not contribute significantly to the explanatory power of the model and can be excluded (Essam & Sadi , 2013).

Tests for the entire model

a. Log likelihood ratio test: nested hypothesis test

The log likelihood ratio test is used to compare two models provided that one is the restricted version of the other by formulating a test statistics. If all the restrictions that distinguish between the restricted and unrestricted models are valid, it is expected for the difference in log-likelihood values at convergence of the two models to be small. If some or all of the restrictions are invalid, the difference in log-likelihood values of the two models will be sufficiently large to reject the hypothesis (Koppleman & Chandra, 2006). The test statistics is;

$$\chi 2 = -2 * (\text{LLR} - \text{LLU})$$

Where

LLR is the log likelihood of the restricted model at convergence and

LLu is the log likelihood of the unrestricted model at convergence.

The test statistics is chi-squared distributed with critical chi-squared ($\chi 2$) values for different level of confidence by number of restrictions. Critical chi-squared value is referred in Appendix.

b. Non-nested hypothesis test

This model test is used to compare two rival models that do not have those types of restricted and unrestricted type of relationships as in log likelihood ratio tests, and with equal numbers of parameters. In non-nested hypothesis, the null hypothesis states that the model with the lower adjusted likelihood ratio index, $\rho_0{}'^2$, is the true model.

The null hypothesis that the model with the lower $\rho 0\ '2$ value is the true model is rejected at the significance level determined by the following equation (Koppleman & Chandra, 2006). The null hypothesis will be rejected if the calculated significance level is less than 0.05 for 95% confidence level.

$Significance\ level = [-(-2* (\rho_H{}'^2 - \rho_L{}'^2) * LL\ (0) + (K_H - K_L))^{0.5}]$

Where;

$\rho_H{}'^2$ and $\rho_L{}'^2$ are the adjusted likelihood ratio index at zero with the higher and lower value,

LL (0) is the log likelihood of the models at zero

K_H and K_L are the numbers of parameters in the models with higher and lower $\rho 0\ '2$ value, respectively.

Φ is the standard normal cumulative distribution function.

2.3.3. Model specification, calibration and Validation

Model specification

Model specification refers to the determination of which independent variables should be included in or excluded from a regression equation. In this study, with an assumption of individuals prefer the mode that maximizes their utility (U), model specification is based on the utility theory. Depending on utility maximization theory we can predict or forecasting preference changes that will occur when an attribute of one of the alternatives changes. According to previous studies utility based models able to capture differences in the responses of different individuals to the same attribute change.

Model Estimation or calibration

Logit model development involves finding the values of parameters of different variables that specified in each utility function by fitting the models to the collected data using different methods. In estimation parameters can be considered non-significant and omitted from the model. The least square method works for linear models only, and may result in incorrect values if used for the estimation of complex models like choice models (Essam Sadi , 2013).For logistic regression, least squares estimation is not capable of producing minimum variance unbiased estimators for the actual parameters. In this study, maximum likelihood estimation is used to solve for the parameters that best fit. Accordingly; the maximum likelihood method is accurate and practical for the estimation of modal choice models.

Maximum Likelihood Estimation (MLE)

Maximum likelihood is a widely used technique for estimation with applications in many areas including time_series_modeling, panel_data and discrete data. According to (Omer , et al., 2004),Developing likelihood function, joint probability density function and estimating parameter values which maximize the likelihood function are two procedures involved in maximum likelihood estimation. The likelihood functions for a sample of 'N' individuals, each with 'i' alternatives as follows;

$$L(\beta)=\prod_{n=1}^{N}\prod_{i}(P_{ni})^{y_{ni}}$$

Where:

$y_{ni}=1$, if a person n chose I alternative and y_{ni} is zero otherwise and

P_{ni} is the probability that individual n chooses alternative i.

The values of the parameters which maximize the likelihood function are obtained by finding the first derivative of the likelihood function and equating it to zero. Since the log of a function yields the same maximum as the function and is more convenient to differentiate, we maximize the log-likelihood function instead of the likelihood function itself.

Methods of model validation

Evaluating the calibrated model its ability to predict modal split for data other than used for calibrating the model is one of the essential stages of modeling. There will be samples prepared for both calibrating and validation of models; the two samples shall be samples from the same population but at the same time are distinct and independent from one another. With the fitting sample we are evaluating how well the model fits the data on which it was developed and for the validation sample we evaluate how valid the model is as it attempts to predict an independent sample (Rosa &Luigi, 2003). One of the methods of validation is the test of reasonableness of the signs of parameters in the model. In this method, models with opposite signs of parameters from the expected sign are to be eliminated. Usually this phase is completed during comparison of models in the calibration process. The data that was reserved for validation (one third or one fourth of the data used for calibration of the models) will be used to predict the mode choice of the trip makers using the calibrated model.

2.4. Home-Based and Non-Home-based Trips

Home based trip is trip having either origin or destination at trip-makers home .Conversely, Non-home based trips are trips neither origin nor destination at trip-makers home. On home-based trips were not considered in earlier done researches as their contribution to transport modeling is judged insignificant. On-home-based (NHB) trip making typically accounts for 25 to 30 percent of travel by individuals in urban areas (*G.W. Schultz and W. G. Allen, 2018).*Non-home based trips are chain of Home based trips. By examining this chain more closely, NHB will be considered is this research as to consider its chaining role in transport modeling.

According to (*G.W. Schultz and W. G. Allen, 2018),*By examining the entire chain that includes an NHB trip, it is possible to develop a more detailed description of NHB trip making by categorized into three classes as:

(a) Journey to/from work (NHBJTW), which are non-home-based trips made while a person is either going to work or coming formwork;

(b) At work (NHBWRK), which are non-home-based trips made while a person is at work, such as a trip for lunch; and

(c) Network (NHBNWK), which are non-home-based trips that have no connection to the person's place of work.

2.5. Transit Priority Measures

Transit priority system is an introduction of either single or integrated priority strategies to make transit mode of transport more attractive than another modes. Transit Priority Measures (TPMs) are techniques that are used to reduce delays for mass transports on congested roads. This strategy is an intervention that provides transit vehicles a competitive advantage over other modes, it can be physical or policy related restrictions. They can include a wide variety of treatments, ranging from modification of traffic signal to the addition of dedicated bus lanes. Transit Priority Measures prioritize the movement of mass transport systems over other vehicles in the transportation network, making public transit service more efficient and reliable for users and providing encouragement to take the bus rather than driving. The most Common transit priority measures are Queue Jump Lane, Transit Signal Priority and Dedicated Lanes. Maintaining exceptional transit services in the longer term can promote modal shifts from personal vehicles to transit." (R. Stewart, 2013.)

According to Stewart, TPMs can be grouped into the following three general categories:

1. **Regulatory Measures:** These measures include, but are not limited to, vehicular lane use restrictions, time-of-day or part-time reserved transit lanes and on-street parking restrictions. It is space (lane) and time specific restriction regulatory system and also a policy related measure.
2. **Transit Signal Priority (TSP):** These include techniques to provide priority for transit vehicles at signalized intersections. They range from passive approaches that prioritize transit movements in standard signal timing plans, actuated TSP that activates a transit signal display when a transit vehicle is physically detected at an intersection, and active TSP where traffic control algorithms are dynamically invoked in response to real-time positioning data provided by transit vehicles**.**
3. **Physical Measures:** Physical improvements may be applied to create an exclusive transit running way or to change the geometric design of a street segment to improve the operation of transit vehicles. Physical improvements to create an exclusive transit running way, as defined in the "Guidelines for the Application and Display of Transit Signals" by TAC, may be "dedicated" (the transit lane is continuous from signalized intersection to signalized intersection), or "localized" (a transit lane is provided on the signalized intersection approach). Examples include bus ways, transit malls, reserved lanes, and queue jump lanes. Physical improvements to the street, such as geometric

improvements at intersections, bus bulbs, and bus bays, are designed to improve transit service when operating in general traffic

2.6. Bus Rapid Transit (BRT) System

Bus rapid transit (BRT) is a high-quality bus-based transit system that provides fast, comfortable, and cost-effective services .This improvement of transit system can be attained through the application of integrated transit priority measures and other supportive techniques as off-board fare collection. It is much more reliable, convenient and faster as light rail transit than regular bus services. BRT can avoid the causes of delay such as being stuck in traffic and queuing to pay on board, that are common problem in regular bus services. Federal Transit Administration (FTA) defines Bus Rapid Transit as “a rapid mode of transportation that can combine the quality of rail transit and the flexibility of buses”. The running ways, vehicles, stations, as well as operational control, fare collection and passenger information systems are most commonly presented as elements of BRT systems. These elements allow BRT services to achieve the speed, capacity, reliability, accessibility and operational safety characteristics that distinguish such systems from ordinary transit system. BRT is flexible rapid transit mode that combined stations, vehicles, services, running ways, and intelligent transportation system (ITS) into an integrated system. (Transit Cooperative Research Program (TCRP), 2006)

Generally BRT is an integrated system of facilities, services and amenities that collectively improve the speed, reliability and safety of bus transit. Even if BRT is like light rail transit (LRT), in many respects, but it is with much more operating flexibility and lower initial construction cost and operating costs.

The result of Transit Cooperative Research Program (TCRP) project point towards that:

- Where BRT vehicles operate totally on exclusive or protected rights-of-way, the level of service provided can be similar to that of full Metro rail rapid transit.
- Where buses operate in combinations of exclusive rights-of-way, median reservations, bus lanes, and street running, the level of service provided is similar to light rail transit.
- Where buses operate mainly on city streets in mixed traffic, the service provided is similar to a tram or streetcar system.

Addis Ababa has seen many firsts in recent years. The city launched the first light rail transit in sub-Saharan Africa. In the same, the city is breaking ground on its first bus rapid transit system. Researches indicate that, transportation sector responsible for approximately 25% global greenhouse gas emission. BRT can provide access and relief to the city residents in addition to its contribution in controlling transportation impact on environment.

Unlike other developed cities the challenge here is not convince a relatively small number of private car owners to switch to BRT. Bigger results are projected from the shift from one type of public transport to BRT.

2.7. Related studies

More than a few researchers contributed in a modeling a traveler's mode preference. This is to minimize a rapidly swelling transport demand problem around the world, especially in developing urban areas. Some related modal choice models for different types of trips around the world cities, including Addis Ababa are going to be discussed in this section.

- **Logit Model of Work Trip Mode Choice For Bole Sub- City Residents By Mekdim Teshome, 2007**

This study developed logit model for work trips of Bole Sub-City residents, bases on disaggregated data at individual traveler's level. However the earlier done studies in Addis Ababa cities are a direct mode choice models based on aggregate data. In this research a Multinomial Logit model is developed for work trips made by Bole Sub-City residents for different available transport modes in the study area.

In addition to secondary date obtained from different government concerning agencies primary data was collected through home interview. STATA, data analysis software package, was in use for estimation purpose. The validation of the model estimated on the data at which the model was calibrated was found to be 100%.Finally, as it can be seen from the study education and other purpose related trips of the study area was not included in the model. Assessment of Modal shift towards transit transportation is not included in the study.

Nowadays, transit transportations are prioritizing to minimize transportation impact on environment and to meet rapidly swelling transport demand. These are identifies as the gap of the study, which is going to be filled.

- **Diagnostic Evaluation of Public Transportation Mode Choice in Addis Ababa**

By Mintesnot Gebeyehu and Shin-ei, 2007

In this research ordered and binary logit models are developed separately. Ordered logit model was developed to examine citizens' perceptions of the bus condition, as a determining factor for their choice of bus transportation.

Whereas, the binary logit model was developed to estimate the likelihood of the public transportation mode choice with the dependent variable being the public transportation mode, bus and taxi. According to the analysis result, in addition to socio-economic characteristics of the work trip makers public transport mode related parameters have a significant influence on the mode choice and the traveler's perceptions of the bus service condition. Finally, spatial expansion of bus service, improving bus frequency conditions, and strengthening the bus linkage with respect to the land use are among suggestions provided for transport policy makers and designers. In this study only one trip type and two transport modes, determined as public transportation mode, are considered alone. When considered trip type is work purpose trip and trip modes are taxi and Anbessa bus, further analysis and considerations of trip types and transport modes is recommenced.

- **Logit Model for School and Work Trip Mode Choice On Railway Route Corridor**

By Etsub, 2015

The study developed multinomial logit model for both work and education trip purposes separately. When travel time, travel cost, work type and income are identified as significant factors affect workers mode choice travel time, travel cost, service cost and gender are significant factors in the case of student mode choice. The main modal shift to LRT is found that from Anbessa, Higer followed by taxi and the insignificant interest is shown from private car users.

- **Development of Modal Choice Model For Home-based Work Trips-The Case of Jemo Area Residents In Addis Ababa, By Firdews,2018**

For home based work trip mode choice model was developed both through revealed and stated preference approach for existing and hypothetical modes, respectively. The collected data of variables related to the trip maker and characteristics of the mode are fitted in special type of multinomial logit model known as conditional logit model using SPSS data analysis software package. Total travel time and total travel cost of the transport modes are proved as the primary factors that significantly affect mode choice in the case of revealed preference approach.

The preference towards the BRT increases with the decrease in total travel cost, in-vehicle travel time and out of vehicle travel time, as proved by hypothetical stated preference approach.

Development of mode choice model for non-work home-based trips and non-home based trips are not included in the study, which is recommended for further future research.

- **Modeling modal shift due to the enhanced level of bus service By P.Vedagiri & V.T.Arasan (2009)**

This study was done in Indian city to estimate the probable shift of the three wheeled motorized para-transit vehicle users to the bus after providing exclusive bus lanes on.

The data on factors that might cause modal shift from the three wheeled motorized para-transit vehicle to the bus was collected conducting a home-interview survey. Revealed and stated preference approaches are used in mode choice analysis. Logit model was applied for this study as its specification and interpretation is straight forwards rather those other models. As three wheeled motorized para-transit vehicle and bus are the only considered modes binary choice model was developed. In addition to travel time difference between two modes gender, walking time to the bus stop and trip purpose are identified as variables that affect travelers modal shift behavior. As the number of student using auto-rickshaw were found to be too small model for education was not developed in this study. This is identified as the gap of the study that should be filled in addition to modes of transport not considered rather than auto-rickshaw and bus.

2.8. Summary

Different researchers have developed a modal split model for different countries worldwide, including Ethiopia. Methodologies in use and results of previously done related studies are briefly discussed here in this chapter. The review courses starts by defining modeling go through discussing four step transport modeling and then different types of mode choice modeling is broadly discussed. After discussing the application of these models discrete choice model and its method of calculation specifically reviewed from different previous studies. It is shown also that logit models are chosen for this research since its estimation and interpretation is simple and its accuracy is high. However, Logit model fails to consider alternatives dependency due to Independence of Irrelevant Alternatives (IIA) property. Previous studies investigated the relationship between the characteristics of travelers, trips, and transport facilities, with the individual’s transport mode choice behavior. They found these three basic factors influencing individuals’ mode choice behavior. Stated and revealed techniques of commuters’ preference assessment technique also Discussed in this review. Finally Model specification, estimation and Validation techniques are discussed here.

Non home-based trips were not considered in earlier done researches, in Addis Ababa, as their contribution to transport modeling is judged lower. Studies indicate that Non-home-based (NHB) trip making typically accounts for 25 to 30 percent of travel by individuals in urban areas.NHB trips are chain of trips that usually starts or ends at the trip maker's place of residence. By examining this chain more closely, NHB trips will be considered is this research as to consider its chaining role in transport modeling. Mostly, studies work with work trips rather than education trips. This research works to fill this gap by modeling both home based and non-home based trips. However, a number of studies are done on mode choice analysis the researcher believe that modal shift analysis is rare. So this study is going to fill this identified gap by modeling modal shift to a newly introduced Bus rapid transit by applying stated preference technique.

CHAPTER THREE: RESEARCH METHODOLOGY

3.1. Study Area

In transportation research, a study area is generally regarded as traffic analysis zone, in which transport planning of transport system is required. Addis Ababa is the most congested city in Ethiopia and with the largest population number. There is a wide variety of transport mode lying on the streets. The first issue to consider in sample design is the target population and the study area. The longer travel times during the peak hours and the queue of vehicles during peak periods shows that the route from Winget to Autobistera is one of the congested routes in the city. Moreover bus rapid transit service is under design and construction in that route for the first time in Addis Ababa and Ethiopia. The study area selected for the research is the western part of Addis Ababa region covering from Wingate to Autobistera following the project referred as "BRT- B2 Corridor" which complements the existing light Rail transport System (LRT) in Addis and set to cover 17.3 km all the way through Wingate – Pasteur – Autobistera –Teklehaimanot – Mexico – Kera – Jemo, drive through five sub-cities. This newly introduced transport system is as an additional mass transport service that could introduce integrated systems to the ever growing gap in public transport accessibility in Addis Ababa.

The study area is the most congested route in the city due to its proximity to shopping center and national transportation outlet. The reason for selecting the study area (along the corridor) is the expected introduction of BRT along the route in the near future to solve deep rooted transportation of the residents. The geographical position of the study area is located on longitude 38.7134° East and latitude 9.0568° North.

The study area in under Gulele, Addis Ketema and kolfe keraneo sub-cities.Gulele woreda 10, Addis ketema woreda 10, kolfe keraneo woreda 13 and15 are included in the study area. These woredas encompasses 2,867 households, 2,011 households, 10,242 household and 3,935 households respectively. During data collection assessment period it is found that there is an average of 1.45 workers/House hold and 1.28 students/ Households. As a result we can take that there is an average of one student and one worker per every house hold. Therefore the total households that have target trip makers were estimated to be 19,055. The google map of the Route map showing the study area is shown in Figure 3-1, below.

Study Area

Figure 3.1: Route map showing the study area.
Source: google map.

Travelers living around General Winget square have crucial effect on a deep rooted transportation congestion encountered on this corridor. The target population household that taken from Ortho-photo of google map is shown below in the figure 3.2.

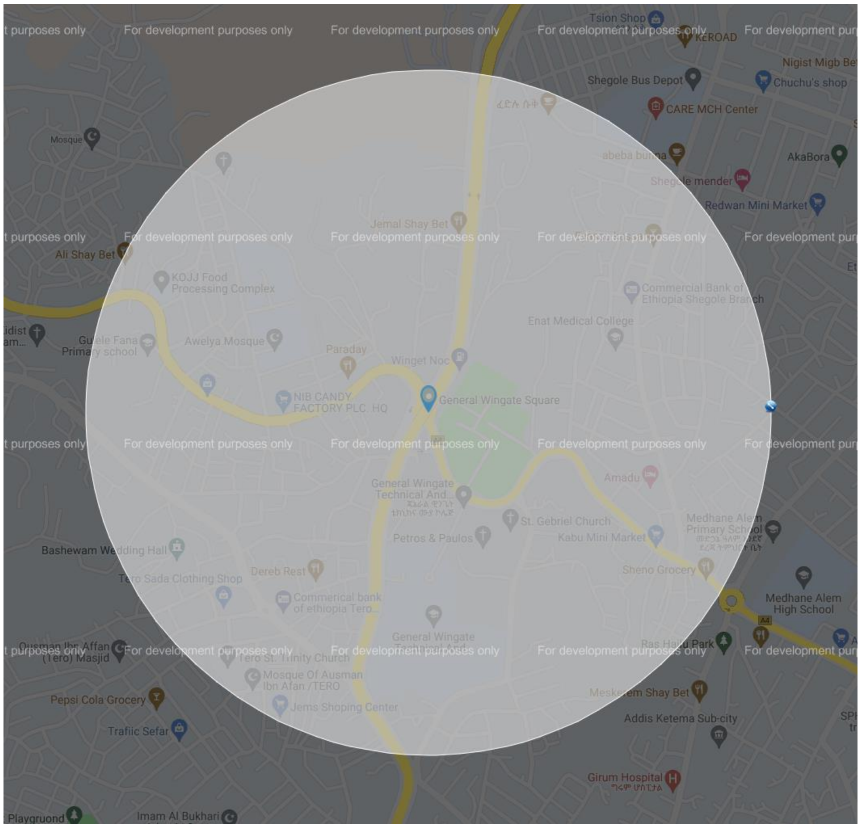

Figure 3.2: Study area boundary.
Source: Google map

3.2. Target population

Students and workers of the Woredas of identified sub cities living in the indicated Woredas were considered as the Universe, population of the study, which means the survey population is limited to only to the residents of woredas which encompassed in the boundary of study area. The total number of the households in each specific woredas in the scope of the study is determined below min table 3.1.Due to the current political issue of our country It was impossible to get the updated data of number of students and employees from Central Statistics Agency. Thus simple assessment was done in the boundary of the study area to determine number of students and employees per head. The result of the assessment indicates that, that there is an average of 1worker per two household and 1 students per house hold. Target populations are Workers and Students living in targeted study areas:

- Addis ketema sub-city: Woreda 10
- Kolfe keraneo sub-city: woreda 13 and 15
- Gulele sub-city- woreda 10

Table 3.1 Household number in the specific woredas

Sub-cities	***Woredas***	***Total Households***
Addis ketema	***10***	***2,011***
Kolfe keraneo	***13***	***10,242***
	15	***3935***
Gulele	***10***	***2867***

Source: Addis ketema, Kolfe keraneo, Gulele sub city construction and housing office

Number of respondents was framed to be proportional to the number of households in each selected woredas. Proportional sample size for both workers and studiers are determined below in the table 3.2.

Table 3.2: Proportional sample size

	Addis ketema Sub-city	Kolfe keraneo sub-city		Gulele sub-city	Total
	Woreda 10	Woreda 13	Woreda 15	Woreda 10	
Number of households	*2,011*	*10,242*	*3935*	*2,867*	19,055
Households percentage	10.55	53.75	20.65	15.05	100
Proportional sample size for workers model formulation	22	113	44	32	211
Sampling interval for workers	90	90	90	90	90
Proportional sample size for workers model validation	6	28	11	8	53
Proportional sample size for students for model formulation	18	91	35	25	169

Sampling interval for workers	112	112	112	112	112
Proportional sample size for students for model validation	5	23	9	6	43

3.3. Alternative transport modes in the study area

The available alternatives on the route around General Winget square for workers include bus, mini bus taxi, private car and ride share car. People who use company services were not included in this study as they do not comply with utility maximization theory just because they are available for free or the transport allowance is deducted from their salary in advance. Therefore, the choice set includes; bus, minibus (taxi), private car and ride share car. Bus rapid transit bus also included as stated preference. For students, bus, minibus taxi, school bus (contract), private car and ride share car are available mode of transport in the study area. Characteristics of available transport was collected by questionnaire except calculated in vehicle travel cost of private car. The travel cost of private car is computed below for work and education trip purposes.Available modes travel cost and travel times were assessed by the researcher by travelling in the study area.Depending on researcher assessment result outlier travel time and cost were excluded.

Travel cost=Fuel cost + Total Maintenance cost + Service cost

Where:

$$\text{Fuel cost per trip(FC)} = \frac{\text{Fuel cost per liter(c)} * \text{Trip distance in km(D)}}{\text{Fuel efficiency(£)}}$$

$$\text{Total maintenace cost(M)} = \text{Average maintenance cost per month(Ma)}$$

$$\text{Service cost(S)} = \frac{\text{Single Service cost(SS)} * \text{Distance(D)}}{\text{5000km}}$$

From the assessment done through questionnaire most targeted workers work 5 days per week. Accordingly every person makes an average of 5 trips per week and there are approximately total trips of 40 working trips per month.

3.4. Design of questionnaire

The questionnaire was developed based on the most pertinent characteristics of trip makers, available modes and trips. Before the collection of the whole data, pilot survey was prepared to assess the questionnaire instruction universality and some questions of the questionnaire were improved. Questionnaire that was finally distributed to respondents can be referred in the appendix part. This questionnaire is generally organized in the two major parts as shown below.

Part1: The questions under this part include the social and economic information of the respondent such as gender, age, education level, occupational category school type, marital status, household monthly income, family size, and car ownership.

Part2: This part of the questionnaire includes trip and available alternative related variables such as; trip length, mode of transportation usually used and mode related variables such as in vehicle travel time, out of vehicle travel time, walk time, waiting time and travel cost.

3.5. Sampling technique and sample size determination

The Determination of sample size to be used is the major issue in survey. The size of the sample required to effectively represent the population is a function of the level of statistical accuracy .The precision of parameter estimates and the statistical validity of estimation results improve with sample size. However, the cost and time of the survey also increases with sample size and in many cases it is necessary to restrict the sample size to ensure that the cost and time of the survey remains within budgetary and time constraints (Koppleman & Chandra, 2006).

The most common sampling method is probability sampling, where each sampling unit has equal probability of being selected into the survey sample (Koppleman & Chandra, 2006). However it may be difficult to obtain a random sample as it may not be possible to get a complete list of potential respondents from which to select a sample. This is the primary reason for using systematic sampling.

Required data are Trip makers' characteristics, Trip characteristics and Mode characteristics. Trip makers characteristics is a primary data collected through questionnaire. Whereas, Trip characteristics is a primary data collected through questionnaire and also a secondary data collected through interview, and Mode characteristics is a secondary data collected through semi-structured interview and written letters from government concerning authorities.

3.5.1. Sample size

The notable issue in sampling was determining the sample size to be used for this specific study. In this specific study required sample size to be adequately representing the population is a function of the smallest of the proportion of negative or positive cases in the population and the number of considered factors. The precision of parameter estimates and the statistical validity of estimation results improved with sample size. However, the cost and time are a limited resource and in many cases it is necessary to restrict the sample size to ensure that the cost and time of the survey remains within budgetary and time constraints (Koppleman & Chandra, 2006).

According to Peduzz et al.1996, the minimum sample size was determined as:

$$N=10K/P$$

Where: N-Sample size

P- The smallest of the proportion of negative or positive cases in the population, assumed 50%

K- Number of considered factors

Assuming a proportion of positive cases of 0.5(50 %) from previous studies.

Sample size determination for workers:

While determining sample size of workers, Gender, Age, family size, Marital status, Education level, monthly family Income level, vehicle owner ship, Occupational category, related travel cost and related travel time are considered factors. Minimum sample size for workers was determined as 200.

However, total sample size required will include the data for validation of the model which will be one fourth of the minimum sample size. Assuming 95% response rate can be to be acceptable, total sample size for model formulation of workers was round up to 211.Considering the same response rate the sample size for the validation purpose was determined to be 53.In this study total number of samples for workers was 264.

Sample size determination for students:

Gender, Age, Family size, school type, Education level, car ownership, related travel cost and related travel time are considered factors to determine the sample size of education purpose travelers. Assuming 95% response rate can be acceptable and including validation sample, total sample size for model formulation and validation purpose of the student was 169 and 43 samples respectively. Generally 212 questionnaires were collected for education trip purposes.

3.5.2. Sampling technique

Sampling technique will be used to select samples. The most common sampling method is probability sampling, where each sampling unit has equal probability of being selected into the survey sample (Koppleman & Chandra, 2006). In this study systematic sampling was used. Systematic sampling is a type of probability sampling method in which sample respondent from larger population are selected according to random starting point but with a fixed and periodic intervals. This interval is specified as sampling interval and computed by dividing the population size by desired sample size. The calculated sampling interval is determined in table 3.2 for all selected woredas correspondingly.

3.6. Data Source, survey and analysis tools

The data type used for this research was both primary and secondary data. The primary data will be generated from the household survey through questionnaire for the purpose of accomplishing this research and secondary data was obtained from different concerning authorities of the Addis Ababa City Administration.

An interview governed structured survey questionnaire was used to collect primary data. This questionnaire was prepared to collect data on the traveler's characteristics, their choice of mode of transport and travel cost, income level, their travel time and other travel related information. Pilot survey was implemented before distributing the whole questionnaire to test the correctness of the instructions to be measured by whether all the respondents in the pilot sample are able to follow the directions as indicated. After piloting the questionnaire was revised and data collection was proceeding.

Time and cost are a precious resource to be saved, without compensating data quality it is found best to use the sampling interval of workers, 72, for both workers and students to collect data from house hold. The questionnaires were interview governed to increase accuracy and minimize missed data. As a result a response rate of 95% can be assumed to be acceptable. Data were collected at household on Saturday morning 9:00am-11:00 pm, afternoon 2:00 pm-5:00 pm and Sunday in the afternoon 2:00 pm -11:00pm. It was also mandatory to get data collector to go through each house hold, paid 350 ETB per day. Generally, Data collection work utilizes 9 days, excluding secondary data of asking house hold number of each target woredas and assessing information about BRT which utilizes around one month .Since there is not well organized data, knowing number of households in the targeted woredas was the most challenging activity.

Revealed preference approach and stated preference approach were performed to determine travelers' modal preference. Revealed preference is used for mode choice of people for the available modes whereas stated preference is used for stated BRT mode of transport. Microsoft excels and SPSS statistical data analysis tool was used to organize and analyze the collected data. Conditional multinomial logistic regression was used in estimating parameters of developed models. Disaggregate choice model, which is a most commonly used logit model, was applied here in this study.

3.7. Research Design

Research design is a conceptual structure within research will likely be done. It comprises the blueprint for the collection, measurement and analysis of the data. Decisions regarding what, where, when, how much, by what means with regards to an enquiry or a research design are taken. This research is an explanatory type of research aimed at showing the transport mode choice of commuters, the factors that determine their mode choice and modal shift behavior of home based trips. In view of this to understand the relations between characteristics and mode choice logit model is applied. Logit models are used to model relationships between dependent variables and set of independent variables. This is the cause and effect relationship between variables. Previously done researches recommend explanatory type of research for cause and effect relationship analysis.

3.8. Research Approach

There are two approaches for collecting and analyzing data: qualitative research and quantitative research. Quantitative research deals with numbers and statistics, while qualitative research deals with words and meanings. This type of research can be used to establish generalizable facts about a topic. This research adopted quantitative research approach.

3.9. Research Methods

3.9.1. Utility function

Utility maximization theory assumes that trip makers prefer alternatives with the maximum utility (Kenneth, 2009). This can be defined with utility function as traveler t will choose mode i if the utility of mode i is larger than all available modes j. This underlying concept will help us rank the available alternatives and choose the alternative with highest utility. This indicates that there is no zero value for utility of available mode rather comparing the utility values. The total utility function is described as the sum of the deterministic and the probabilistic portion of the utility as shown below.

$Uit = Vit + \varepsilon\ it$

Where;

Uit- is the total utility of traveler t while using mode i

Vit- is the deterministic utility portion

$\varepsilon\, it$ -is the probabilistic portion

3.9.2. Method of analysis

There are two methods of parameter estimation including maximum likelihood and least square method. Analysis of logit models is the estimation of the parameters in the utility function with the maximum likelihood approach. Method of maximum likelihood contains determining likelihood function for the random term in the utility function and estimating values for parameters which maximize the likelihood function (Koppleman & Chandra, 2006). The likelihood function for sample of t individuals with j alternatives is as shown below. The parameter values which maximize the likelihood function are attained by finding the first derivative of the likelihood function and equating it to zero (Koppleman & Chandra, 2006). Since it is simple to differentiate, use a log likelihood function. Therefore, the log-likelihood function is maximized instead of the likelihood function itself.

$L(\beta) = \prod \prod (Pjt(\beta))\delta jt \forall j \,\square\, J \forall\, t \,\square\, T$

Where

δjt = 1 is chosen indicator (=1 if j is chosen by individual t and 0, otherwise) and

Pjt is the probability that individual t chooses alternative j

3.9.3. Conditional multinomial logistic regression in SPSS

The special type of logit modeling which works best for modeling of discrete choices whose one or more independent variables are alternative specific is known as conditional multinomial logit modeling. In SPSS, the conditional logit modeling which primarily includes the variables that vary among the transport modes, for example; travel time and travel cost in modal choice modeling, cannot be handled by the NOMREG (conventional multinomial logistic regression) command which can only handle the variables that vary with the decision makers. Instead of the NOMREG command, the conditional MNL is computed with a COXREG command in SPSS.

Table3.3: Example of the data view in SPSS user interface

Traveller ID	Available alternative	Gender	Age	Income level	Total travel time, minute	Total travel cost, ETB	Chosen alternative
1	1	1	2	4	50	3.00	1
1	2	1	2	4	50	5.00	0
1	4	1	2	4	30	100.00	0
2	1	1	3	5	50	3.00	0
2	2	1	3	5	50	5.00	0
2	3	1	3	5	25	19.00	1
2	4	1	3	5	30	100.00	0
3	1	2	2	3	50	3.00	1
3	2	2	2	3	55	5.00	0
3	4	2	2	3	30	100.00	0

3.9.4. Model specification

The decision maker in this study area are the people living around Winget area making all specified trip purposes. The alternatives included are bus, minibus (taxi), private car, ride share car and school bus (contract). In addition to these the bus rapid transit system, which is at construction stage at present time, in Addis Ababa is included under the stated preference survey. The trip makers are assumed to choose the mode which maximizes their utility. Therefore, all the data about the trip maker and the modal attributes of each mode for each trip maker is recorded in the data set of SPSS.

1. Model specification for workers

Variables synthax	Description	Ranges	Label	Categories
GENDER	Respondent Gender	1-2	1	Male
			2	Female
AGE	Respondent Age	1-4	1	10<=Age<18
			2	18<=Age<35
			3	35<=Age<65
			4	>=65
FSIZE	Monthly size	1-3	1	1
			2	2<=FSIZE<=5
			3	>=6
MSTATUS	Marriage mstatus	1-4	1	Single
			2	Married
			3	Divorced
			4	Widowed
ELEVEL	Education level	1-5	1	Primary school and below
			2	Secondary school
			3	Certificate and Diploma
			4	First Degree
			5	Second degree and above
FMINCOME	Family monthly income	1-3	1	<=5000
			2	5001-20000
			3	>=20001
COSHIP	Car ownership	1-2	1	Own car
			2	Not own car

OCAT	Occupational category	1-5	1	Government employee
			2	Private company employee
			3	Self employed
			4	NGO
			5	Others
TPURPOSE	Trip purppose	1-3	1	Home based work trip
			2	Home based others trip
			3	Non home based work related trips
RMCHOICE	Respondent revealed modal choice	1-4	1	Bus
			2	Mini bus taxi
			3	Private car
			4	Ride share
Choice	Choice	1-2	0	Yes
			1	No
ATIME	Accesing time	1	1	
WTIME	Waiting time	1	1	
OVTTIME	Out of vehicle travel time	1	1	
IVTTIME	In vehicle travel time	1	1	
TTTime	Total travel time	1	1	
CACCESS	Accessing cost	1	1	
IVTCOST	Invehicle travel cost	1	1	
TTCost	Total travel cost	1	1	
SMCHOICE	Respondent stated model choice	1-2	1	Yes
			2	No
CTaxi	Taxi constant	1		
CPcar	Private car constant	1		
CRshare	Ride share constant	1		

2. Model specification for student

Variables synthax	Description	Ranges	Label	Categories
GENDER	Respondent gender	1-2	1	Male
			2	Female
AGE	Respondent age	1-3	1	10<=Age<18
			2	18<=Age<35
			3	>=30
FMSIZE	Family size	1-3	1	1
			2	2<=FSIZE<=5
			3	>=6
STYPE	School type	1-2	1	Government school
			2	Private school
ELEVEL	Education level	1-5	1	Primary school and below
			2	Secondary school
			3	Certificate and Diploma
			4	First Degree
			5	Second Degree and above
COSHIP	Car ownership	1-2	1	No car
			2	Own car
TPURPOSE	Trip purpose	1	1	Home based education
RMCHOICE	Revealed modal choice	1-5	1	Bus
			2	Mini bus taxi
			3	Private car
			4	Contract
			5	Walk
ATIME	Access time	1	1	
WTIME	Waiting time	1		
OVTTIME	Out of vehicle travel time	1	1	
IVTTIME	In vehicle travel time	1	1	
TTTIME	Total travel time	1	1	
ACOST	Access cost	1	1	

IVTCOST	Invehicle travel cost	1	1	
TTCOST	Total travel cost	1	1	
SMSHIFT	Respondent modal shift interest	1-2	1	Yes
			2	No
Choice	Modal choice	1-2	0	No
			1	Yes
Ctaxi	Taxi constant	1	1	
Cpcar	Private car constant	1	1	
Ccontract	Contract constant	1	1	
Cwalk	Walk cost	1	1	

3.9.5. Method of comparison and test of estimated models

There are different methods to test and compare estimated models as stated in section 2.3.2 in detail. In this study informal sign tests and tests for the individual parameters were used to test parameters separately. The overall goodness of fit measures using chi-squared, rho-squared and adjusted rhosquared values, log likelihood ratio tests and non-nested hypothesis tests are used to test each developed model and compare one model over others.

3.9.6. Method of validation

The validation of the most fitting model is assessed using samples that were collected for validation purpose. These data were used to evaluate how well the model fits the data by determining the prediction capability of the model. The prediction capability of the model is determined by dividing the number of correctly predicted modes to the total number of validation data.

The general methodology of the modeling approach is shown below in figure 3.3 in the form of flow chart. The shaded portion of the flow chart indicates the sequential step followed in the model development the researcher was undertaken.

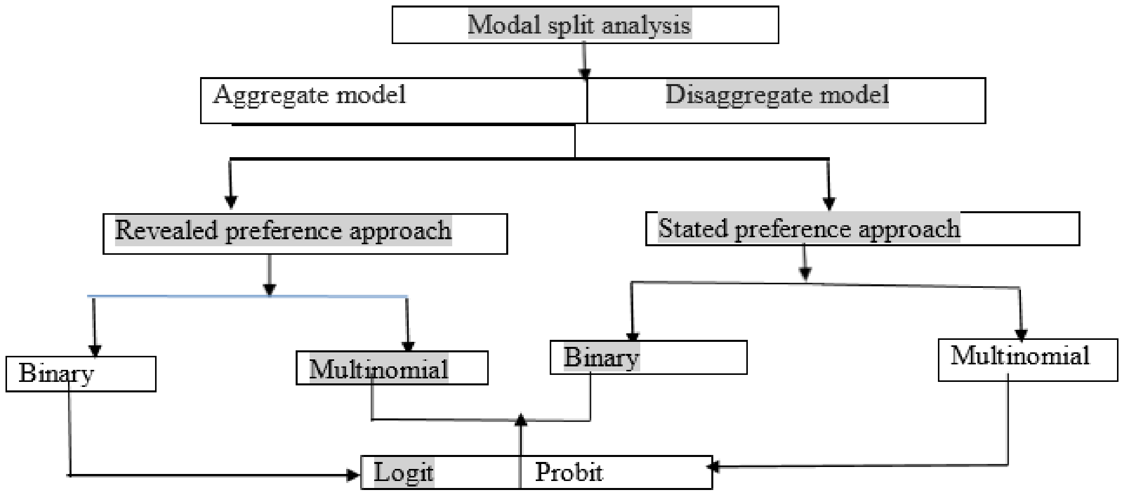

Figure 3.3: Modeling approach for modal split analysis

CHAPTER FOUR: RESULTS AND DISCUSSION

4.1 Descriptive Data Analysis

In this part, the descriptive analysis shows by relating socio-demographic characteristic of trip makers with the available modes of transports which are the most common by using tables, charts and figures. The variable presented in the descriptive data analysis includes traveller's characteristic, socio-demographic characteristic, available mode characteristics and trip characteristics.

4.1.1. Socio –economic data presentation of worker respondents

For work purpose trips data was collected from a total of 281 valid respondents. The collected socio economic data about trip makers include trip maker gender, trip maker age, family member size, marriage status, education level, monthly income of family in ETB, car ownership, occupation category. These data was analyzed using SPSS 21. These descriptive statistics on the of workers socio economic information are summarized as shown in Table 4-1 below.

Table 4.1: Socio demographic statics of employee

Attributes	Attributes syntax	Label	Value	Frequency	Percentage
Gender	GENDER	1	Male	152	54.1
		2	Female	129	45.9
Age	AGE	1	$10\leq$ Age<18	9	3.2
		2	$18\leq$ Age<35	140	49.8
		3	$35\leq$ Age<65	87	31.0
		4	≥ 65	45	16.0
Family Size	FSIZE	1	Only one member	67	23.8
		2	2-5 members	144	51.2
		3	6 and above 6 members	70	24.9
Marriage status	MSTATUS	1	Single	58	20.6
		2	Married	157	55.9
		3	Divorced	48	17.1
		4	Widowed	18	6.4

Education level	ELEVEL	1	Primary school and below	40	14.2
		2	Secondary school	43	15.3
		3	Certificate and Diploma	54	19.2
		4	First degree	111	39.5
		5	Second degree and above	33	11.7
Family monthly income in ETB	FMINCOME	1	Less than or equal to 2,500 ETB	42	14.9
		2	2,501-5,000 ETB	114	40.6
		3	5,001-10,000 ETB	61	21.7
		4	10,001-20,000 ETB	27	9.6
		5	Above 20,001 ETB	37	13.2
Car ownership	COSHIP	1	Yes	220	78.3
		0	No	61	21.7
Occupation category	OCAT	1	Government employee	116	41.3
		2	Private company employee	72	25.6
		3	Self employed	41	14.6
		4	NGO	40	14.2
		5	Other	12	4.3

Source: Researchers' own survey, 2022

According to the data summarized from in the above table descriptive frequency analysis indicates that 54.1% of the respondents were men and 45.9% were female. About 3.2% of the respondents are aged in between 10-18 years, whereas 49.8% of them were in between 18-35, 31.0% were in between 35-65 years and about 16.0% are above 65. The analysis also shows that trip makers house hold had 23.8% with only one family size, 51.2% with 2-5 family members and 24.9% with 6 and above 6 family members .Above half (55.9%) of respondents were Married whereas lowest number of respondents were widowed (6.4%) and 20.6% of single respondents are followed by 17.1% divorced respondents. 39.5% of respondents with education level of first degrees are followed by 19.2% Certificate and Diploma level, 15.3% Secondary level school, 14.2% primary school level and below and 11.7% second degree and above respectively. 21.7% of respondents has income level of 5,001-10,000 ETB followed by 14.9% of respondent with monthly income of Less than or equal to 2,500 ETB. Large percentage of respondents, 40.6%, were with 2,501-5,000 ETB monthly income where 13.2% and 9.6 % of respondents have above 20,001 ETB and 10,001-20,000 ETB monthly income level respectively. The analysis summary tells that most of the trip makers do not own private car which account for 78.3%.on the other hand lowest number of respondents, 21.7%, own car. The analysis also illustrates that majority (41.3%) of the respondents occupation category is government organization followed by 25.6% of private company employees. NGO, self employed and others worker respondents occupies were 14.2%, 14.6% and 4.3 % respectively.

4.1.2. Socio –economic data presentation of student respondents

There were 168 responded questionnaires of home based school trips that were collected through interview governed questionnaire at their house and 3 questionnaires are excluded for they were with a missed value. Therefore only 165 valid respondents are included in the analysis. The collected socio economic data about trip makers include Trip makers' gender, Trip maker age, Trip makers' Family member size, Trip makers' school type, Trip makers' Education level and Trip makers' family Car ownership. These descriptive statistics on the profile of students are summarized as shown in Table 4.2 below.

Table 4.2: Socio demographic characteristics of students

Attributes	Attributes syntax	Label	Value	Frequency	Percentage
Gender	GENDER	1	Male	93	56.4
		2	Female	72	43.6
Age	AGE	1	10≤ Age<18	59	35.8
		2	18≤ Age<35	106	64.2
		3	18≤ Age<35	0	0
Family member size	FSIZE	1	Only one member	0	0
		2	2-5 members	99	60.0
		3	6 and above 6 members	66	40.0
School type	STYPE	1	Government School	100	60.6
		2	Private School	65	39.4
Education level	EDLEVEL	1	Primary school and below	65	39.4
		2	Secondary school	99	60.0
		3	Certificate and Diploma	0	0
		4	First degree	1	0.6
		5	Second degree and above	0.0	0.0
Car ownership	COSHIP	0	No car in the household	119	72.1
		1	Own car	46	27.9

Source: Researchers' own survey, 2022

According to the data summarized in the above table descriptive frequency analysis of students indicates that 56.4% of the respondents were men and 43.6% were female. About 43.6% of the respondents are aged in between 10-18 years, whereas 35.8% of them were in between 18-35 and 64.2% were in between 35-65 years. The analysis also shows that trip makers' house hold had 60.0% with 2-5 family members and 40.0 % with 6 and above 6 family members .Where Above half (60.6%) of respondents were government school student 39.4% respondents private school students. 60.0% of respondents with education level of secondary are followed by 39.4%

primary school and below level. Only one student is first degree level. The analysis summary also tells that most of the trip makers do not own private car which account for 72.1%.On the other hand lowest number of respondents, 27.9%, own car.

4.1.3. Revealed preference data presentation

Home based work trips

The modal share of home based work purpose trips in the study area and their willing to divert their choice to the newly introducing BRT buses is presented in table 4.2 below, in line for to statistical analysis output. According to this crosstab analytical output, 82.61% of home based work related travellers are willing to divert their modal preference to the newly introducing BRT buses. The detailed modal shares of all available modes are shown in the table 4.3 below.

Table 4.3: Modal share of home based work trip and travellers interest to divert BRT bus

Respondent revealed mode choice	Respondent stated modal shift interest		Total trip makers	Total trip makers, in %	Interested to divert to BRT, in %
	Yes	No			
Bus	46	1	47	29.19	97.87
Mini bus taxi	63	3	66	40.99	95.45
Private car	9	22	31	19.25	29.03
Ride share	9	1	10	6.21	90.00
Contract(lada)	1	0	1	0.62	100.00
Walk	5	1	6	3.73	83.33
Total	133	28	161	100.00	82.61

Additionally, modal share of home based work trip travelers are presented below in pie chart, in figure 4.1 below.

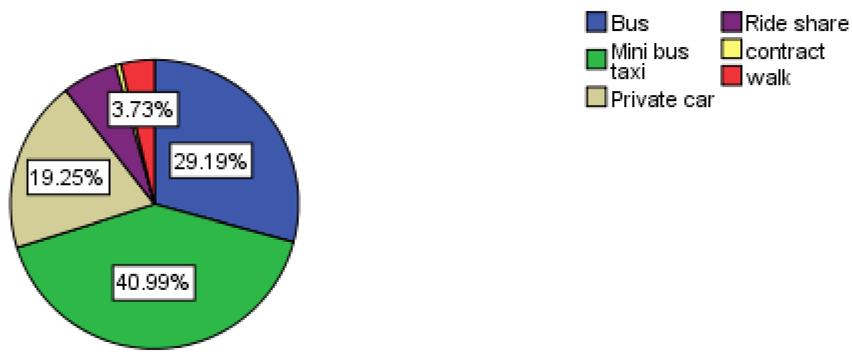

Figure 4.1 Modal share of home based work travelers

The relation between home based work commuter's gender and their revealed modal choice is shown below in figure 4.2.As shown below ratio of male to female of private car user has largest value which is followed by ratio of walk. Another way ride share user is only one man. In contrast large bus, taxi and contract users have ratio of male to female commuters close to 1.Therefore private car and walk are mostly used by men commuters whereas bus, minibus taxi and contract modes have almost the same number of male and female users. Consequently, the researcher can conclude that gender has a visible effect on home based work commuters' modal choice.

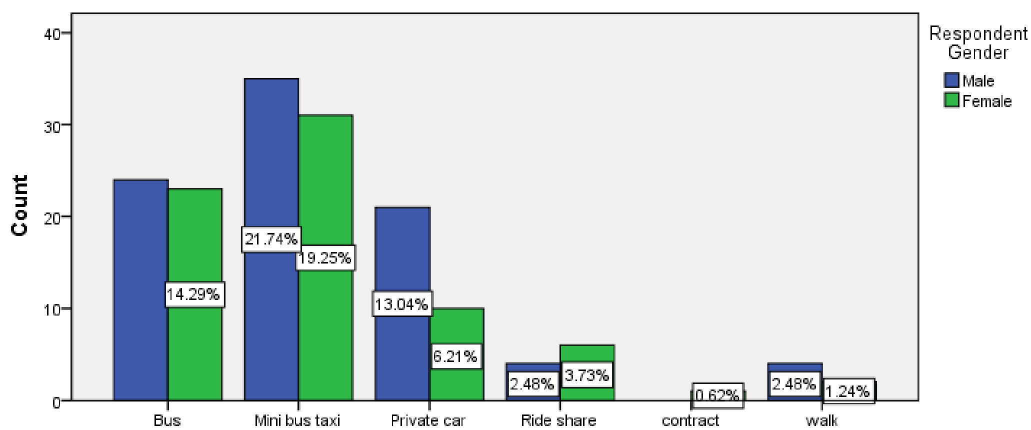

Figure 4.2: Revealed preference relative to respondent gender

As it can be seen in figure 4.3 below, a highest percentage of workers (23.60 %) age in between 18-35 prefer minibus taxi. Whereas, workers with age of in between 35-65 and above 65 ages have 8.07% modal share of minibus taxi. Students in both age ranges have the ratio close to 1 for private car and walk mode. Detailed information is shown below in the figure.

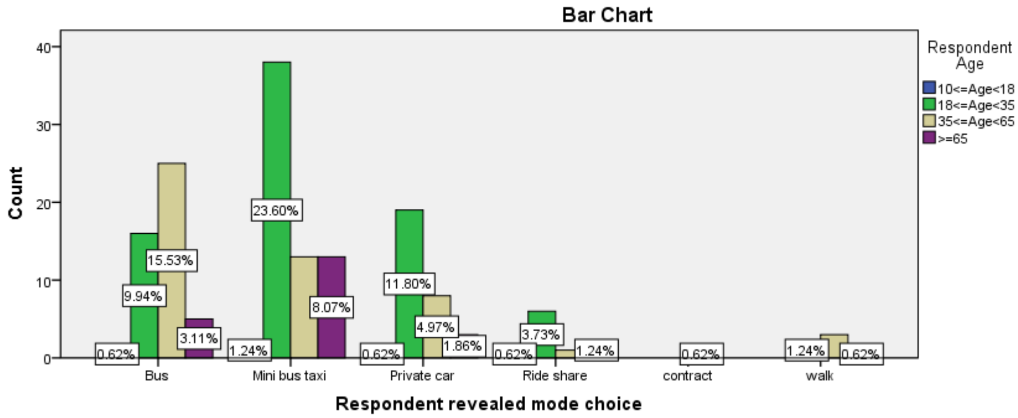

Figure 4.3: Revealed preference relative to respondent age

The effect of family size on modal preference of home based work travelers is tried to be determined in figure 4.4, as shown below. Highest percentage of trip makers with middle class family size prefers to use minibus taxi mode. From all the available modes highest percentage of trip makers with family size of in between 2 and 5 prefers to use mini bus taxi followed by contract mode. The ratio of trip makers with family size groups in between 2-5 to that of family live above 6 of private car users is close 2.Ride share users retail the smallest percentage of modal share.

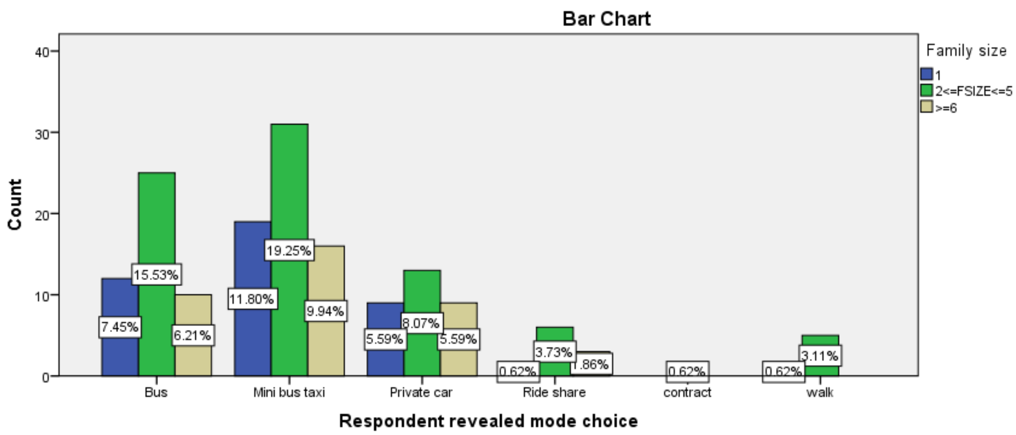

Figure 4.4: Revealed preference relative to employee respondent house hold family size

Below, Figure 4.5 shows the relation between employee marriage status and home based work trips modal preference of commuters. As it can be seen from the figure, highest percentage of married employee (22.98%) uses minibus taxi followed by bus modal preference. While highest percentage of single employee preference is minibus, divorced employee prefers bus. Ratio of divorced to widowed employees over minibus taxi is almost similar. Addition preference indicators are shown below in the figure 4.5.

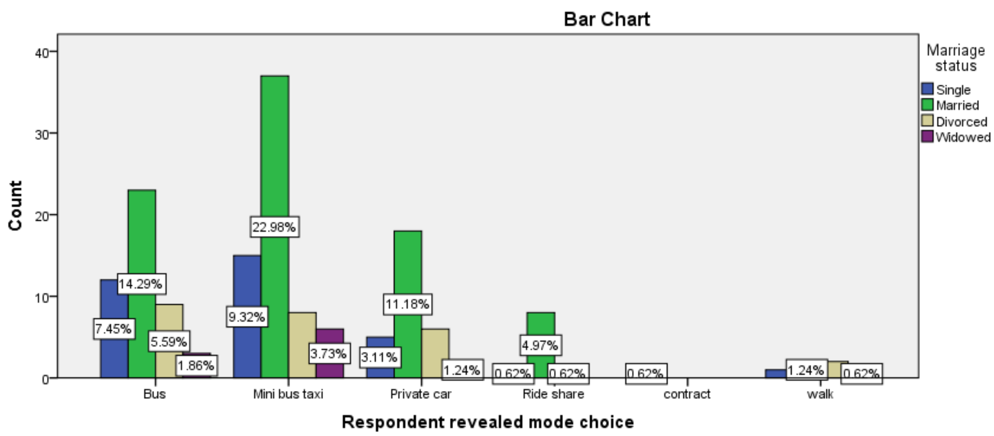

Figure 4.5: Revealed preference relative to employee respondent marriage status

According to output of crosstab analysis shown in figure 4.6, minibus taxi mode is preferred by employees that are first degree holder. On the other hand, most of the trip makers with education level of first degree and above prefer minibus taxi mode and the largest modal share of walk it taken by Certificate and degree level employees. It is also apparent from the figure that private car, contract and walk mode users have ratio of primary school and below to secondary school trip makers close to 1.

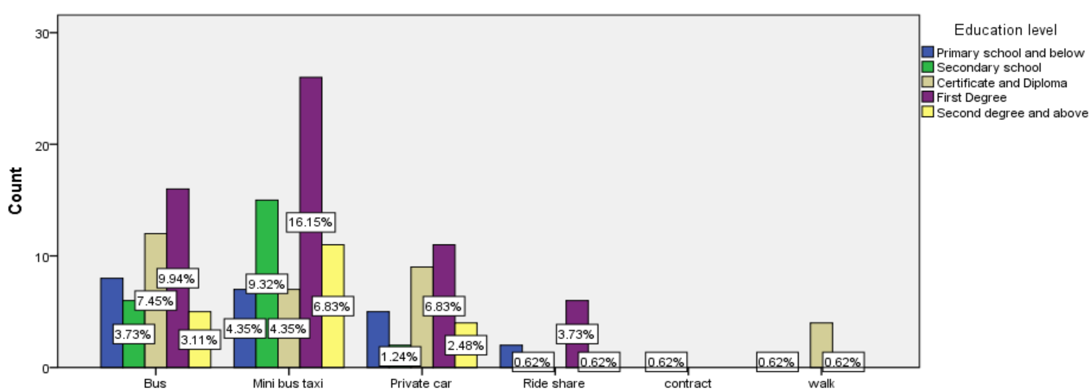

Figure 4.6: Revealed preference relative to employee respondent education level

As figure 4.7 shows below, the largest percentage of minibus taxi user, 24.84%, are home based work purpose travels with a monthly family income level less than 5000 ETB.most of the people who own personal are travellers with monthly income level of larger than 20,000 ETB.Larger number of bus mode users, 20.50%, are trip makers with income level of less than 5000 ETB.

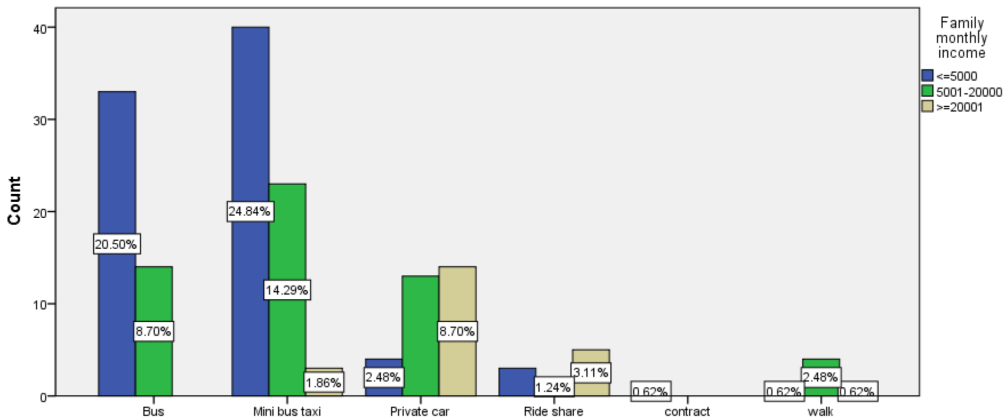

Figure 4.7: Revealed preference relative to employee respondent family monthly income

As figure 4.8 shows below, Bus mode is used fully used by travelers that do not own private care. Largest modal share of mini bus taxi, 36.02%, are travellers that do not own private car. Also larger modal share of ride share, 4.35%, are home based work trip purpose travellers that do not own private car. Additional information trip maker modal preference with respect to private car ownership is shown in detail below in figure 4.8.

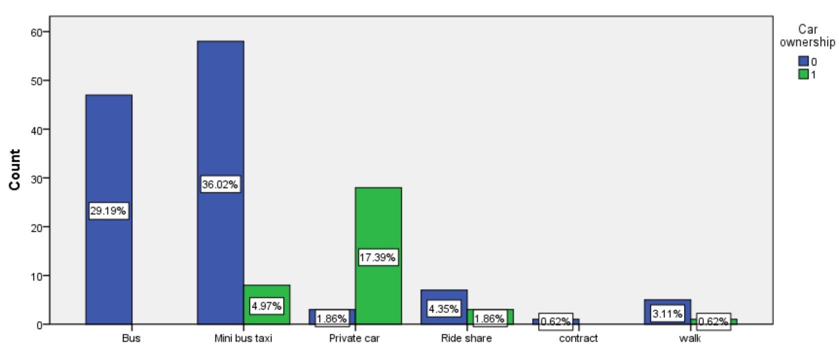

Figure 4.8: Revealed preference relative to employee respondent education level

The ratio government employee that prefer bus mode and private company employee that prefer minibus taxi is 1.Most of NGO workers, 10.56%, prefer private car. Larger share walk is taken by government employee whereas most of self-employee travelers choices mini bus taxi.

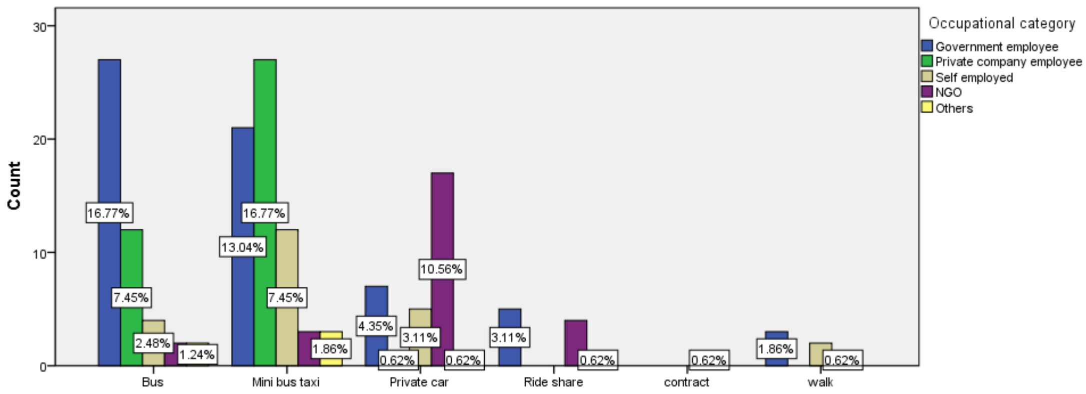

Figure 4.9: Revealed preference relative to employee respondent occupational category

Home based others trips

Home based others trips included 120 valid respondents. The modal share of this trip purpose is shown below in the table 4.12. In line for to statistical analysis output, 88.33% of home based work related travellers are willing to divert their modal preference to the newly introducing BRT buses.

Table 4.4: Modal share of home based others trip and travellers interest to divert to BRT bus.

Respondent revealed mode choice	Respondent stated modal shift interest		Total trip makers	Total trip makers, in %	Interested to divert to BRT,%
	Yes	No			
Bus	27	0	27	22.50	100.00
Mini bus taxi	63	4	67	55.83	94.03
Private car	5	9	14	11.67	35.71
Ride share	7	1	8	6.67	87.50
Walk	4	0	4	3.33	100.00
Total	106	14	120	100.00	88.33

Moreover, modal share of home based others trip travelers are presented below in pie chart, in figure 4.10 below.

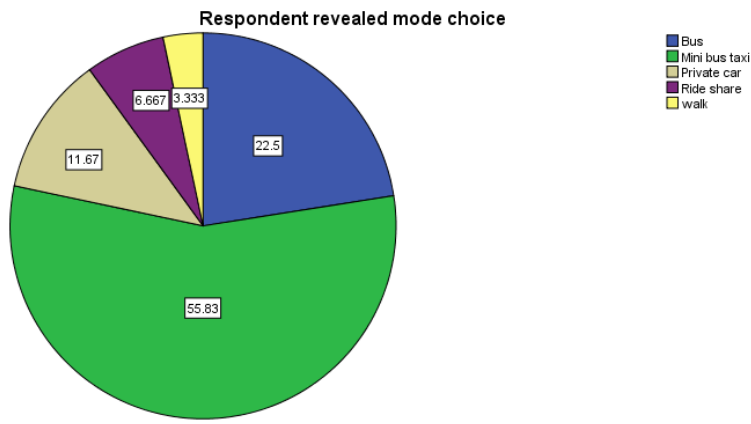

Figure 4.10: modal share of home based others trip

The relation between home based others travellers gender and their modal preference is shown below in figure 4.11.For this trip purpose the modal share of male and females are almost similar rather that walking where male share to female share around 2. The modal interest of males and females to wars ride share is equal in home based others trip purpose. Moreover, the relative interest of travellers with respect to their gender in shown below in the crosstab analysis output presented in figure.

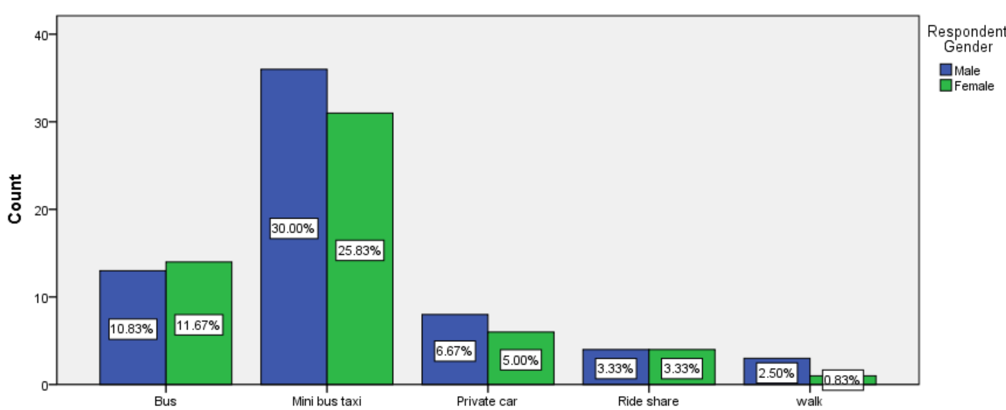

Figure 4.11: Revealed preference relative to employee respondent occupational category

As it can be seen in figure 4.12 below, a highest percentage of workers (23.60 %) age in between 18-35 prefer minibus taxi. Whereas workers with age of in between 35-65 and above 65 ages have 8.07% modal share of minibus taxi. Students in both age ranges have the ratio close to 1 for private car and walk mode. Detailed information is shown below in the figure.

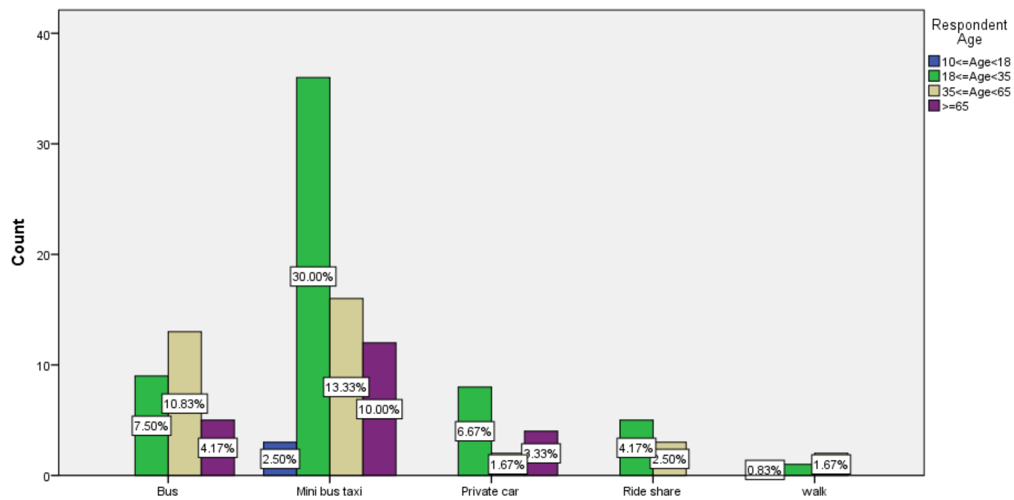

Figure 4.12: Revealed preference relative to employee respondent occupational category.

As figure 4.13 shows below, the largest percentage of minibus taxi user, 24.84%, are e home based work purpose travels with a family size in between 2 and 5.the ratio of travellers living alone to that of with family size above 6 over bus and private car mode is close to one.

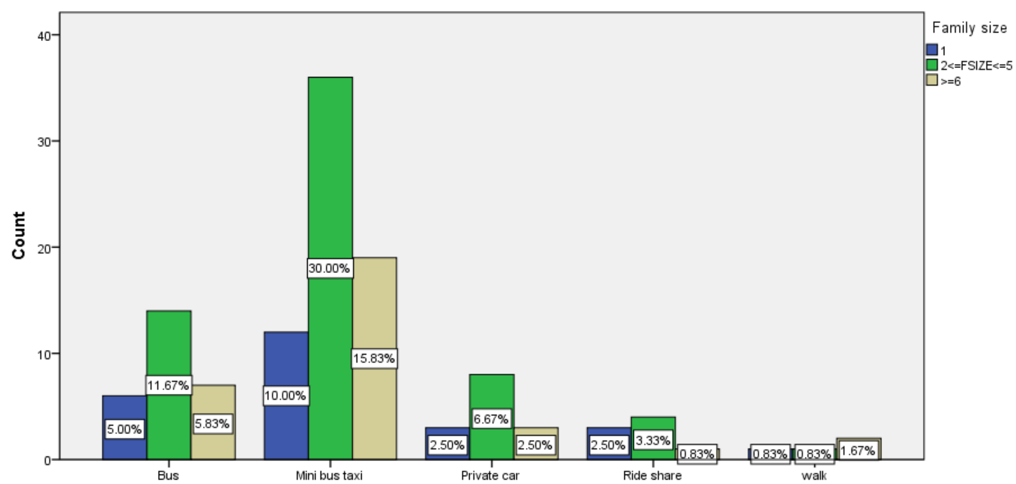

Figure 4.13: Revealed preference relative to employee respondent occupational category

The relation between employee marriage status and home based others trips modal preference of commuters is shows below in Figure 4.14.As it can be seen from the figure, highest percentage of married employee (35.00%) uses minibus taxi followed by bus modal preference. While highest percentage of single employee preference is minibus, divorced employee prefers bus. Ratio of divorced to widowed employees over minibus taxi is almost similar. Addition preference indicators are shown below in the figure 4.14.

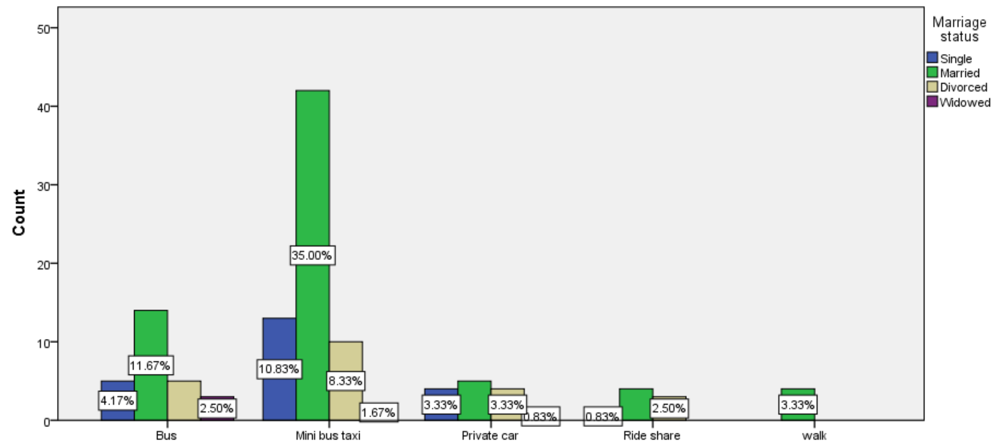

Figure 4.14: Revealed preference relative to employee respondent marriage status

According to output of crosstab analysis shown in figure 4.15, minibus taxi mode is mostly chosen by employees that are first degree holder. On the other hand, most of the trip makers with education level of second degree and above prefer minibus taxi mode and the largest modal share of walk it taken by first degree level employees. It is also apparent from the figure that private car, the ratio of primary school and below to secondary school education level is close to1.

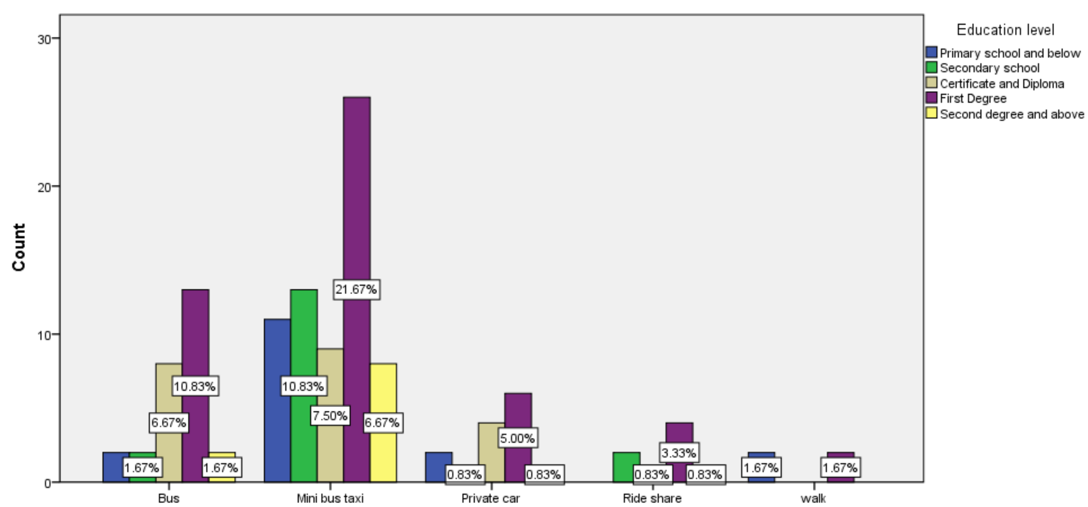

Figure 4.15: Revealed preference relative to respondent employee education level

As show below, the largest percentage of minibus taxi user, 37.19%, are home based others trip purpose travellers with a monthly family income level less than 5000 ETB. Most of the people who own private car are travellers with monthly income level of larger than 20,000 ETB.Larger numbers of bus mode users, 17.50 %, are trip makers with income level of less than 5000 ETB.

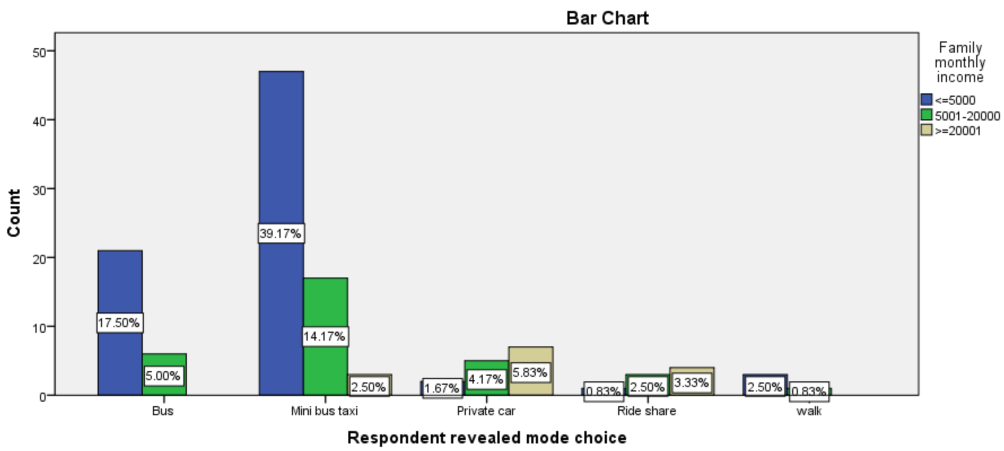

Figure 4.16: Revealed preference relative to employee respondent family monthly income

As figure 4.17 shows below, Bus mode is used fully used by travelers that do not own private care. Largest modal share of mini bus taxi, 49.17%, are travellers that do not own private car. Also larger modal share of ride share, 5.83 %, are home based work trip purpose travellers that do not own private car. Additional information trip maker modal preference with respect to private car ownership is shown in detail below in figure 4.17.

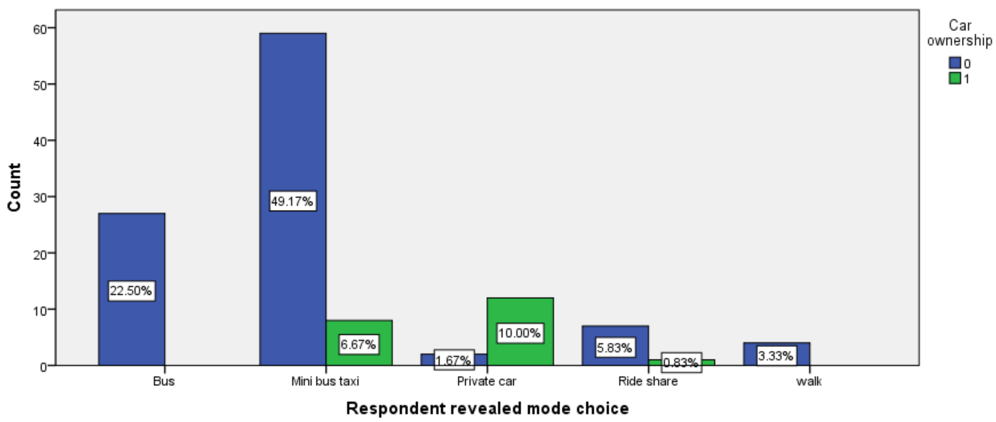

Figure 4.17: Revealed preference relative to respondent employee car ownership

The ratio of government employee to private company employee over minibus taxi mode is close to 1 whereas their ration over bus mode is close to 4. Largest share of walk is taken by government employee whereas most of NGO employee traveler’s choice is ride share mode.

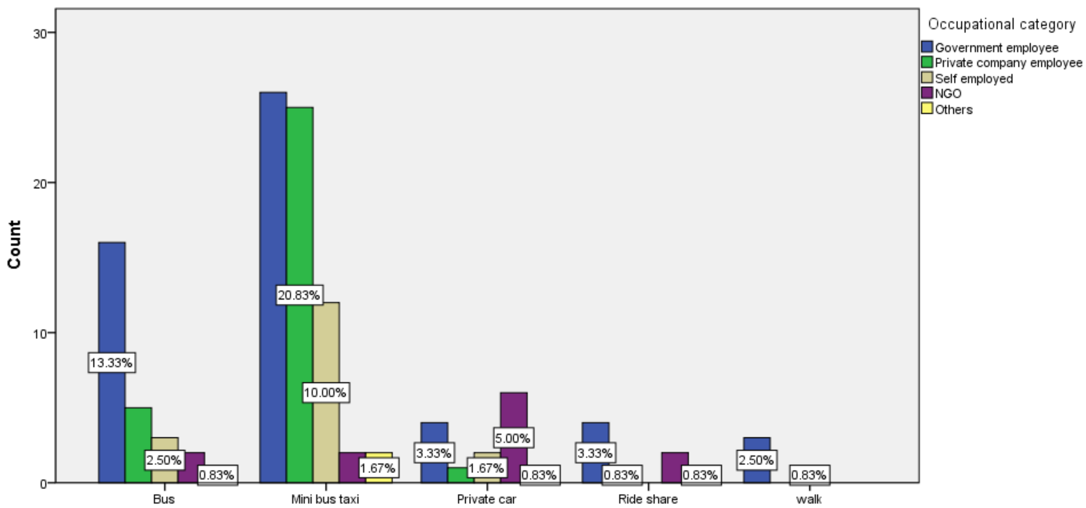

Figure 4.18: Revealed preference relative to employee respondent occupational category

Non-home based work related trips

In non- Home based Work related about 120 valid respondents were included. Detailed modal share of this trip purpose and trip maker's interest to change their modal preference to the newly introducing system, BRT bus is shown below appropriately in the figure. As it can be seen below 84.17% of non-home based work related travellers are interested to use coming BRT bus with respect of this newly introducing bus characteristics determined in the questionnaire.

Table 4.5: Modal share of non-home based work related trips and travellers interest to divert BRT bus

Respondent revealed mode choice	Respondent stated modal shift interest		Total trip makers	Total trip makers , in%	Interested to divert to BRT,in %
	Yes	No			
Bus	40	1	41	34.17	97.56
Mini bus taxi	53	8	61	50.83	86.89
Private car	5	9	14	11.67	35.71
Ride share	3	0	3	2.50	100.00
walk	0	1	1	0.83	0.00
Total	101	19	120	100.00	84.17

Moreover, modal share of non-home based work related trip travelers are presented below in pie chart, in figure 4.19 below.

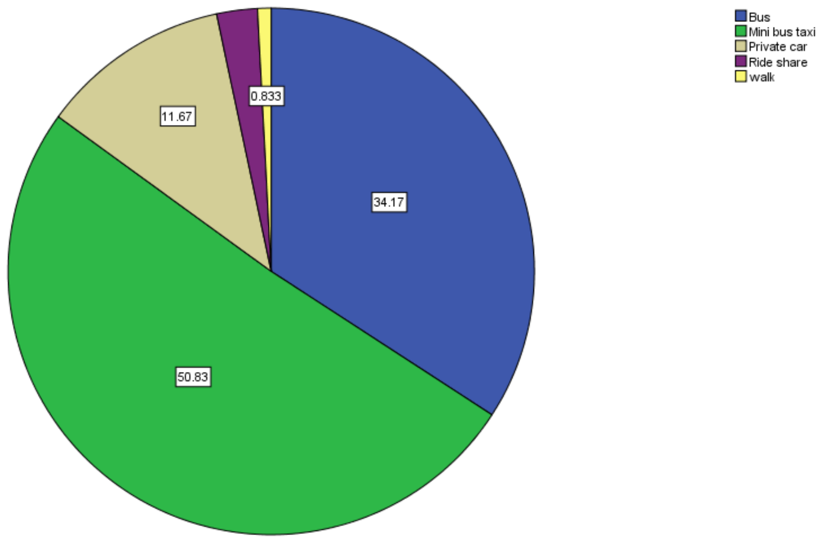

Figure 4.19: Non-home based work related travellers modal share

The relation between non-home based work related commuter's gender and their revealed modal choice is shown below in figure 4.20.As shown below ratio of male to female of private car user has largest value which is followed by ratio of walk. Another way ride share user is only one man. In contrast large bus, taxi and contract users have ratio of male to female commuters close to 1.Therefore private car and walk are mostly used by men commuters whereas Bus, minibus taxi and contract modes have almost the same number of male and female users. Consequently, the transport can understand that gender has a visible effect on home based work commuters' modal choice.

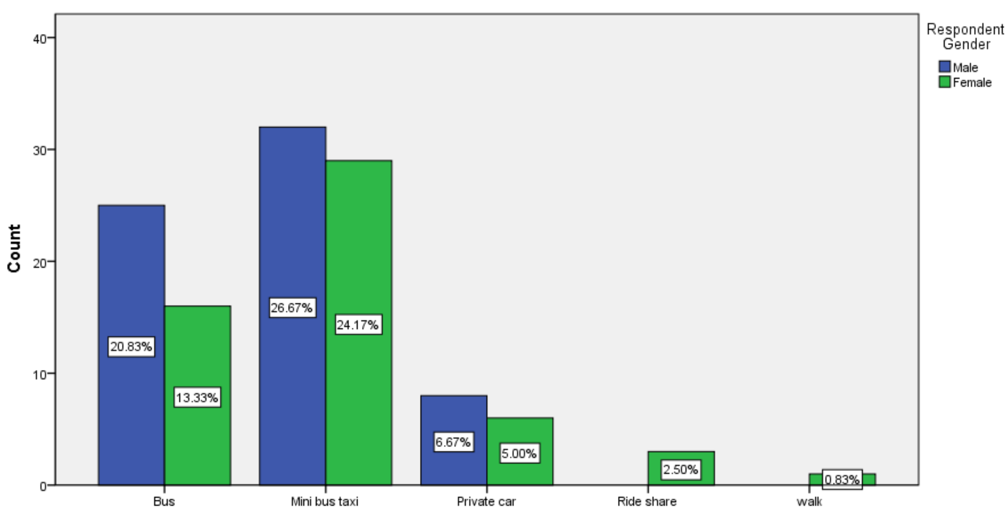

Figure 4.20: Non-home based work related travellers modal share relative to gender

As it can be seen in figure 4.21, the highest percentage of workers (25.83 %) age in between 18-35 prefer minibus taxi whereas ratio of workers with age of in between 18-35 to that of between 35-65 is close to 1 over bus mode. All ride share preference is occupied by travellers with age of between 18 and 35 years. Detailed information is shown below in the figure.

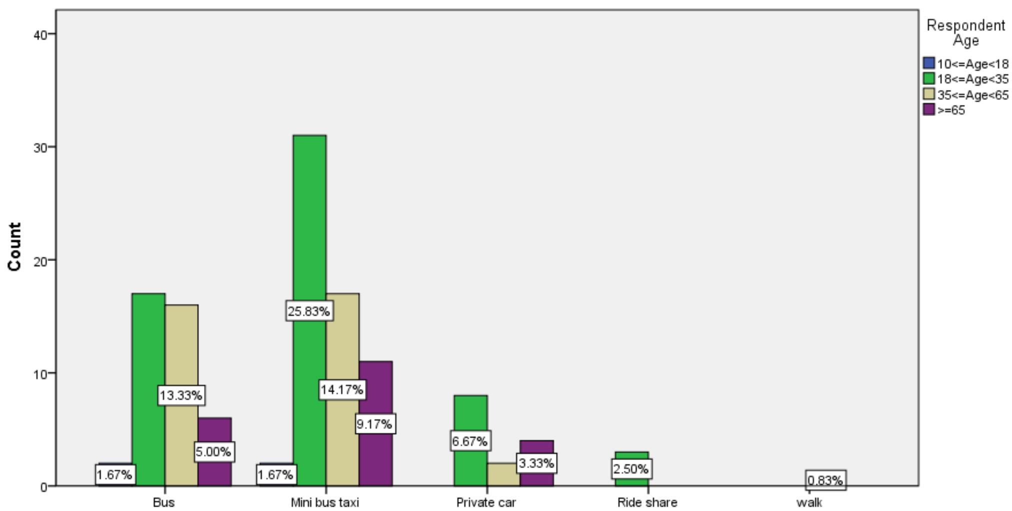

Figure 4.21: Non-home based work related travellers revealed preference relative to age

The effect of family size on modal preference of non-home based work travelers is tried to be determined in figure 4.22, as shown below. Highest percentage of trip makers with middle class family size prefers to use minibus taxi mode. Whereas highest percentage of trip makers with family size of in between 2 and 5 prefers to use mini bus taxi followed by contract mode. The ratio of trip makers with family size groups in between 2-5 to that of family size above 6 over minibus taxi mode is close 1.for non-home based work related trip purpose most of private car user employees are with age between 18 and 35.

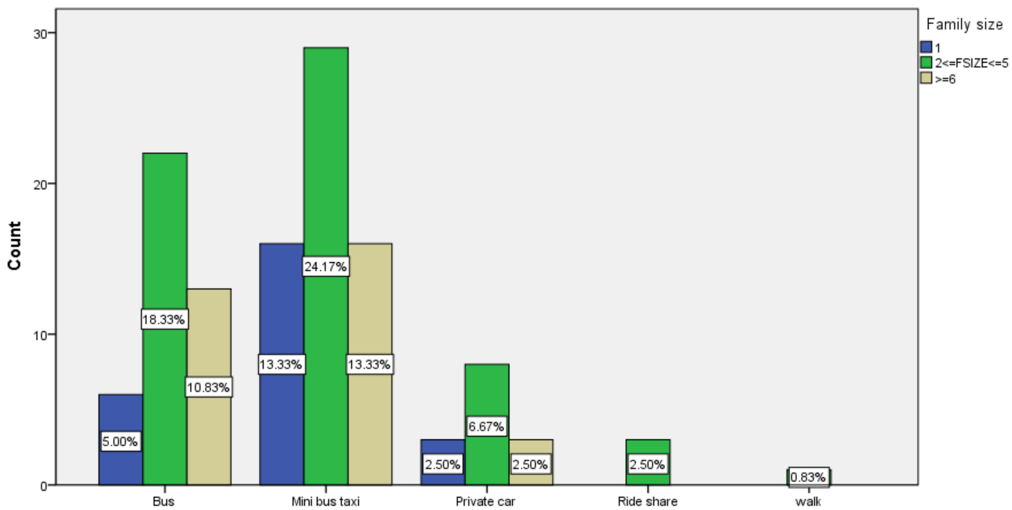

Figure 4.22: Non-home based work related travellers revealed preference relative to family size

The relation between employee marriage status and home based work trips modal preference of commuters shown below. As it can be seen from figure 4.23, highest percentage of married employee (31.67%) uses minibus taxi followed by 19.17% bus users. While highest percentage of single employee preference is minibus, divorced employee prefers bus. Ratio of single to divorced employees is close to 1 private car preference. Addition preference indicators are shown below in the figure 4.23.

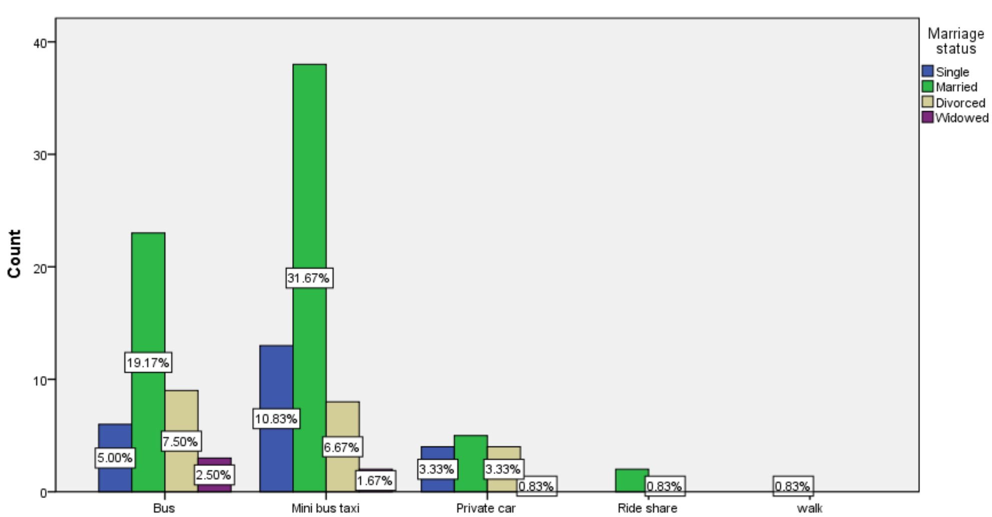

Figure 4.23: Non-home based work related travellers revealed preference relative to marriage status

According to output of crosstab analysis shown in figure 4.24, mostly, minibus taxi mode is preferred by employees that are first degree holder. On the other hand, primary school and below to secondary school education level traveller ratio is close to 1 over bus mode. The ratio of second degree and above to certificate and diploma education lever travellers over minibus taxi is 1.

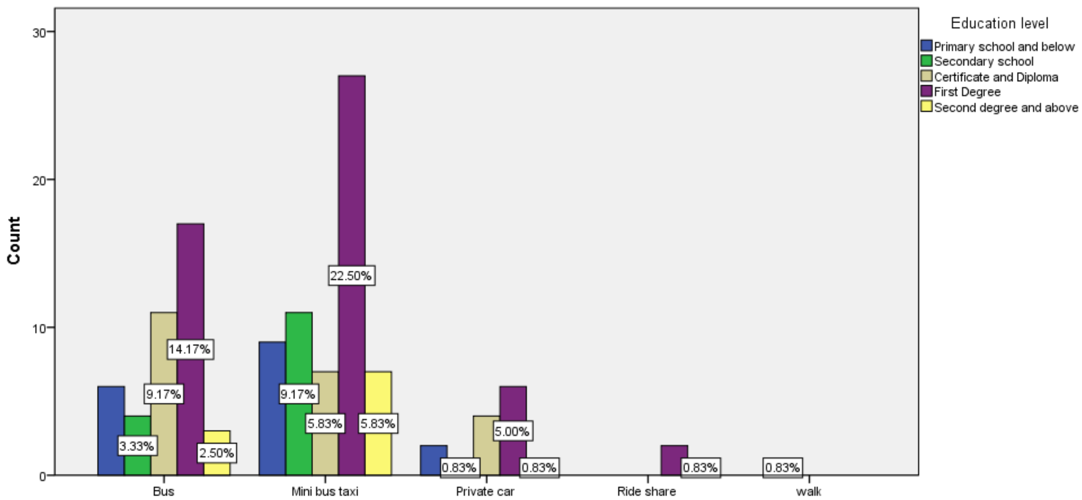

Figure 4.24: Non-home based work related travellers revealed preference relative to education level

As shown in figure 4.25, the largest percentage of minibus taxi user, 31.67%, are non-home based work purpose travels with a monthly family income level less than 5000 ETB. The ration of travellers with family income of 5000-2000 ETB to that with family income of greater than 20,000 ETB is close to 1. It is also apparent that travellers with monthly family income level of higher than 20,000 have no share in bus mode.

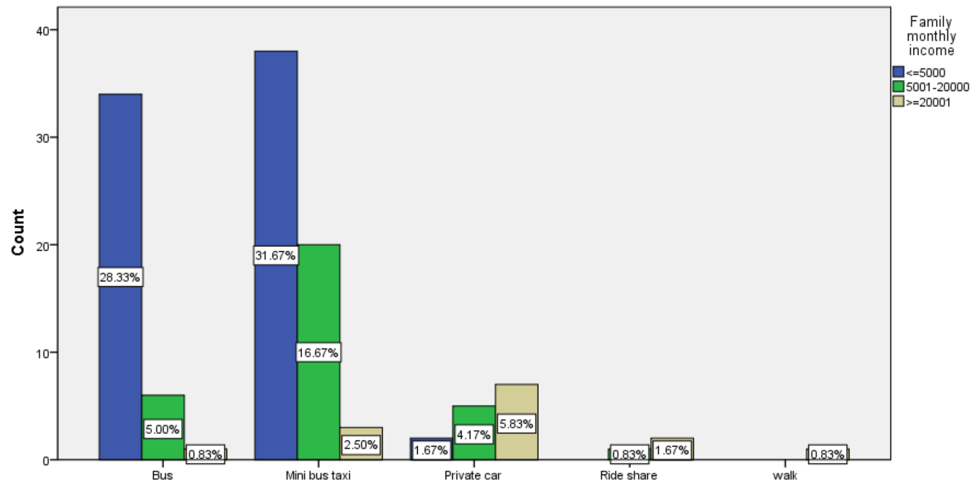

Figure 4.25: Non-home based work related travellers re income level preference relative to

For non-home based work related trip purpose Bus mode is fully used by travelers that do not own private care. Largest modal share of mini bus taxi, 44.17% are travellers that do not own private car. On the other hand larger modal share of ride share, 10.00%, are private car owner travellers.

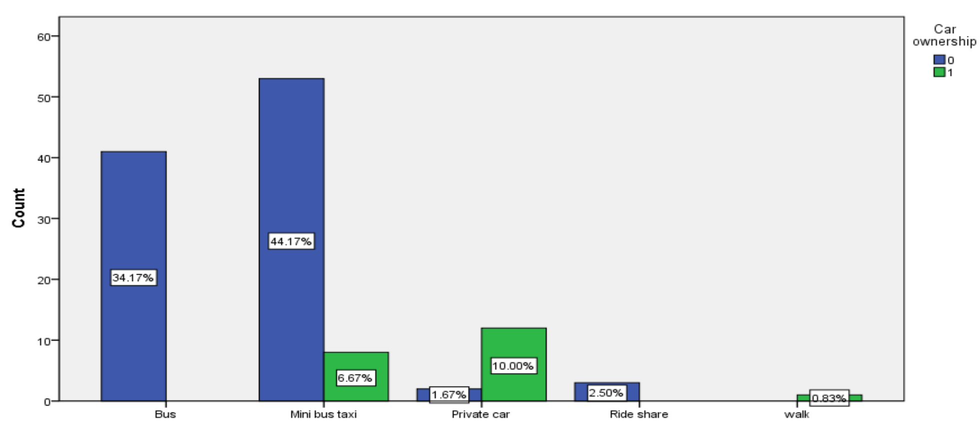

Figure 4.26: Non-home based work related travellers revealed preference relative to car ownership

The ratio government employee that prefer minibus taxi mode and private company employee that prefer minibus taxi is close 1.Most of NGO workers, 5%, prefer private car. Largest modal share of bus is taken by government employee whereas most of self-employee travelers choices mini bus taxi.

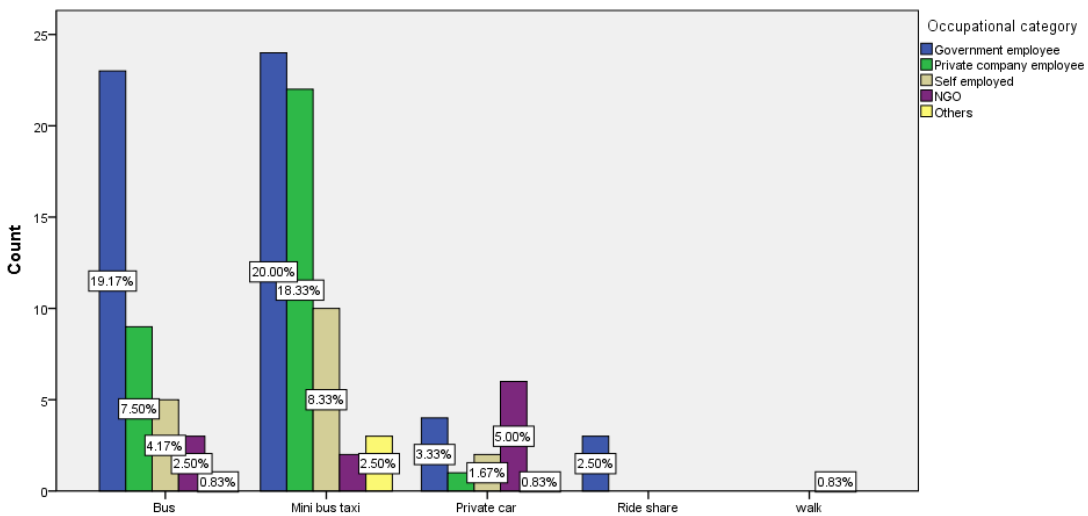

Figure 4.27: Non-home based work related travellers revealed preference relative to occupational category

Home based education trips

The modal share of home based education purpose trips in the study are and trip maker's interest to divert their choice to the newly introducing BRT buses is presented below in table 4.6, in line for to crosstab statistical analysis output. According to this crosstab analytical output, 76.36% of home based education commuters are agreeable to turn away their reveled preference to the newly introducing BRT buses. The detailed modal share of all available modes is shown in the table 4.6 below.

Table 4.6: Modal share of home based education trips

Respondent revealed mode choice	Respondent stated modal shift interest		Total trip makers	Total trip makers, in%
	Yes	No		
Bus	38	0	38	23.03
Mini bus taxi	42	8	50	30.30
Private car	6	13	19	11.52
Contract	26	15	41	24.85
Walk	14	3	17	10.30
Total	126	39	165	100.00

Moreover, modal share of home based education travelers are presented below in pie chart, in figure 4.28 below.

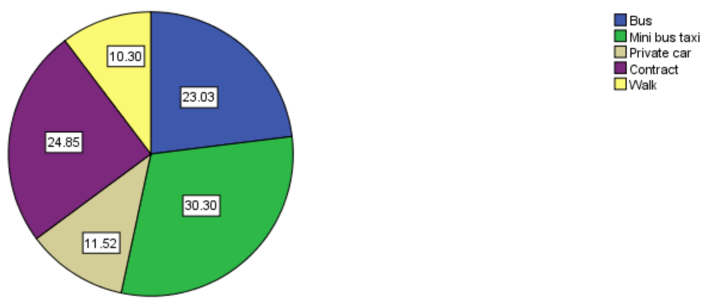

Figure 4.28 Modal share of home based education trip makers

The relation between home based education trip makers' gender and their revealed modal choice is shown below in figure 4.29.As shown below ratio of male to female of contract (lada) and minibus taxi is around one. In contrast private car users have ratio of male to female commuters close to 4.Detailed analysis result is shown below in the chart .

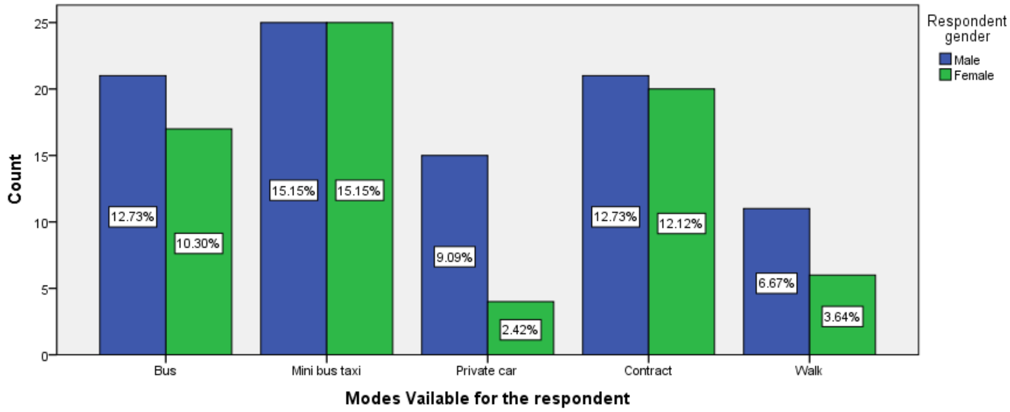

Figure 4.29: Revealed modal preference of students relative to gender

As it can be seen in figure 4.30, a highest percentage of workers (23.60 %) age in between 18-35 prefer minibus taxi. Whereas workers with age in between 35-65 and above 65 ages have 8.07% modal share of minibus taxi. Students in both age ranges have the ratio close to 1 for private car and walk mode. Detailed information is shown below in the figure.

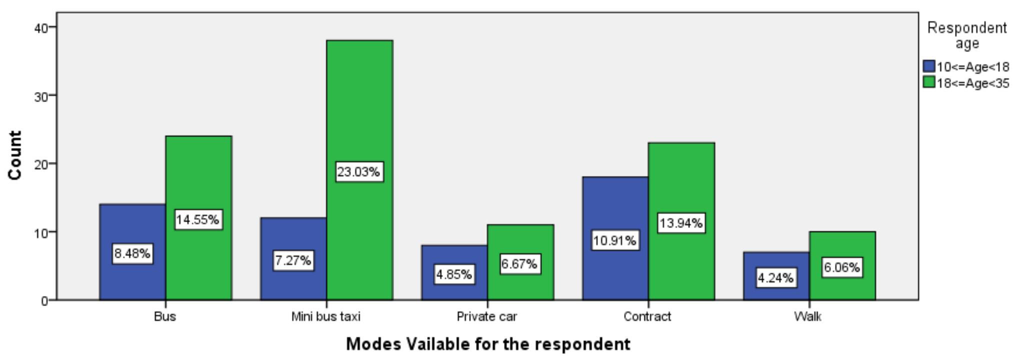

Figure 4.30: Revealed modal preference of students relative to age

The effect of family size on modal preference of home based education trip makers is tried to be determined in figure 4.31, as shown below. From all the available modes highest percentage of trip makers with family Size of in between 2 and 5 prefers to use mini bus taxi followed by contract (lada) mode.

The ratio of trip makers with family size groups in between 2-5 to that of family size above 6 of private car users is close 2.The same ratio works for bus mode.

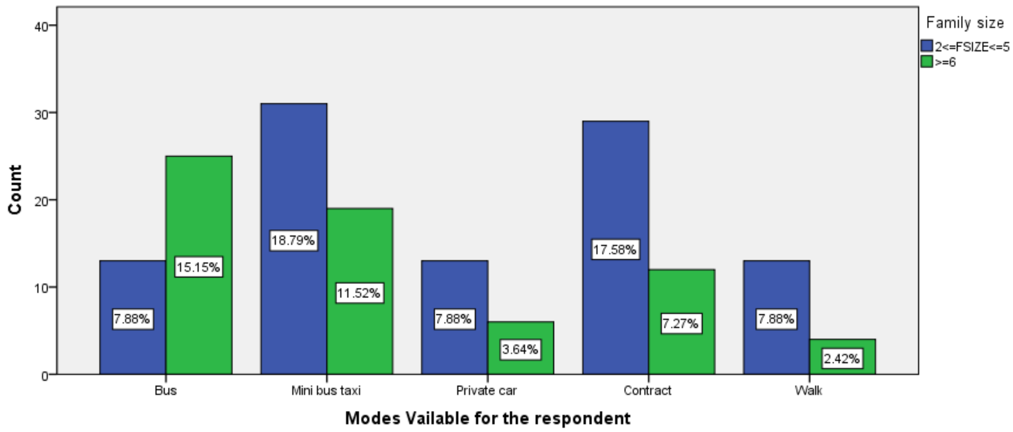

Figure 4.31: Revealed modal preference of student relative to family size

Below, Figure 4.32 shows the relation between school type and home based education traveler's modal preference. As it can be seen from the figure, the ratio government school to private school student over bus modal share close to 6 followed by contract (lada) mode. While highest percentage of single employee preference is minibus, divorced employee prefers bus. Ratio of divorced to widowed employees over minibus taxi is almost similar. Addition preference indicators are shown below in the figure 4.32.

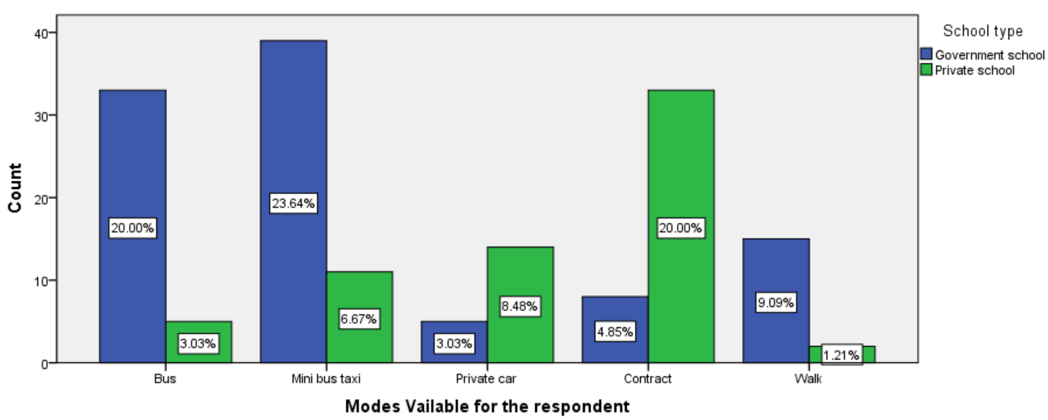

Figure 4.32: Revealed modal preference of student relative to school type

According to output of crosstab analysis shown below in figure 4.33, education trip maker's preference towards private car, contract (lada) and walk almost similar. On the other hand, the ratio of secondary school travellers to primary school travellers over both bus and minibus taxi closes to 1.

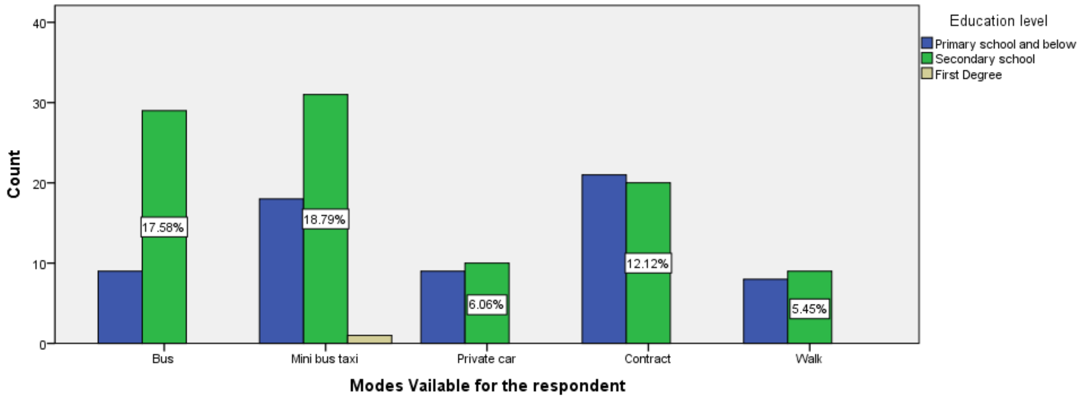

Figure 3.33: Revealed modal preference of students relative to education level

As shown below, travellers that do not own private car prefer to use minibus taxi and bus mostly. The ratio of non-car owner to car owner trip makers over contract (lada) mode is close to 2. Larger modal share of walk, 9.70%, are home based work education purpose travellers that do not own private car. Additional information of trip maker modal preference with respect to private car ownership is shown in detail below in figure 3.34.

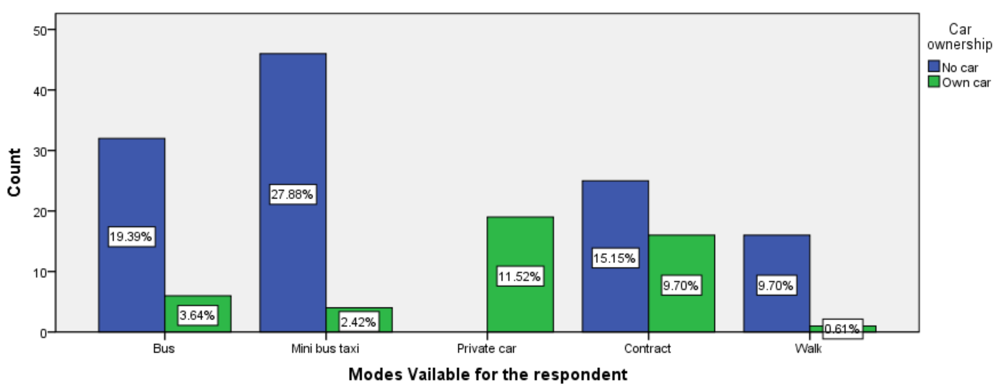

Figure 3.34: Revealed modal preference of students relative to car ownership

4.1.4. Stated preference data presentation

Home based work trips

The stated preference survey ties to determine the trip maker's interest to divert their transport preference to the stated bus rapid transit system. The pie chart shown below in Figure 4.36 shows the interest of commuters to change their mode choice due to characteristics of the newly introducing BRT that determined in the questionnaire .Accordingly, 82.61% of the home based work purpose travellers are willing to change their revealed mode choice to the stated BRT buses. However, the remaining 17.39 % were decided to remain on their revealed modal choice. This implicates that most home based work trip makers are interested to divert their modal share to the newly introducing bus rapid transit system.

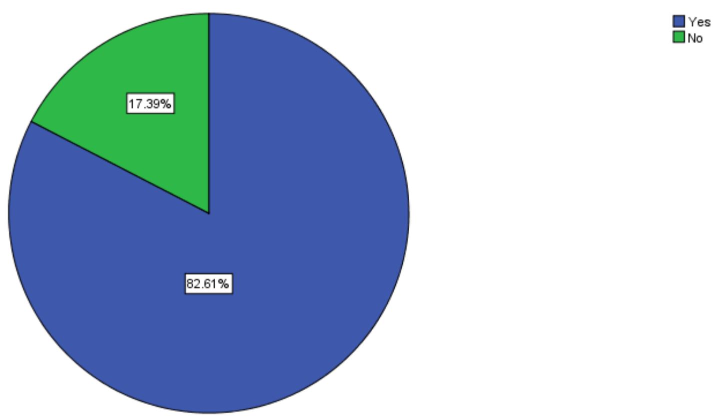

Figure 4.35: Home based work travelers interest to change their modal share to BRT

Travelers willing to divert to the BRT bus in relation to each available modes of transport are shown below in figure 4.36 through crosstab analysis.

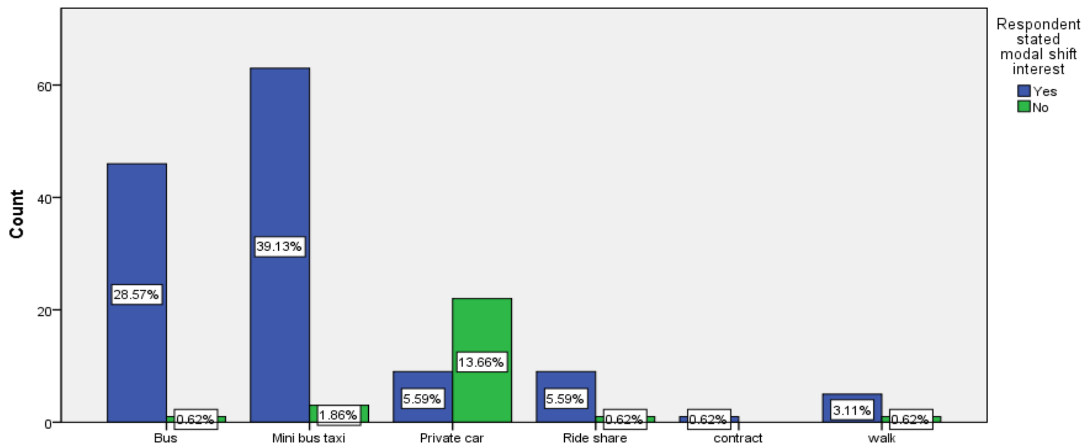

Figure 4.36: Home based work travellers to change modal preference to BRT bus

Almost all travelers that prefer bus mode under revealed preference are willing to change their modal preference to BRT buses. Largest share of the travelers are interested to divert their choice is taken by minibus taxi users, about 39.13%, out of 82.61% travellers interested to divert their preference modal share to newly introducing BRT buses.

Home based others trips

The stated preference survey draws to determine the trip maker's interest to change their modal preference to the stated bus rapid transit system. The pie chart shown below in Figure 4.37 shows the interest of travelers to change their mode choice due to characteristics of the newly introducing BRT buses that was determined in the questionnaire .Accordingly, 88.33% of the home based others trip purpose travellers are agreeable to change their revealed mode choice to the stated BRT buses. However, the remaining 11.67 % were decided to remain on their revealed modal choice. This implicates that most home based others trip makers are interested to divert their modal share to the newly introducing bus rapid transit system.

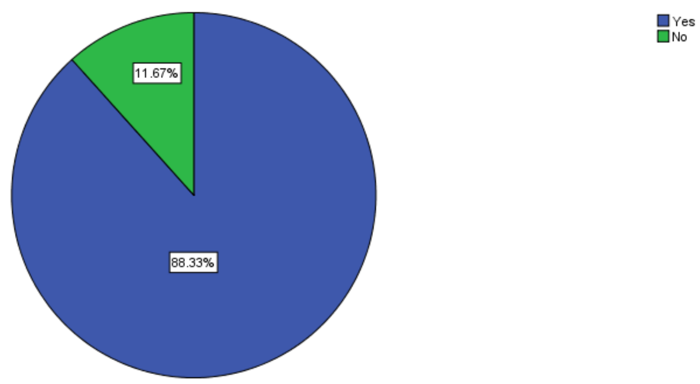

Figure 4.37: Home based others travellers to change modal preference to BRT bus

In the case of home based others trip purpose, travelers willing to divert their revealed preference to the BRT bus in relation to each available modes of transport are shown below in figure 4.38 through crosstab analysis.

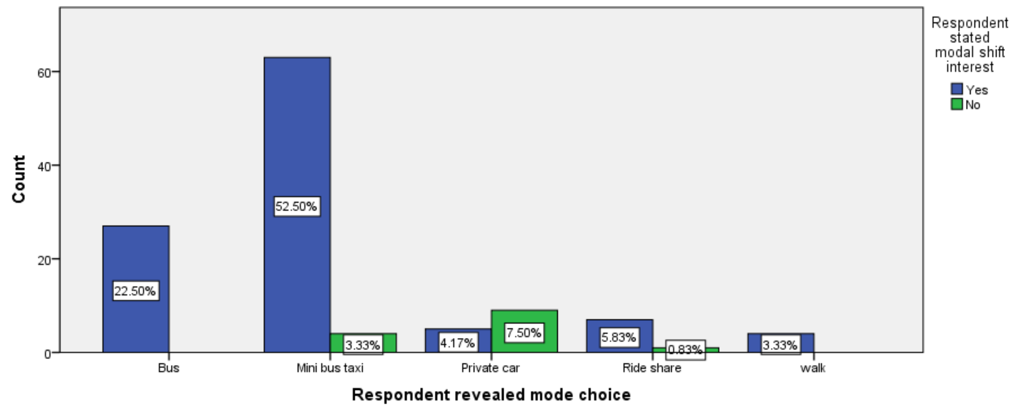

Figure 4.38: Home based others travellers to change modal preference to BRT bus relative to available modes

All travelers that were preferred bus mode under revealed preference are willing to change their modal preference to BRT buses. Largest share of the travelers that are interested to divert their choice is taken by minibus taxi users, about 52.50%.

Non-home based work related trips

For non-home based work related trips, stated preference survey was undertaken to determine the trip maker’s interest towards newly introducing BRT buses in the study are. The pie chart shown below in Figure 4.39 shows the interest of commuters to change their mode choice due to characteristics of the newly introducing BRT that determined in the questionnaire .Accordingly, 84.17% of the non-home based work related travellers are willing to change their revealed mode choice to the stated BRT buses. However, the remaining 15.83 % were decided to remain on their revealed modal choice. This implicates that most the trip makers are interested to accept a newly introducing bus rapid transit system.

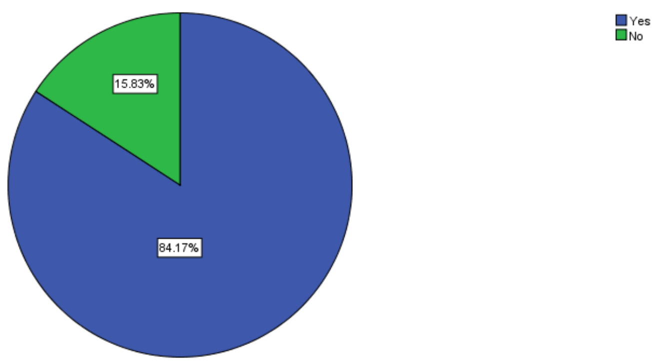

Figure 4.39: Non-home based work related travellers to change modal preference to BRT bus

Travelers willing to divert to the BRT bus in relation to each available modes of transport for the specific trip purpose are shown below in figure 4.40.

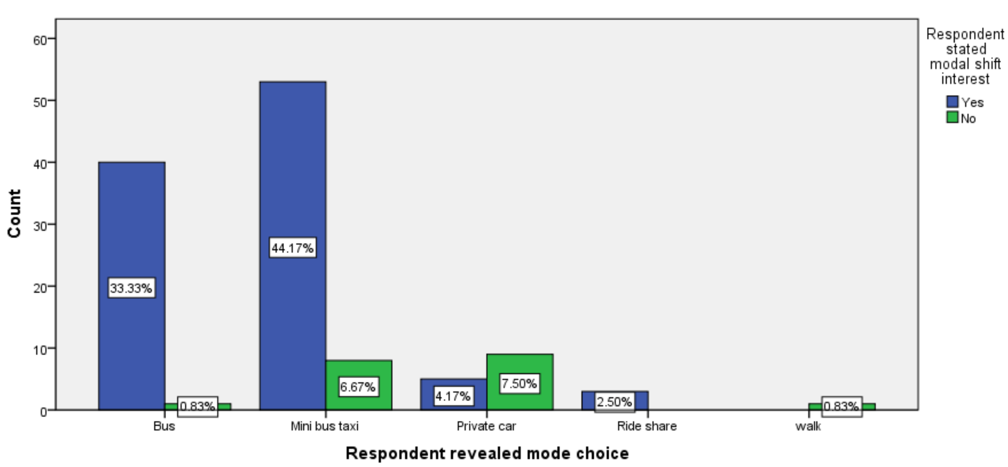

Figure 4.40: Non-home based others travellers to change modal preference to BRT bus relative to available modes

Almost all travelers that were preferred bus mode under revealed preference are willing to change their modal preference to BRT buses. Largest share of the travelers interested to divert their choice is occupied by minibus taxi users, about 44.17%.All ride share users are agreed to use BRT buses.

Home based education trips

The stated preference survey was undertaken to determine the trip maker's interest to towards newly introducing, under construction, bus rapid transit buses. The pie chart shown below in Figure 4.41 shows the interest of commuters to change their revealed modal preference due to characteristics of the newly introducing BRT buses that determined in the questionnaire .Accordingly, 76.36% of the home based education purpose travellers are willing to change their revealed mode choice to the stated BRT buses. However, the remaining 23.64 % were decided to remain on their revealed modal choice. This implicates that most home based education trip makers are interested to agree to use the newly introducing buses.

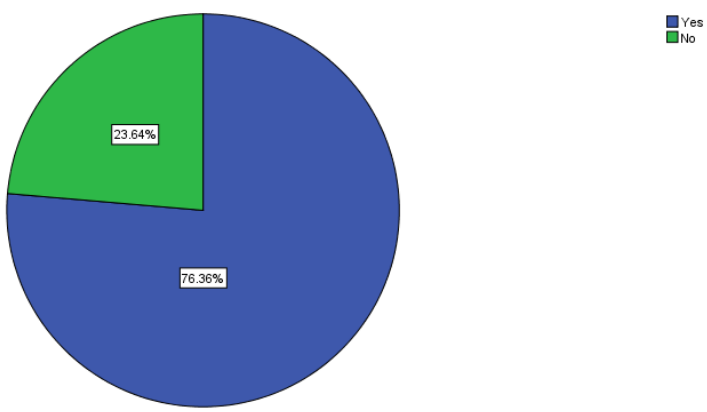

Figure 4.41: Home based education travellers to change modal preference to BRT bus

Travelers willing to divert to the BRT bus in relation to each available modes of transport are shown below in figure 4.42 through crosstab analysis.

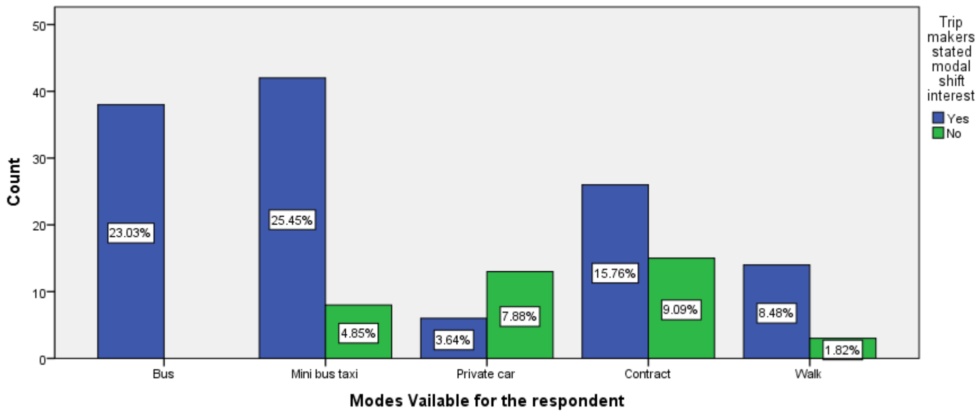

Figure 4.42: Home based education travellers to change modal preference to BRT bus relative to available modes

In this specific trip purpose, all travelers that had bus revealed preference are willing to change their modal preference to BRT buses. Largest share of the travelers that are interested to divert their choice is engaged by minibus taxi users, about 25.45%.

4.2. Estimation, validation and application of revealed preference model of HBW trips

4.2.1. Parameter estimation, test and comparison of revealed preference models of HBW trips

This model was developed for **home based work** commuters. In the study area bus, taxi, private car and ride share type of transport modes are available, as the assessment result indicates. Cost and time related variables are included in the model as mode (alternative) specific characteristics. Socio economic variables are included in the model as case specific characteristics.

In this study bus mode is considered as reference category .There are 493 observations and 154 cases .To determine the best fit model for the data, different models were developed and analyzed step by step. Base model was developed of dummy variables of available modes rather than reference category. Herein consider Bus mode as reference category. Base model assumes that all constant are zero, as null hypothesis. The null hypothesis was rejected as all coefficients are statistically significant, different from zero. As shown in the table 4.7 below all constant is statistically significant to reject the null hypothesis.

Base model:

Table 4.7: Variables in the Equation

	B	SE	Wald	Df	Sig.	Ext(B)	95.0% CI for Exp(B)	
							Lower	Upper
dtaxi	-.376	.191	3.857	1	.050	.687	.472	.999
dpcar	-3.259	.615	28.053	1	.000	.038	.012	.128
drshare	1.653	.350	22.285	1	.000	5.224	2.630	10.377

Model 1: Include total travel time (TTT) and total travel cost (TTC) in addition to the constant parameters. The output of the statistical analysis is shown below. As shown in the table 4.6 below the p-value of total travel time, total travel cost and private car is less than 0.05.This implies that these variables have statistically significant effect on the model. After this it can be seen that generic variables are not significant. Even though they are significant generic variables should be retained in the equation. Moreover, if it is found reasonable to retain variables such as the level of service (travel time variables) or policy variables (travel cost) in the model, those variables will be kept even if it is statistically insignificant (Ortuzar & Willumsen, 2011). The p-value of Mode specific variables (constant) taxi and ride share are greater than 0.05. These variables are statistically insignificant. But they represent variables even not considered here. Even though they are not significant mode specific variables should be retained in the equation. The lack of significance of the alternative specific constants is irrelevant since the constants represent the average effect of all the variables not included in the model and should always be retained despite the fact that they do not have a well understood behavioral interpretation (Koppleman & Chandra, 2006).Also adjusted rho-squared value (ρ'^2) lies between 0 and 1 should be calculated to determine how the model is explanatory and how one model is better than the other, which is determined widely in the literature review. A value of zero implies that the model is no better than the reference model; whereas, a value of one implies the model is perfect (Koppleman & Chandra, 2006). Moreover it is logical for signs of travel time and travel cost parameters to be

negative because the utility of modes will increase with deceasing of travel time and travel cost. This is compatible with our judgment.

Table 4.8: Variables in the Equation of Model 1

Parameters	**B**	**Sig.**	**Exp(B)**
TTCost	-.041	.028	.960
TTTime	-.049	.033	.952
CBus	Reference category		
CTaxi	.138	.688	1.148
CPcar	-2.876	.005	.056
CRshare	-1.142	.582	.319
-2LL(0	356.209		
-2LL(C)	245.010		
-2LL(β)	235.556		
Degree of freedom (k)	5		
Adjusted rho squared w.r.t. zero ($\boldsymbol{\rho 0\ '2}$)	0.339		
Adjusted rho squared w.r.t. constants ($\boldsymbol{\rho c\ '2}$)	0.038		

The utilities for each alternative in model 1 are shown below, according to the output statistical analysis of SPSS software:-

U_{Bus}= -0.049*TTTime - 0.041* TTCost

U_{Taxi} = 0.138 -0.049* TTTime - 0.041* TTCost

U_{Pcar} = -2.876 - 0.049 * TTTime - 0.041* TTCost

U_{Rshare}=– 1.142 0.049 * TTTime - 0.041* TTCost

Models 2 and 3 compared to Model 1: Model 2 was developed by adding Age interaction with taxi variable over Model 1. In Model 2, the coefficient for Age variable interaction with taxi was included and the age-taxi interaction results in a p-value of 0.011 < 0.05 as shown in the Table 4.9 below.

Table 4.9: Variables in the equation of Model 2& 3

	Model 2			**Model 3**		
Parameters	**B**	**Sig.**	**Exp(B)**	**B**	**Sig.**	**Exp(B)**
TTCost	-.039	.034	.961	-.052	.014	.949
TTTime	-.054	.028	.948	-.055	.033	.947
CBus	Reference category					
CTaxi	-.473	.412	.623	-.747	.237	.474
CPcar	-2.858	.006	.057	-3.251	.004	.039
CRshare	-.848	.686	.428	-3.654	.174	.026
Age taxi		.011			.002	
Age_taxi(2)	-.937	.402	.392	-.843	.503	.431
Age_taxi(3)	-.252	.663	.777	-.423	.507	.655
Age_taxi(4))	-1.584	.011	.205	-1.985	.003	.137
Age_rshare	-------	-------	-------		.099	
Age_rshare(2)	-------	-------	-------	-.031	.984	.969
Age_rshare(3)	-------	-------	-------	-1.154	.262	.315
Age_rshare(4)	-------	-------	-------	-3.320	.019	.036
-2LL(0	356.209			356.209		
-2LL(C)	245.010			245.010		
-2LL(β)	223.659			214.782		
Degree of freedom (k)	8			11		
Adjusted rho squared w.r.t. zero ($\boldsymbol{\rho 0\ '2}$)	0.372			0.397		
Adjusted rho squared w.r.t. constants ($\boldsymbol{\rho c\ '2}$)	0.087			0.123		

This makes the null hypothesis to be rejected; the Age_taxi interaction effect to the utility of the taxi mode that makes different over Model 1. Moreover, checking for its chi-squared value, taking Model 1 as the restricted and Model 2, as the unrestricted model.

$\chi 2$ = 235.556−223.659= 11.897 > 7.81

Where, 7.81 is the critical chi-squared value for 95% confidence level. This makes it possible to reject the null hypothesis that the parameter of age_taxi interaction variable is zero. According to estimation result in the above table, the utilities of the available modes with the statistically significant values of parameters in model 2 are as follows:

U_{Bus}= -0.054*TTTime-0.039 *TTCost

U_{taxi} =-0.473 -0.054*TTTime -0.039 *TTCost – 1.584 *Age-Taxi

U_{pcar} = -2.858 -0.054*TTTime -0.039 *TTCost

U_{rshare}=-0.848 -0.054*TTTime -0.039 *TTCost -3.320 * Age_ rshare(4)

So continue with model 2.

Model 3: Model 3 was developed by adding age variable interactions with ride share to Model 2. In Model 3, the coefficient for Age_rshare (4) was included as its p-value .0.019< 0.05, as shown in the Table below. Moreover, checking for its chi-squared value (taking Model 2 as the restricted and Model 3 as the unrestricted model) results in the following value.

$\chi 2$ = 223.659 −214.782= 8.877 > 7.81

According to estimation result shown in the above table 4.9, the utilities of the available modes with the statistically significant values of parameters in model 7 are shown as follows:

U_{Bus}= -0.055TTTime -0.052*TTCost

U_{taxi} =-0.747 -0.055TTTime -0.052*TTCost-1.985*Age_taxi (4)

U_{pcar} = -3.251-0.055TTTime -0.052*TTCost

U_{rshare}=-3.654 -0.055TTTime -0.052*TTCost

Therefore, continue with model 3.

Model 4: Was developed by adding family income interactions with ride share to Model 3. Estimation value is shown below in the table 4.10.P-value of Fincome_rshare (3) is 0.008. This is by far less than 0.05 as shown in the table below. Moreover, checking for its chi-squared value (taking Model 3 as the restricted and Model 4 as the unrestricted model) results in the following value, which can makes it possible to reject the null hypothesis that the parameter of Fincome_rshare interaction is zero.

$\chi 2 = 214.782 - 199.954 = 14.828 > 9.49$

This implies to continue with model 4.

According to the estimation result shown below, statistically significant values of parameters in model 4 are shown as follows:

U_{Bus}= -.053*TTTime -.069*TTCost

U_{taxi} = -.795 -.053*TTTime -.069*TTCost -1.965 *Age_taxi (4)

U_{pcar} = -3.783 -.053*TTTime -.069*TTCost

U_{rshare}= -7.315 -.053*TTTime -.069*TTCost +3.580* Fincome_ rshare (3)

Table 4.10: Variables in the Equation of Model 4

	Model 4		
Parameters	**B**	**Sig.**	**Exp(B)**
TTCost	-.069	.008	.933
TTTime	-.053	.041	.949
CBus			
CTaxi	-.795	.210	.452
CPcar	-3.783	.002	.0236
CRshare	-7.315	.032	.001
Age_taxi		.002	
Age_taxi(2)	-1.034	. .393	.355
Age_taxi(3)	-.421	.508	.656
Age_taxi(4))	-1.965	.004	.140
Fincome_rsh		.098	
Fincome_rsh(2)	1.799	.105	.165
Fincome_rsh(3)	3.580	.008	.028

Fincome_rsh(4)	13.351	.956	.000
Fincome_rsh(5)	1.220	.240	.295
-2LL(0	356.209		
-2LL(C)	245.010		
-2LL(β)	199.954		
Degree of freedom (k)	15		
Adjusted rho squared w.r.t. zero ($\rho 0\ '2$)	0.439		
Adjusted rho squared w.r.t. constants ($\rho c\ '2$)	0.184		

Model 5 to 6: The earlier models were developed assuming that out of vehicle and in vehicle travel times have the same effect on the utility of commuters. Therefore out of vehicle and in vehicle travel time were summed up to one variable named total travel time. Here in model 5 let us consider out of vehicle and in vehicle travel time separetly to assess commuter sensitivity towards these variables. Model 5 was developed by replacing total travel time in model 4with out of vehicle and in vehicle travel time. Model 5 was evident that trip makers are more sensitive to out of vehicle travel time than in-vehicle travel time since the parameter coefficient of OVTTIME and IVTTIME are -0.371 and -0.053 respectively. This indicates that a minute of out of vehicle travel time will generate a higher disutility than a minute of in-vehicle travel time. Therefore continue with model 5.

Table 4.11: Variables in the equation of Model 5 & 6

	Model 5			**Model 6**		
Parameters	**B**	**Sig.**	**Exp(B)**	**B**	**Sig.**	**Exp(B)**
TTCost	-.069	.008	.933	-.065	.014	.937
ATIME	-------	-------	-------	-.017	.937	.984
WTIME	-------	-------	-------	-.427	.004	.652
OVTTIME	-.371	.010	.690	-------	-------	-------
IVTTIME	-.053	.041	.949	-.053	.043	.949
CBus	Reference category					
CTaxi	2.068	.120	7.908	2.551	.062	1.814
CPcar	5.759	.120	3.900	5.913	.113	3.640
CRshare	3.23	.01	5.32	4.23	.022	2.32

Age_taxi		.002			.003	
Age_taxi(2)	-1.034	.393	.355	-1.088	.373	.337
Age_taxi(3)	-.421	.508	.355	-.415	.525	.660
Age_taxi(4))	-1.965	.004	.140	-1.953	.004	.142
Age_rshare		.380			.454	
Age_rshare(2)	-.208	.901	.813	.411	.821	1.508
Age_rshare(3)	-1.326	.233	.266	-1.000	.418	.368
Age_rshare(4)	-2.447	.110	.087	-2.030	.196	.131
Fincome_rsh		.098			.051	
Fincome_rsh(2)	1.799	.105	.165	2.296	.047	.101
Fincome_rsh(3)	3.580	.008	.028	4.318	.003	.013
Fincome_rsh(4)	13.351	.956	.000	15.105	.967	
Fincome_rsh(5)	1.220	.240	.295	1.403	.220	.246
-2LL(0	356.209			356.209		
-2LL(C)	245.010			245.010		
-2LL(β)	199.954			191.484		
Degree of freedom (k)	15			16		
Adjusted rho squared w.r.t. zero ($\boldsymbol{\rho 0\ '2}$)	0.439			0.462		
Adjusted rho squared w.r.t. constants ($\boldsymbol{\rho c\ '2}$)	0.184			0.218		

To check commuters' sensitivity towards waiting time, which is a part of out of vehicle travel time model 6 was developed additionally. This model was developed by replacing Out of vehicle travel time with the two independent variables, waiting time and access time. As shown in the table 4.11 above, waiting time is the most sensitive variable than all other generic variables. The comparision between Models 5 and 6 was done using the non-nested hypothesis test using the outputs of the parameter estimation in Tables 4-11. The null hypothesis that the model with the lower $\rho 0\ '2$ value is the true model is rejected due to the significance level determined by the following equation (Koppleman & Chandra, 2006). The null hypothesis that the model with the lower $\boldsymbol{\rho 0}\ '^2$, in this case model 5is the true model, will be rejected if the significance level computed below is less than 0.05, for 95% confidence level.

$$Significance\ level = \Phi\ [-\ (-2 * (\rho H\ '2 - \rho L\ '2) * LL\ (0) + (KH - KL))^{0.5}]$$

$$= \Phi\ [-\ ((0.462 - 0.439) * 356.209 + (16 - 15))^{0.5}]$$

$= \Phi\,[-3.032] = 0.00121 < 0.05$

The complementary cumulative probability and percentile for 3.032 Z score is displayed above. Since the significance level calculated above is less than 0.05 then the null hypothesis that model 5 is the true model can be rejected. Therefore, at this stage, the true model is Model 6.

According to estimation result shown above, table 4.11.The utilities of the available modes with the statistically significant values of parameters in model 6 are shown as follows:

U_{Bus}= -.053* IVTTIME - 0.427 * WTIME -0.065*TTCost

U_{taxi} = 2.551 -.053* IVTTIME - 0.427 * WTIME -0.065*TTCost -1.953 *Age_taxi (4)

U_{pcar} = 5.913 -.053* IVTTIME - 0.427 * WTIME -0.065*TTCost

U_{rshare}=3.23 -0.053* IVTTIME - 0.427 * WTIME -0.065*TTCost +2.296 * Fincome_rsh (2) +4.318 Fincome_rsh (3)

According to the SPSS software analysis output the developed models, in vehicle travel time, waiting time and total travel cost of the modes, Age interacted with taxi and family monthly income interacted with taxi and ride share are the factors that have statistically significant effect on the trip makers reveled preference among four available alternatives. The parameters of generic variables, variables related to time and cost have negative coefficients. This shows that the decrease in these variables will result in the enhancement of the trip maker utility. Even though improvement level of the trip makers' utility is deferent for all these variables, in vehicle travel time, waiting time and travel cost, minimization of this variables value increase the commuters' utility towards the mode.

The socio-economic variables are expressed as interaction with the chosen modes, rather than reference category. Based on the resulted revealed preference model, trip makers with age range above 65 are less likely to choose taxi over bus than those of aged under 65.This implies that elders prefer bus over taxi. This means other factors kept similar. The utility of using bus for a trip maker with older than 65 is higher than that of a trip maker younger than 65.

4.2.2. Validation of revealed preference model of HBW trip

The validation of the most fitting model was done by informal test of basic parameters. Moreover validation of the model was checked by determining the prediction capacity of the model. The validation of the most fitting model is assessed using samples that were collected for validation purpose during data collection stage. These data were used to assess how well the model fits the data by determining the prediction capability of the model.

$$\text{Prediction capability } = \frac{\text{Number of correctly predicted modes} * 100}{\text{Total number of validation data}}$$

As determined in section 4.1, 43 samples were collected for testing the validation of the most satisfactory model. Below, in the table 4.12, partial examples of the validation of model 27 were shown.

Table 4.12: Partial examples of the validation of model 6

ID	Available alternatives	Utility of the mode	Exponent	Probability of choosing	Predicted choice	Chosen mode	Predicted vs. chosen mode
10	1	-3.65	0.025991129	0.0009	0	0	
10	2	-8.88	0.000139144	4.93E-06	0	0	
10	3	3.34005	28.2205377	0.9991	1	1	Similar
11	1	-4.505	0.01105359	0.9450	1	1	Similar
11	2	-11.841	7.20309E-06	0.0006	0	0	
11	4	-7.36	0.000636198	0.0575	0	0	
12	1	-9.661	6.37208E-05	0.0014	0	0	
12	2	-3.299	0.036920069	0.7874	1	1	Similar
12	4	-4.615	0.009902183	0.21120	0	0	
13	1	-9.305	9.09683E-05	9.6420E-06	0	0	
13	2	-1.894	0.150468729	0.0159	0	0	
13	3	2.2283	9.284069738	0.9840	1	1	Similar
14	1	-10.72	2.20985E-05	8.687E-05	0	0	
14	2	-1.369	0.254361194	0.9999	1	1	Similar
14	4	-11.229	1.32833E-05	5.22151E-05	0	0	

15	1	-11.471	1.04282E-05	0.0014	0	0	
15	2	-6.815	0.001097193	0.1455	0	0	
15	4	-5.046	0.006435022	0.8532	1	1	Similar

For validation, 43 samples of data were used and the prediction ratio of model 27 are calculated The resulting utility and probability of choosing the modes for each trips, the chosen and the predicted preferences is as shown above in the table above. The numbers of preferences that are correctly predicted by the Development of Modal Choice Model for Home-Based Work Trips model are 38 out of 43 validation data. This implies that the calibrated model is capable of predicting 88.37% of the preference of trip makers, as computed below.

$$\text{Prediction Accuracy} = \frac{\text{Predicted choice}}{\text{Observed choice}} * 100$$

=38/43 *100

=88.37%

4.2.3. Application of revealed preference model of HBW trips to predict modal shifts under different scenario

The developed model can be used to predict the modal share of the large bus by applying different counteractive action to enhance the desirability of large bus which is revitalized to minimize the vast transportation problems rooted in the city. Moreover studies point out that increasing the attractiveness of the large bus is environmentally friendly.

Increment of large buses model share can be introduced by reducing waiting time, in vehicle travel time and total travel cost. Accordingly different scenarios are shown below in the table 4.13. The effects of decreasing waiting time, in vehicle travel time and total travel cost of large buses were determined using the developed models and the data collected for validation purposes. The average waiting time, in vehicle travel time and total travel cost of large buses of the collected samples for validation purpose are 18.18 minute, 30 minute and 3.70 ETB respectively. At these values, using the developed models, the resulted modal share of large buses were 38.64%. Reducing waiting time, in vehicle travel time and total travel cost different scenarios are shown below in the table4.13

Table: 4.13: Home based work trips scenarios

TTCost reduction	Waiting time reduction						IVTtime reduction						
	0%	10%	20%	30%	40%	50%		0%	10%	20%	30%	40%	50%
0%	39 %	52%	53%	56%	57%	58%	0%	39%	45%	46%	49%	52%	54%
10%	48%	54%	55%	57%	58%	60%	10%	42%	47	49%	52%	54%	55%
20%	49%	57%	56%	59%	59%	62%	20%	45%	50%	52%	54%	55%	57%
30%	52%	61%	57%	60%	61%	63%	30%	46%	52%	55%	56%	58%	59%
40%	55%	62%	58%	62%	63%	65%	40%	47%	55%	57%	58%	60%	61%
50%	57%	65%	59%	63%	65%	68%	50%	49%	57%	58%	59%	62%	63%

According to the results shown in Table 4-13 above, for example, a scenario resulted in reducing 40% of waiting time and keeping the TTC the same, and another scenario resulted in reducing 50% of TTC and keeping the Time the same result in similar additional 18% modal share to large buses. This indicated that waiting time has significantly more effect than total travel time in the modal preference of trip makers.

Reducing 10% of IVTT and keeping the TTC the same, and another scenario resulted in reducing 20% of TTC and keeping the IVTT the same result in similar additional 6% modal share to large buses. This implies that in vehicle travel time has more effect over total travel cost to increase the modal share of the bus in the study area. The largest increment of bus modal share was attained by reducing 50 % of waiting time and at the same time reducing 50% of TTC. Generally, the scenario analyses results that asses trip makers' sensitivity towards different variables will guide policy makers and transport planners which remedial actions are more efficient and which actions to consider as policies in increasing the modal share of large buses to minimize the transportation problems rooted in the city and also to make transportation system environmentally friendly. Mode over policy makers can consider different scenarios determined in the table 4.13 during transport planning activities.

4.3. Estimation, validation and application of HBW stated preference model

4.3.1. Parameter estimation, test and comparison of stated preference model

Bus rapid transit mode is a new transport option introducing in Addis Ababa city. The detailed characteristic of this transport option was determined in the questionnaire as stated by Addis Ababa transport management office. Therefore respondents were assessed if they would interested to shift their mode choice to the stated mode keeping the modal characteristics of other alternatives the same as they were and changing waiting time and in vehicle travel time of the stated bus mode as stated by the Addis Ababa city transport management office and determined in the questionnaire. As determined by the management office average in vehicle travel time is about

15 minutes and average waiting time is 4.5 minute. The parameter estimation method is used as for the earlier modeling technique.

In this modeling process the bus rapid transit mode is considered as the reference alternative. There are 154 cases to determine the best fit model for this data, different models were developed and analyzed step by step. Base model assumes that all constant are zero, as null hypothesis. The null hypothesis was rejected as all coefficients are statistically significant, different from zero. As shown in the table 4.14 below, all constant are statistically significant to reject the null hypothesis.

Table 4.14: Base model

	B	SE	Wald		Sig.	Exp(B)	95.0% CI for Exp(B)	
							Lower	Upper
CBUS	4.097	.714	32.934	1	.000	60.144	14.844	24.688
Ctaxi	3.691	.586	39.732	1	.000	40.096	12.724	16.349
Cpcar	-.538	.514	1.098	1	.295	.584	.213	1.597
Crshare	4.825	1.004	23.093	1	.000	124.548	17.408	19.104

Base model assumes that all constant are zero, as null hypothesis. The null hypothesis was rejected as all coefficients are statistically significant, different from zero. Similar technique of model estimation and comparison between estimated models is performed as in the revealed modeling. The different levels of models estimated with their deterministic portion of the utility of each mode are presented in detail below.

Model 1: This model was developed by adding total travel time and total travel cost to the constants.

Table 4.15: Variables in the Equation for model 1

	B	SE	Wald		Sig.	Exp(B)	95.0% CI for Exp(B)	
							Lower	Upper
TTTime	-.075	.030	6.217	1	.013	.927	.874	.984
TTCost	-.172	.053	10.393	1	.001	.842	.759	.935

CBUS	4.028	.779	26.731	1	.000	56.163	12.197	2.611
Ctaxi	3.318	.650	26.066	1	.000	27.603	7.723	9.657
Cpcar	-5.015	1.412	12.613	1	.000	.007	.000	.106
Crshare	-10.484	4.270	6.027	1	.014	.000	.000	.121

As it is shown in the table 4.15 all parameters included in the model are statistically significant as their alpha value is less than 0.05. Therefore it is possible to reject the null hypothesis states that the values of the parameters are zero.

Developing different models step wise, trip makers related (socio-economic) variables interacted with the available modes are excluded since the null hypothesis cannot be rejected as they are resulted in statistically insignificant parameters.

Model 2: check the trip maker's sensitivity towards in vehicle travel time and out of vehicle travel time explicitly deducting total travel time in to in vehicle and out of vehicle travel time Model 2 was developed. The result of this model is tabulated below in table 4.16.

Table 4.16: Variables in the Equation for model 2

	B	SE	Wald	df	Sig.	Exp(B)	95.0% CI for Exp(B)	
							Lower	Upper
OVTTIME	-.078	.038	4.116	1	.042	.925	.858	.997
IVTTIME	-.144	.063	5.260	1	.022	.866	.766	.979
TTCost	-.191	.055	11.980	1	.001	.826	.741	.920
CBUS	2.661	.773	11.846	1	.001	14.315	3.145	6.153
Ctaxi	2.461	.749	10.808	1	.001	11.720	2.702	5.840
Cpcar	-6.558	1.735	14.292	1	.000	.001	.000	.043
Crshare	-12.445	4.440	7.856	1	.005	.000	.000	.024

Even if model 1 assumes that in vehicle and out of vehicle travel times have the same effect model 2 trip makers have different sensitivity towards these two variables .The effect of these valuables is shown above in the table 4.16.

This model was compared to the first model and resulted in the following significance level at which it resulted in the alpha value less than 0.05.Moreover compare these two models by non-nested test, where the null hypothesis that the model with lower adjusted rho-squared value is the true model is rejected.

$$\rho 0L\ '2 = 1 - \frac{(97.277\ - 6)}{446.303}$$

$$= 0.795$$

$$\rho 0H\ '2 = 1 - \frac{(95.429 - 7)}{446.303}$$

$$=0.802$$

$$Significance\ level = \Phi\ [-(-2* (\rho H\ '2 - \rho L\ '2) * LL\ (0) + (KH - KL))^{0.5}]$$

$$= \Phi\ [-(((0.802 - 0.795) * (446.303) + (7 - 6))^{0.5}]$$

$$= \Phi\ [-2.031]$$

$$=0.978$$

The result showed that the null hypothesis that the model with lower adjusted rho-squared value is the true model cannot be rejected. Therefore model 1 is the better model to represent he collected data.

Model 3: This model was developed by deducting out of vehicle travel time to waiting and access. Herein waiting time is estimated statistical significant, the result of the estimation is shown below, in the table 4.17.

Table 4.17: Variables in the Equation for model 3

	B	SE	Wald	df	Sig.	Exp(B)	95.0% CI for Exp(B)	
							Lower	Upper
ATIME	.023	.109	.044	1	.835	1.023	.826	1.266
WTIME	-.088	.042	4.361	1	.037	.916	.843	.995
IVTTIME	-.146	.063	5.309	1	.021	.864	.763	.978
TTCost	-.187	.055	11.593	1	.001	.829	.745	.924
CBUS	2.670	.778	11.765	1	.001	14.442	3.141	66.417
Ctaxi	2.337	.754	9.610	1	.002	10.353	2.362	45.378
Cpcar	-6.638	1.747	14.429	1	.000	.001	.000	.040
Crshare	-12.124	4.409	7.562	1	.006	.000	.000	.031

Then compare model 1 with model 3.Compare these models by non-nested test. This comparison is shown below.

$$\rho 0L\ '2 = 1 - \frac{(97.277 - 6)}{446.303}$$

=0.795

$\boldsymbol{\rho 0}_H{}'^2$ = 1- (94.931-8)

446.303

=0.805

$Significance\ level = \Phi\ [-(-2* (\rho H\ '2 - \rho L\ '2) * LL\ (0) + (KH - KL))^{0.5}]$

$= \Phi\ [-(((0.805 - 0.795) * (446.303) + (8 - 6))^{0.5}]$

$= \Phi\ [-2.542]$

=0.0055

This result implied that the null hypothesis that the model with lower adjusted rho-squared value is the true model can be rejected. Therefore model 3 is the best model to represent he collected data.

Finally, the estimation results of different models shown above indicate that model 3 is the best model to represent the stated preference of the trip makers. The utilities of the available modes with the statistically significant values of the parameters in model 3 are shown as follows:

U_{BRT}= -0.146* IVTTIME - 0.088 * WTIME -0.187*TTCost

U_{Bus}= 2.670 -0.146* IVTTIME - 0.088 * WTIME -0.187*TTCost

U_{taxi} = 2.337 -0.146* IVTTIME - 0.088 * WTIME -0.187*TTCost

U_{pcar} = -6.638 -0.146* IVTTIME - 0.088 * WTIME -0.187*TTCost

U_{rshare}= -12.124 -0.146* IVTTIME - 0.088 * WTIME -0.187*TTCost

According to the above formulated stated preference of models, the decrease in in-vehicle travel time, Waiting time and travel cost of the available alternatives increases the utility of the specific modes, which results in the enhancement of the preference of that specific mode. This model can be applied in the fare structure and arrival frequency of the stated BRT system, to improve the preference opportunity of this system.

4.3.2. Validation of stated preference model

The negative sign of travel time travel cost and waiting time generally indicated validity of the developed model. Common understanding indicates that the utility of the mode should be increased as travel time and cost decreases. More over the sign of the variables in the utility of the modes the models validity of should be checked by the data collected for the validation purpose. Table 4-18 below, shows the validation data of the stated preference model.

Table 4.18 partial data of validation of the stated preference model

ID	Available alternatives	Exponent	Probability of choosing	Predicted choice	Chosen mode	Predicted vs. chosen mode
10	1	0.2120	2.63E-09	0	0	
10	2	0.004883	2.251E-02	0	0	
10	3	1.4E-14	6.47E-14	0	0	
10	5	5.7E-10	0.977	1	1	Similar
11	1	2.12E-01	0.815837	1	0	
11	2	0.004883	0.018788	0	0	
11	4	1.91E-15	0.000	0	0	
11	5	0.042981	0.165375	0	1	Not Similar
12	1	0.145876	0.831458	0	0	
12	2	9.41E-11	5.36E-10	0	0	
12	4	1.44E-07	8.21E-07	0	0	
12	5	0.02957	0.168541	0		
13	1	2.87E-03	1.00E+00	1	1	Similar
13	2	1.46E-10	5.08E-08	0	0	
13	3	1.21E-06	4.19E-04	0		
13	4	9.91E-08	3.45E-05	0	0	
13	5	5.7E-10	1.98E-07	0	0	
14	1	0.212036	0.807452	1	1	Similar
14	2	0.007582	0.028872	0	0	
14	4	1E-42	3.82E-42	0	0	
14	5	0.042981	0.163675	0	0	
15	1	0.145876	0.831458	0	0	
15	2	1.46E-10	8.33E-10	0	0	
15	4	1.44E-07	8.21E-07	0	0	
15	5	0.02957	0.168541	1	1	Similar

The validation of the stated preference model is shown above in the Table 4-18, and the prediction capacity of the model is determined below. According to the collected data for the validation purpose the model prediction ratio is 86.79%.

$$\text{Prediction Capacity} = \frac{46 \ * 100}{53}$$

$$= 86.79\ \%$$

The bus rapid transit mode is included the stated preference model, in addition to the present available transport modes. The bus rapid transit system is expected to have an average waiting, in vehicle travel time and total travel cost of 4.5 minutes, 15 minutes and 3.70 ETB respectively. The BRT was found to have 86% modal share at these values. Five scenarios were analyzed with cases that increase and decrease the modal share of BRT system, using the collected data for validation purposes and the developed model to predict the modal choice of the trip makers.

4.3.2. Application of the stated preference models to predict the modal shifts under different scenarios

Table: 4.19: Stated preference work trips scenarios

TTCost reduction	**Waiting time reduction**				**IVTtime reduction**			
	0%	30%	50%	70%	0%	30%	50%	70%
0%	86 %	88%	91%	93%	86%	87%	90%	92%
30%	87%	89%	93%	93%	88%	89%	91%	93%
50%	89%	91%	94%	95%	89%	91%	93%	94%
70%	90%	94%	95%	97%	91%	92%	94%	94%
TTCost increase								
0%	86%	88%	91%	93%	86%	87%	90%	92%
30%	86%	88%	91%	93%	83%	83%	89%	90%
50%	82%	85%	90%	93%	81%	82%	86%	88%
70%	80%	80%	88%	91%	78%	80%	86%	85%

Different scenarios are considered here from the above table. Three scenarios which have a distinguishable effect are discussed below.

Scenario 1: Reduce waiting time by 70% keep others as average

As results shown in the table 4.19 above this scenario is the best scenario to maximize the modal share of newly introducing BRT system. Reduction of waiting time by 70% resulting in 11% increments in the modal share of BRT, which means the BRT modal share, will be about 97% of all available modes in the study area.

Scenario 2: reduce waiting time by 50%, reduce waiting time by 30% and reduce ttcost by 30%

Different scenarios may result in the same result. As it can be seen here reduction of waiting time 30% by keeping ttcost as an average and reduction of both waiting time and ttcost by 50 % was result in the same output of increasing BRT modal share 5%. Scenarios with such a like case are shown above in the table. Therefore transport planners should be guided with these determined scenarios to optimize commuters' utility through considering their interest.

Scenario 3: Increase total travel cost by 70%

Keeping all other attributes the same, the modal share of the BRT system will be 80% with a

Decrease in 6% of the share. In this study this is the worst scenario of the modal share of this newly introducing system.

4.4. Estimation, validation and application of revealed preference model of HBO trips

4.4.1. Parameter estimation, test and comparison of revealed preference models of HBO trips

This model will be developed for a home based others trip Travelers. Available mode of transport for this trip purpose includes bus, taxi, private car and ride share, as indicated in the previous sections. Variables syntax and their corresponding description are shown above in the table 3.1.

359 observations and 116 cases are included in the model, out of 120 respondents. To determine the best fit model for

The specified trip purpose, different models were developed and compared step wise. In this model bus mode is considered as reference category. The developed models are shown below step wise.

Base model:

Table 4.20 Variables in the Equation for base model

	B	SE	Wald	df	Sig.	Exp(B)	95.0% CI for Exp(B)	
							Lower	Upper
ctaxi	-.773	.221	12.271	1	.000	.462	.299	.711
cpcar	-3.148	.771	16.668	1	.000	.043	.009	.195
crshare	1.446	.420	11.843	1	.001	4.247	1.864	9.678

As we can see in the table above all constant parameters have statistically significant effect. Comparison of different models will continue as follows.

Model 1: This model was developed by adding total travel time and total travel cost over constant parameters. As shown in the table 4.21 below the p-value of total travel time and total travel cost is less than 0.05.This implies that these variables have statistically significant effect on the model. The p-value of Mode specific variables (constant) taxi, private car and ride share are greater than 0.05. In addition, we can see that constant parameters are not significant. Even though they are not significant constant variables should be retained in the equation since they represent variables even not considered here. The lack of significance of the alternative specific constants is irrelevant since the constants represent the average effect of all the variables not included in the model and should always be retained despite the fact that they do not have a well understood behavioral interpretation (Koppleman & Chandra, 2006).

Moreover it is logical for signs of travel time and travel cost parameters to be negative because the utility of modes will increase with deceasing of travel time and travel cost. As it is shown in the table below this is compatible with our judgment.

Table 4.21: Variables in the Equation for model 1

	B	SE	Wald	df	Sig.	Exp(B)	95.0% CI for Exp(B)	
							Lower	Upper
TTTIME	-.203	.078	6.696	1	.010	.817	.700	.952
TTCOST	-.095	.046	4.299	1	.038	.909	.831	.995
ctaxi	2.273	1.245	3.331	1	.068	9.704	.845	1.400
cpcar	1.601	2.933	.298	1	.585	4.956	.016	1.989
crshare	1.745	3.926	.198	1	.657	5.724	.003	2.867

Compare Model 2 to 1: This model was developed by adding interaction between ride share mode and family monthly income to the model 1.

Table 4.22 Variables in the Equation for model 2

	B	SE	Wald	df	Sig.	Exp(B)	95.0% CI for Exp(B)	
							Lower	Upper
TTTIME	-.198	.079	6.352	1	.012	.820	.703	.957
TTCOST	-.118	.051	5.376	1	.020	.889	.805	.982
Ctaxi	2.136	1.250	2.921	1	.087	8.467	.731	8.078
Cpcar	.717	3.028	.056	1	.813	2.049	.005	7.206
Crshare	-1.943	4.287	.205	1	.650	.143	.000	8.790
Fminc_rshare			9.253	4[a]	.055			
Fminc_rshare(2)	14.331	545.305	.001	1	.979	.000	.000	.432
Fminc_rshare(3)	3.739	1.414	6.990	1	.008	.024	.001	.380
Fminc_rshare(4)	2.306	1.281	3.239	1	.072	.100	.008	1.228
Fminc_rshare(5)	.126	1.164	.012	1	.914	.882	.090	8.629

As shown in the Table 4.22, the coefficient of family income variable interaction with ride share mode have a p-value of 0.012 is statistically significant as its' value is less than α value of 0.05 which results in the rejection of the null hypothesis that the family income _ ride share interaction coefficient is zero. These imply that family income _ ride share interaction variable has a significant effect on the utility of ride share mode that makes different Model 2 from model 1. So this value is decided to be included in the model. In addition, to confirm this, comparisons made between Models 1 and 2 by computing the chi-squared value (χ 2) between the two models and compare this with the critical chi-squared value.

Taking Model 1 as restricted model and Model 2 as unrestricted model:

χ 2 = $-2 * (LLR - LLU)$

= $-2 *$ ((Model1) – (Model 2))

= $-2LLR$ – ($-2LLU$) ……$-2LLR$ and $-2LLU$ are at the convergence.

= 167.448 - 150.751 =16.70

= 16.70 > 14.06,

This indicates to continue with model 1.Checking for its chi-squared value results in the above value, which makes it possible to reject the null hypothesis that the parameter of Family income variable interaction with taxi is zero. According to estimation result shown in the table 4.22, the utilities of the available modes with the statistically significant values of parameters in model 2 are shown as follows:

U_{Bus}= -0.198TTTime -0.118*TTCost

U_{taxi} = 2.136-0.198TTTime -0.118*TTCost

U_{pcar} = 0.717 – 0.198 TTTime - 0.118*TTCost

U_{rshare}= -1.943 - 0.198 TTTime - 0.118*TTCost + 3.738 * Fminc_rshare (4)

Model 3: The earlier models were developed assuming that out of vehicle and in vehicle travel times have the same effect on the utility of the trip makers. Therefore out of vehicle and in vehicle travel times were summed up to one variable named as total travel time. Here in model 3, let us consider out of vehicle and in vehicle travel time independently to assess commuters' sensitivity towards these variables. Model 3 was developed by replacing total travel time with out of vehicle and in vehicle travel time. Model 3 was evident that trip makers are more sensitive to out of vehicle travel time than in-vehicle travel time since the parameter coefficient of OVTTIME and IVTTIME are -0.4 and -0.159, respectively. This indicates that a minute of out of vehicle travel time will generate a higher disutility than a minute of in-vehicle travel time.

Table 4.23: Variables in the Equation for model 3

	B	SE	Wald	df	Sig.	Exp(B)	95.0% CI for Exp(B)	
							Lower	Upper
OVTTIME	-.400	.175	5.247	1	.022	.670	.476	.944
IVTTIME	-.159	.083	3.664	1	.046	.853	.725	1.004
TTCOST	-.117	.052	5.102	1	.024	.890	.804	.985
ctaxi	3.828	1.937	3.907	1	.048	45.974	1.033	6.592
cpcar	5.309	4.686	1.284	1	.257	202.162	.021	1.843
crshare	2.710	5.399	.252	1	.616	15.033	.000	5.040
Fminc_rshare			9.079	4[a]	.059			
Fminc_rshare(2)	-14.119	539.722	.001	1	.979	.000	.000	.
Fminc_rshare(3)	3.541	1.362	6.755	1	.009	.029	.002	.419
Fminc_rshare(4)	2.338	1.286	3.309	1	.069	.096	.008	1.199
Fminc_rshare(5)	.139	1.170	.014	1	.905	.870	.088	2.625

The comparison between Models 2 and 3 was prepared using the non-nested hypothesis test using the outputs of the parameter estimation of the analysis. According to (Koppleman & Chandra, 2006), the model with the lower $\rho 0\ '2$ value is the true model. The null hypothesis that the model with the lower $\boldsymbol{\rho 0}\ '^{2}$ is the true model will be rejected if the significance level computed below is less than 0.05, for 95% confidence level.

$$Significance\ level = \Phi\ [-(-2 * (\rho H\ '2 - \rho L\ '2) * LL\ (0) + (KH - KL))\ 0.5]$$

$$\rho_L 0\ '2 = 1 - \frac{153.151\text{-}9}{260.736} = 0.447$$

$$\rho_H 0\ '2 = 1 - \frac{150.315\text{-}10}{260.736} = 0.462$$

$= \Phi\ [-((0.462\text{-}0.447) * 260.736 + (10 - 9))\ 0.5]$

$= \Phi\ [-2.216] = 0.986 > 0.05$

Since the significance level calculated above is greater than 0.05 then the null hypothesis that model 2 is the true model cannot be rejected. Therefore, at this stage, the true model is **Model 2**. As a result continue with this model.

Model 4: To check the trip makers' sensitivity towards waiting time, which is a part of out of vehicle travel time model 4 was developed furthermore. This model was developed by replacing Out of vehicle travel time with the two independent variables, waiting time and access time. As shown in the table 4.24, waiting time is even not statistically significant in this trip purpose. Therefore it is recommended to continue with model 2 further. Therefore, for home based others trip purpose, continue with **mode1 2**.

Table 4.24: Variables in the Equation for model

	B	SE	Wald	df	Sig.	Exp(B)	95.0% CI for Exp(B)	
							Lower	Upper
ATIME	-.614	2.995	.042	1	.837	.541	.002	1.720
WTIME	-1.781	2.823	.398	1	.528	.168	.001	2.569
IVTTIME	-.092	.067	1.879	1	.170	.912	.800	1.040
TTCOST	-.127	.055	5.399	1	.020	.881	.791	.980
Ctaxi	17.377	28.230	.379	1	.538	35211543.572	.000	3.000
Cpcar	33.245	58.469	.323	1	.570	2.600	.000	1.608
Crshare	30.078	58.513	.264	1	.607	13.215	.000	7.394
Fminc_rshare			9.717	4[a]	.045			
Fminc_rshare(2)	5.428	5.630	.929	1	.335	.004	.000	2.385
Fminc_rshare(3)	3.704	1.418	6.824	1	.009	.025	.002	.397
Fminc_rshare(4)	2.487	1.314	3.584	1	.058	.083	.006	1.092
Fminc_rshare(5)	.239	1.205	.039	1	.843	.787	.074	8.352

4.4.2. Validation of revealed preference model of HBO trip

Studies indicate that the validation of the most fitting model was done by informal test of basic parameters. Moreover validation of the model was checked by determining the prediction capacity of the model. The validation of the most fitting model is assessed using samples that were collected for validation purpose of this trip purpose. These data were used to assess how well the model fits the data by determining the prediction capability of the model. As determined in section 4.1 53 samples are needed for testing the validation of the most fitting model. Below, in the table 4.25, partial examples of the validation of model 2 were shown.

Table 4.25: Validation sample of home based others trips.

ID	Available alternatives	Utility	Exponent	Probability of choosing	Predicted choice	Chosen mode	Predicted vs. chosen mode
አዲስ	1	-8.274	0.000255	0.007611	0	0	
አዲስ	2	-3.404	0.03324	0.991843	1	1	Similar
አዲስ	4	-17.307	3.05E-08	9.09E-07	0	0	
559	1	-9.264	9.48E-05	0.020023	0		
559	2	-5.384	0.004589	0.969577	1	1	Similar
559	4	-20.055	1.95E-09	4.16E-07	0	0	
994	1	-9.264	9.48E-05	0.007585	0	0	
994	2	-4.394	0.012351	0.988475	1	0	Not similar
994	4	-27.531	9.48E-05	8.88E-11	0	1	
620	1	-9.264	0.000104	0.007585	0	0	
620	2	-4.394	0.012351	0.988475	1	1	Similar
620	4	-20.055	1.95E-09	1.57E-07	0	0	
891	1	-9.854	5.25E-05	0.003115	0	0	
891	2	-4.984	0.006847	0.405896	0	1	Not similar
891	3	-4.6083	0.009969	0.590989	1	0	

The validation of the developed model is shown above in the Table 4-25, and the prediction capacity of this model is determined below. According to the collected validation data for the validation purpose of this model is shown below.

$$Prediction\ \text{Capacity} = \frac{48 * 100}{53} = 90.56\ \%$$

4.4.3. Application of revealed preference model of HBO trips under different scenario.

The developed model can be used to predict the modal share of the bus by applying different counteractive action to enhance the desirability of bus.

Increment of the buses model share can be introduced by reducing waiting time, in vehicle travel time and total travel cost. Accordingly different scenarios are shown below in the table 4.26. The effects of decreasing waiting time, in vehicle travel time and total travel cost of the buses were determined using the developed models and the data collected for the validation purposes. The average total travel time and total travel cost of the buses of the collected samples for validation purpose are 28 and 3.77 ETB respectively. At these values, using the developed models, the resulted modal share of buses were 42.36%. Reducing waiting time, in vehicle travel time and total travel cost different scenarios are shown below in the table 4.26.

Table 4.26.: Application of the model developed for home based others trip.

TTCost reduction	**Total travel time reduction**					
	0%	10%	20%	30%	40%	50%
0%	43 %	47%	48%	51%	52%	52%
10%	45%	48%	49%	50%	51%	53%
20%	47%	49%	51%	53%	52%	55%
30%	50%	49%	51%	53%	54%	56%
40%	51%	51%	52%	54%	55%	58%
50%	52%	52%	53%	55%	56%	59%

According to the results shown in Table 4-26 above, for example, a scenario resulted in reducing 30% of total travel cost and keeping the TTtime the same, and another scenario resulted in reducing 40% of total travel cost and keeping the TTtime the same result in the similar case of increasing the modal share to bus mode by 8%. This indicated that total travel time has significantly more effect than total travel cost in the modal preference of trip makers. Generally, the scenario analyses results that asses trip makers' sensitivity towards different variables will guide policy makers and transport planners which remedial actions are more efficient and which actions to consider as policies in increasing the modal share of bus mode to minimize the transportation problems rooted in the city and also to make transportation system environmentally friendly. More over Transport planners should consider the different scenarios considered in the table 4.26.

4.5. Estimation, validation and application of revealed preference model of NHBW trips

4.5.1. Parameter estimation, test and comparision of revealed preference model of NHBW trips

This model will be developed for a non-home based work related trip travelers. Available mode of transport for this trip purpose includes bus, taxi, private car and ride share, as indicated in the previous sections. Variables syntax and their corresponding description are shown above in the table 3.1. 116 cases with 359 observations are included in the model, out of 120 respondents. To determine the best fit model for this trip purpose, different models were developed step wise. In this model bus mode was considered as reference category. The developed models are shown below.

Base model: This model was developed including constant parameters of the available mode of transport.

Table4. 27: Variables in the Equation for base model

	B	SE	Wald	df	Sig.	Exp(B)
Ctaxi	-.773	.221	12.271	1	.000	.462
Cpcar	-3.148	.771	16.668	1	.000	.043
Crshare	1.446	.420	11.843	1	.001	4.247

As it is shown in the table above all constant parameters are statistically significant as their p-value is less than 0.05.

Model 1: This model was developed by adding travel time and cost over the constant parameters included over the base model. Studies indicate that even if they are not significant constant parameters should be retained in the model as they represent variables even considered in the table. Therefore these constant parameters are retained in the model.

Table 4.28: Variables in the Equation for model 1

	B	SE	Wald	df	Sig.	Exp(B)	95.0% CI for Exp(B)	
							Lower	Upper
TTTIME	-.166	.063	6.953	1	.008	.847	.748	.958
TTCOST	-.100	.047	4.596	1	.032	.905	.826	.991
Ctaxi	1.690	1.019	2.752	1	.097	5.420	.736	3.918
Cpcar	.063	2.442	.001	1	.980	1.065	.009	1.543
Crshare	.124	3.710	.001	1	.973	1.132	.001	1.124

Model 2: By adding marital status and taxi interaction over model 1 this model was developed. As shown below in the table this interaction variable is statistically significant.

Table 4.29: Variables in the Equation for model 2

	B	SE	Wald	df	Sig.	Exp(B)	95.0% CI for Exp(B)	
							Lower	Upper
TTTIME	-.210	.071	8.696	1	.003	.810	.705	.932
TTCOST	-.115	.049	5.510	1	.019	.892	.810	.981
Ctaxi	4.127	1.642	6.317	1	.012	61.995	2.481	4.868
Cpcar	1.201	2.604	.213	1	.645	3.322	.020	7.185
Crshare	.621	3.877	.026	1	.873	1.861	.001	11.339
Mstatus_ctaxi			5.251	3[a]	.154			
Mstatus_ctaxi(2)	1.298	1.078	1.450	1	.228	3.663	.443	3.292
Mstatus_ctaxi(3)	2.118	1.023	4.287	1	.038	8.310	1.120	6.681
Mstatus_ctaxi(4)	1.595	1.096	2.120	1	.145	4.930	.576	4.211

Moreover, checking for its chi squared value (taking Model 1 as the restricted and Model 2 as the unrestricted model) results in the following value, which makes it possible to reject the null hypothesis that the parameter of age variable interaction with taxi is zero.

$\chi 2 = 168.193 - 162.703 = 8.602 > 7.81$

The result implies that the marital status interaction with taxi have a significant effect on the utility of taxi mode. Therefore this variable should be included in the model.

Model 3: This model was developed adding another interaction variable over model 2.The result of the estimation is shown below in the table 4.30.

This variable is statistically significant as its' p-value is less than 0.05.In addition the chi squared value was checked to assess representing strength of the model, considering model 2 as restricted and model 3 unrestricted.

$\chi 2 = 162.703 - 148.968 = 13.735 > 3.84$

Therefore this model is preferable over model 2.

Table 4.30 Variables in the Equation for model 3

	B	SE	Wald	df	Sig.	Exp(B)	95.0% CI for Exp(B)	
							Lower	Upper
TTTIME	-.208	.074	7.918	1	.005	.812	.703	.939
TTCOST	-.128	.053	5.714	1	.017	.880	.792	.977
Ctaxi	4.206	1.705	6.084	1	.014	67.112	2.372	18.625
Cpcar	.618	2.809	.048	1	.826	1.854	.008	4.522
Crshare	-2.452	4.324	.322	1	.571	.086	.000	4.614
Mstatus_ctaxi			5.183	3[a]	.159			
Mstatus_ctaxi(2)	1.503	1.093	1.893	1	.169	4.495	.528	3.257
Mstatus_ctaxi(3)	2.240	1.036	4.677	1	.031	9.398	1.234	7.589
Mstatus_ctaxi(4)	1.874	1.120	2.801	1	.094	6.513	.726	5.452
FMincome_crshare			9.223	4[a]	.056			
FMincome_crshare(2)	14.410	536.070	.001	1	.979	.000	.000	.8698
FMincome_crshare(3)	3.731	1.406	7.038	1	.008	.024	.002	.377
FMincome_crshare(4)	2.472	1.296	3.638	1	.056	.084	.007	1.071
FMincome_crshare(5)	.366	1.219	.090	1	.764	.693	.064	7.560

Model 4: Replacing total travel time with out of vehicle and in vehicle travel time model 4 was developed. The result of the estimation is shown below. Compare this model with model 3 by non-nested test to prefer the better model.

Table 4.31: Variables in the Equation for model 4

	B	SE	Wald	df	Sig.	Exp(B)	95.0% CI for Exp(B)	
							Lower	Upper
OVTTIME	-.264	.098	7.289	1	.007	.768	.634	.930
IVTTIME	-.195	.084	5.427	1	.020	.823	.698	.970
TTCOST	-.124	.052	5.547	1	.019	.884	.797	.979
Ctaxi	4.450	1.628	7.475	1	.006	85.655	3.525	6.123
Cpcar	1.909	2.911	.430	1	.512	6.746	.022	1.887
Crshare	-.923	4.384	.044	1	.833	.397	.000	1.160
Mstatus_ctaxi			4.798	3[a]	.187			

Mstatus_ctaxi(2)	1.233	1.089	1.282	1	.258	3.431	.406	29.002
Mstatus_ctaxi(3)	2.034	1.014	4.021	1	.045	7.644	1.047	55.819
Mstatus_ctaxi(4)	1.638	1.106	2.192	1	.139	5.144	.588	44.971
FMincome_crshare			9.051	4[a]	.060			
FMincome_crshare(2)	-14.433	534.309	.001	1	.978	.000	.000	.
FMincome_crshare(3)	3.796	1.448	6.877	1	.009	.022	.001	.383
FMincome_crshare(4)	2.487	1.298	3.671	1	.055	.083	.007	1.059
FMincome_crshare(5)	.407	1.222	.111	1	.739	.666	.061	7.308

According to Koppleman & Chandra, 2006, the model with the lower $\rho 0\ '2$ value is the true model. The null hypothesis that the model with the lower $\boldsymbol{\rho 0}\ '\ 2$ is the true model will be rejected if the significance level computed below is less than 0.05, for 95% confidence level.

$$\rho_L 0\ '2 = 1 - \frac{148.968\text{-}12}{260.736} = 0.475$$

$$\rho_H 0\ '2 = 1 - \frac{146.191\ \text{-}13}{260.736} = 0.489$$

$$Significance\ level = \Phi * [-(0.489 - 0.475) * 260.736 + (13 - 12))\ 0.5]$$

$$= \Phi * [-2.156] = 0.0155 < 0.05$$

Since the significance level calculated above is less than 0.05 then the null hypothesis that Model with the lower is the true model can be rejected. As a result, the true model is Model 4.

Model 5: Replacing out of vehicle travel time with access time and waiting time this model was developed.

Table 4.32: Variables in the Equation for model 5

	B	SE	Wald	df	Sig.	Exp(B)	95.0% CI for Exp(B)	
							Lower	Upper
ATIME	-.087	.146	.352	1	.553	.917	.688	1.222
WTIME	-.435	.178	5.974	1	.015	.647	.457	.917
IVTTIME	-.239	.098	5.887	1	.015	.787	.649	.955
TTCOST	-.129	.053	5.954	1	.015	.879	.792	.975
Ctaxi	6.143	2.264	7.363	1	.007	465.603	5.507	39.128
Cpcar	4.865	4.002	1.478	1	.224	129.634	.051	33.718
Crshare	1.553	4.840	.103	1	.748	4.725	.000	62.413
Mstatus_ctaxi			4.240	3[a]	.237			
Mstatus_ctaxi(2)	.958	1.101	.757	1	.384	2.606	.301	22.551
Mstatus_ctaxi(3)	1.822	1.017	3.209	1	.043	6.184	.842	45.402
Mstatus_ctaxi(4)	1.431	1.105	1.677	1	.195	4.184	.480	36.513
FMincome_crshare			9.225	4[a]	.056			
FMincome_crshare(2)	14.434	533.829	.001	1	.978	.000	.000	.
FMincome_crshare(3)	3.741	1.413	7.015	1	.008	.024	.001	.378
FMincome_crshare(4)	2.542	1.298	3.836	1	.050	.079	.006	1.002
FMincome_crshare(5)	.447	1.224	.133	1	.715	.640	.058	7.044

Using non-nested test method, comparing model 4 and 5.

$$\rho_L 0'^2 = 1 - \frac{146.191-13}{260.736} = 0.489$$

$$\rho_H 0'^2 = 1 - \frac{143.621-14}{260.736} = 0.503$$

$$Significance\ level = \Phi * [-(0.503 - 0.489) * 260.736 + (14-13))^{0.5}]$$

$$= \Phi * [-2.156] = 0.0155 < 0.05$$

Since the significance level calculated above is less than 0.05 then the null hypothesis that Model with the lower is the true model can be rejected. As a result, the true model is Model 5. Finally, the estimation results of different models shown above indicate that model 5 is the best model to represent the preference of the trip makers. The utilities of the available modes with the statistically significant values of the parameters in model 5 are shown as follows:

U_{BUS}= -0.435 WTIME - 0.239 * IVTTIME -0.129 * TTCost

U_{taxi} = 6.143 -0.435 WTIME - 0.239 * IVTTIME -0.129 * TTCost -

U_{pcar} =4.865 -0.435 WTIME - 0.239*IVTTIME -0.129*TTCost + 1.822*Mstatus_ctaxi (3)

U_{rshare}=-0.435 WTIME - 0.239*IVTTIME -0.129*TTCost +3.741* FMincome_crshare (3)

4.5.2. Validation of revealed preference model of NHBW trips

The validation of the most fitting model was done by informal test of basic parameters. Moreover validation of the model was checked by determining the prediction capacity of the model. The validation of the most fitting model is assessed using samples that were collected for validation purpose. These data were used to assess how well the model fits the data by determining the prediction capability of the model.

$$\text{The prediction capability} = \frac{\text{Number of correctly predicted modes}}{\text{Total number of validation data}} * 100$$

As determined in section 4.1 53 samples are needed for testing the validation of the most satisfactory model. Below, in the table 4.33, partial examples of the validation of model 5 were shown.

Table 4.33: Validation sample for non-home based work related trips

ID	Available alternatives	Utility	Exponent	Probability of choosing	Predicted choice	Chosen mode	Predicted vs chosen mode
979	1	-9.264	9.48E-05	1.09E-05	0	0	
979	2	-4.394	0.012351	0.999979	1	1	Similar
979	4	-20.055	1.95E-09	1.05E-05	0	0	
727	1	-9.264	9.48E-05	1.06E-05	0	0	
727	2	-4.394	0.012351	0.973654	0	1	Not similar
727	3	-4.6083	0.009969	0.778136	1	0	
727	4	-23.793	4.64E-11	3.08E-07	0	0	
አዲስ	1	-9.854	5.25E-05	1.09E-05	0	0	

አዲስ	2	-4.984	0.006847	0.999982	1	1	Similar
አዲስ	4	-23.793	4.64E-11	7.39E-06	0	0	
641	1	-9.264	9.48E-05	1.09E-05	1	1	Similar
641	2	-4.394	0.012351	0.999982	0	0	
641	4	-20.055	1.95E-09	7.12E-06	0	0	
ጨረቃ	1	-10.254	3.52E-05	1.06E-05	0	0	
ጨረቃ	2	-5.5983	0.004589	0.973654	0	0	
ጨረቃ	3	-5.5983	0.003704	0.778136	1	1	Similar
ጨረቃ	4	-31.269	2.63E-14	1.38E-07	0	0	

The validation of the developed model is shown above in the Table 4-33, and the prediction capacity of this model is determined below. According to the collected validation data for the validation purpose of this model is shown below.

The prediction capability = $\frac{39 * 100}{53}$=74%

4.5.3. Application of revealed preference model of NHBW trips to predict modal shift under different scenarios

The developed model can be used to predict the modal share of the bus by applying different remedial action to develop the desirability of large bus which is wired to minimize the vast transportation problems engrained in the city. Moreover studies point out that increasing the attractiveness of the large bus is environmentally friendly.

Increment of large buses modal share can be introduced by reducing waiting time, in vehicle travel time and total travel cost. Accordingly different scenarios are shown below in the table 4.34. The effects of decreasing waiting time, in vehicle travel time and total travel cost of large buses were determined using the developed models and the data collected for validation purposes. The average waiting time, in vehicle travel time and total travel cost of large buses of the collected samples for validation purpose are 12.45 minute, 22 minute and 2.80 ETB respectively.

The resulted modal share of buses was 32.43%. Reducing waiting time, in vehicle travel time and total travel cost at different scenarios are shown below in the table 4.34.

Table 4.34: Application of the developed model for non-home based trips

TTCost reduction	**Waiting time reduction**						**IVTtime reduction**						
	0%	10%	20%	30%	40%	50%		0%	10%	20%	30%	40%	50%
0%	32 %	38%	40%	43%	44%	47%	0%	32%	37%	39%	41%	42%	42%
10%	36%	39%	41%	45%	46%	48%	10%	36%	38%	39%	42%	44%	45%
20%	37%	40%	43%	45%	47%	49%	20%	37%	40%	42%	43%	46%	47%
30%	39%	41%	42%	46%	47%	51%	30%	39%	41%	44%	45%	47%	48%
40%	41%	43%	44%	48%	51%	53%	40%	41%	41%	45%	46%	49%	50%
50%	42%	44%	46%	50%	52%	57%	50%	42%	43%	45%	47%	50%	52%

According to the results shown in Table 4-34 above, for example, a scenario resulted in reducing 30% of waiting time and keeping the TTC the same, and another scenario resulted in reducing 40% of TTC and keeping the WTime the same result in similar increment of 11% in modal share to the bus mode. This indicated that waiting time has significantly more effect than total travel time in the modal preference of trip makers.

Reducing 10% of IVTT and keeping the TTC the same, and another scenario resulted in reducing 20% of TTC and keeping the IVTT results in the same result of additional 5% modal share to bus mode. This implies that in vehicle travel time has more sensitive attribute over total travel cost to increase the modal share of the bus in the study area for the specific trip purpose. The leading increment of bus modal share was attained by reducing 50 % of waiting time and at the same time reducing 50% of TTC. Generally, the scenario analyses asses trip makers' sensitivity towards different variables will guide policy makers and transport planners which remedial actions are more efficient and which actions to considered as policies, in increasing the modal share of large buses to minimize the transportation problems rooted in the city and also to make transportation system environmentally friendly. More over policy makers can consider different scenarios determined in the table 4.34 during transport planning activities.

4.6. Estimaion, validation and application of revealed preference model of HBE trips

4.6.1 Parameter estimation, tests and comparicion of revealed preference Model of HBE trips

This model will be developed for a home based education related commuters. Available mode of transport for this trip purpose includes bus, taxi, private car, school bus and walk. Variables syntax and their corresponding description are shown above in the table 3.1. 563 observations and 165 cases are included in the model, out of 169 respondents. To determine the best fit model, different models were developed step wise. In this model **bus** mode was considered as reference category. The developed models are shown below.

Base model: This model was developed including constant parameters of the available mode of transport for the determined education related trips.

Table 4.35: Variables in the Equation for base model

	B	SE	Wald	Df	Sig.	Exp(B)	95.0% CI for Exp(B)	
							Lower	Upper
Cpcar	-1.156	.340	11.569	1	.001	.315	.162	.613
Ccontract	-.473	.260	3.294	1	.070	.623	.374	1.038
Cwalk	-.075	.269	.078	1	.280	.927	.547	1.572
Ctaxi	-.337	.218	2.395	1	.122	.714	.466	1.094

Even though they are not statistically significant the constant parameters should be retained in this model. Studies indicate that constant parameters represent variables even not included in the model. As a result these variables kept in the model.

Model 1: By adding travel and cost related variables to the constant parameters this model was developed. As shown in the table below the p-value of total travel time and total travel cost is less than 0.05.This implies that these variables have statistically significant effect on the model. The p-value of mode specific variables (constant) of school bus is greater than 0.05. Studies show that, even though they are not significant constant variables should be retained in the equation since they represent variables even not considered here. The lack of significance of the alternative specific constants is irrelevant since the constants represent the average effect of all the variables not included in the model and should always be retained despite the fact that they do not have a well understood behavioral interpretation (Koppleman & Chandra, 2006).

Moreover it is logical for signs of travel time and travel cost parameters to be negative because the utility of modes will increase with deceasing of travel time and travel cost. As it is shown in the table below this is compatible with our judgment.

Table 4.36: Variables in the Equation for model 1

	B	SE	Wald	df	Sig.	Exp(B)	95.0% CI for Exp(B)	
							Lower	Upper
TTTIME	-.035	.015	5.254	1	.022	.965	.937	.995
TTCOST	-.118	.046	6.626	1	.010	.889	.813	.972
Cpcar	-2.984	1.219	5.992	1	.014	.051	.005	.552
Ccontract	-6.532	2.736	5.700	1	.017	.001	.000	.310
Cwalk	1.289	.511	6.351	1	.012	3.628	1.332	9.885
Ctaxi	-.755	.267	7.975	1	.005	.470	.278	.794

Model 2: This model was developed by adding Age-taxi interaction to model 1.

As shown in the table 4.37, the coefficient Age-taxi interaction variables have a p-value of less than 005.Which make the variables statistically significant as its value is less than α value of 0.05.This imply that this variable has significant effect on the utility of trip makers.
In addition, to confirm this, comparisons made between models 1 and 2 by computing the chi-squared value (χ 2) between the two models and compare this with the critical chi-squared value.
Taking Model 1 as restricted model and model 2 as unrestricted model:

$\chi 2 = -2 * (LLR - LLU)$

$= -2 *$ ((Model1) – (Model 2))

$= -2LLR$ – $(-2LLU)$ ……$-2LLR$ and $-2LLU$ are at the convergence.

= 363.070 - 358.961 =4.109

= 4.109> 3.84

Checking for its chi-squared value interpretation makes it possible to reject the null hypothesis that the parameter of Age variable interaction with taxi zero. This indicates to continue with model 2.

Table 4.37: Variables in the Equation for model 2

	B	SE	Wald	df	Sig.	Exp(B)	95.0% CI for Exp(B)	
							Lower	Upper
TTTIME	-.035	.015	5.037	1	.025	.966	.937	.996
TTCOST	-.120	.046	6.679	1	.010	.887	.810	.971
Cpcar	-3.020	1.233	5.995	1	.014	.049	.004	.547
Ccontract	-6.676	2.777	5.780	1	.016	.001	.000	.291
Cwalk	1.269	.515	6.064	1	.014	.558	.296	.771
Ctaxi	-1.020	.299	11.632	1	.001	.361	.201	.648
Age_ctaxi			3.904	1[a]	.048			
Age_ctaxi(2)	-.804	.407	3.904	1	.048	.448	.202	.994

Model 3: Adding School type –taxi interaction over model 2 this model was developed. The result of the parameter estimation is shown in the table below.

Table 4.38: Variables in the Equation for model 3

	B	SE	Wald	df	Sig.	Exp(B)	95.0% CI for Exp(B)	
							Lower	Upper
TTTIME	-.035	.016	5.003	1	.025	.965	.936	.996
TTCOST	-.119	.047	6.373	1	.012	.888	.809	.974
Cpcar	-2.877	1.254	5.266	1	.022	.056	.005	.657
Ccontract	-6.551	2.823	5.385	1	.020	.001	.000	.361
Cwalk	1.258	.520	5.860	1	.015	3.517	1.270	9.737

Ctaxi	-.393	.428	.842	1	.359	.675	.292	1.563
Age_ctaxi			3.872	1[a]	.049			
Age_ctaxi(2)	-.823	.418	3.872	1	.049	.439	.193	.997
Stype_ctaxi			4.505	1[a]	.034			
Stype_ctaxi(2)	.902	.425	4.505	1	.034	2.465	1.072	5.671

As shown in the table 4.38, the coefficient of school type-taxi interaction variables have a p-value of less than 0.05.Which make the variables statistically significant as its value is less than α value of 0.05.This imply that this variable has significant effect on the utility of trip makers.

In addition, to confirm this, comparison was made between models 2 and 3 by computing the chi-squared value (χ 2) between the two models and compares this with the critical chi-squared value. Taking Model 1 as restricted model and model 2 as unrestricted model:

$\chi\ 2 = -2 * (LLR - LLU)$

$= -2 *$ ((Model1) – (Model 2))

$= -2LLR - (-2LLU)$ ……$-2LLR$ and $-2LLU$ are at the convergence.

= 358.961 - 354.153=4.201

= 4.201> 3.84

Checking for its chi-squared value interpretation makes it possible to reject the null hypothesis that the parameter of school type variable interaction with taxi is zero. This indicates to continue with model 3.

Model 4: This model was developed by adding interaction between school type and contract mode over model 3**.**The result of estimation is shown below.

Table 4.39: Variables in the Equation for model 4

	B	SE	Wald	df	Sig.	Exp(B)	95.0% CI for Exp(B)	
							Lower	Upper
TTTIME	-.036	.016	5.142	1	.023	.964	.934	.995
TTCOST	-.115	.051	5.140	1	.023	.891	.807	.984
Cpcar	-3.233	1.344	5.785	1	.016	.039	.003	.550
Ccontract	-7.607	3.047	6.234	1	.013	.000	.000	.195
Cwalk	1.304	.528	6.099	1	.014	3.686	1.309	.378
Ctaxi	-.990	.473	4.387	1	.036	.372	.147	.938

Age_ctaxi			4.470	1[a]	.034			
Age_ctaxi(2)	-.887	.420	4.470	1	.034	.412	.181	.937
Stype_ctaxi			.045	1[a]	.832			
Stype_ctaxi(2)	.100	.470	.045	1	.832	1.105	.440	.776
Stype_ccontract			22.168	1[a]	.000			
Stype_ccontract(2)	-3.059	.650	22.168	1	.000	.047	.013	.168

As shown in the table 4.39, the coefficient of school type-contract mode interaction variables have a p-value of less than 0.05.Which make the variables statistically significant as its p-value is less than α 0.05.This imply that this variable has significant effect on the utility of trip makers.to confirm this, comparisons was made between models 3 and 4 by computing the chi-squared value (χ 2) between the two models and compare this with the critical chi-squared value.

Taking Model 3 as restricted model and model 4 as unrestricted model:

$$\chi\ 2 = -2 * (LLR - LLU)$$

$$= -2LLR - (-2LLU)$$

$$=354.153-344.322$$

$$= 9.831 > 3.84$$

The chi-squared value interpretation makes it possible to reject the null hypothesis that the parameter of school type variable interaction with contract mode is zero. Accordingly, continue with model 4.

Model 5: Was developed by replacing total travel time with out of vehicle and in vehicle travel time, in model 4.

Table 4.40: Variables in the Equation for model 5

	B	SE	Wald	df	Sig.	Exp(B)
TTCOST	-.135	.055	6.056	1	.014	.873
IVTTIME	-.365	.147	6.162	1	.013	.694
OVTTIME	-.032	.016	3.901	1	.048	.969
Cpcar	-2.218	1.469	2.280	1	.131	.109
Ccontract	-7.252	3.220	5.073	1	.024	.001

Cwalk	7.830	2.972	6.942	1	.008	.010
Ctaxi	.547	.816	.450	1	.503	.728
Age_ctaxi			4.934	1[a]	.026	
Age_ctaxi(2)	-.938	.422	4.934	1	.026	.391
Stype_ctaxi			.064	1[a]	.800	
Stype_ctaxi(2)	.120	.475	.064	1	.800	.128
Stype_ccontract			22.186	1[a]	.000	
Stype_ccontract(2)	-3.079	.654	22.186	1	.000	.046

Since total travel time is decomposed in to two variables, in vehicle and out of vehicle travel time, Compare between Models 3and 4 using the non-nested hypothesis test using the outputs of the parameter estimation. According to Koppleman & Chandra, 2006, the model with the lower $\rho 0\ '2$ value is the true model. The null hypothesis that the model with the lower $\boldsymbol{\rho 0}\ '2$ is the true model will be rejected if the significance level computed below is less than 0.05, for 95% confidence level.

$$\rho_L 0\ '2 = 1 - \frac{354.153\text{-}8}{395.787} = 0.125$$

$$\rho_H 0\ '2 = 1 - \frac{324.322\text{-}9}{395.787} = 0.203$$

$$Significance\ level = \Phi * [-(0.203 - 0.125) * 395.787 + (13-12))^{0.5}]$$

$$= \Phi * [-5.645)] = 0.01 < 0.05$$

Since the significance level calculated above is less than 0.05 then the null hypothesis that Model with the lower is the true model can be rejected. As a result, the true model is Model 5.

Model 6: This model was developed by replacing out of vehicle travel time with access and waiting time of the trip maker, in model 5.

Table 4.41: Variables in the Equation for model 6

	B	SE	Wald	df	Sig.	Exp(B)
WTIME	-.035	.017	4.161	1	.041	.966
ATIME	-.019	.065	.085	1	.771	.981
TTCOST	-.134	.055	5.984	1	.014	.874
IVTTIME	-.360	.147	6.013	1	.014	.698
Cpcar	-2.251	.485	2.300	1	.129	.105
Ccontract	-7.230	.208	5.081	1	.024	.001

Cwalk	7.822	.962	6.976	1	.008	.044
Ctaxi	.586	.850	.475	1	.491	1.796
Age_ctaxi			4.895	1[a]	.027	
Age_ctaxi(2)	-.935	.423	4.895	1	.027	.392
Stype_ctaxi			.058	1[a]	.810	
Stype_ctaxi(2)	.114	.476	.058	1	.810	1.121
Stype_ccontract			22.232	1[a]	.000	
Stype_ccontract(2)	-3.085	.654	22.232	1	.000	.046

Since out of vehicle travel time is decomposed in to two variables, waiting and access time, Compare between Models 5 and 6 using the non-nested hypothesis test using the outputs of the parameter estimation. According to Koppleman & Chandra, 2006, the model with the lower $\rho 0\ '2$ value is the true model. The null hypothesis that the model with the lower $\boldsymbol{\rho 0}\ '2$ is the true model will be rejected if the significance level computed below is less than 0.05, for 95% confidence level.

$$\rho_L 0\ '2 = 1 - \frac{324.322\text{-}9}{395.787} = 0.203$$

$$\rho_H 0\ '2 = 1 - \frac{318.309\text{-}10}{395.787} = 0.221$$

$$Significance\ level = \Phi * [-(0.221 - 0.2030.125) * 395.787 + (10-9))\ 0.5]$$

$$= \Phi * [-2.85)] = 0.218 > 0.05$$

Since the significance level calculated above is greater than 0.05 then the null hypothesis that Model with the lower $\boldsymbol{\rho 0}\ '2$ is the true model cannot be rejected. As a result, the true model is **Model 5.**

Finally, the estimation results of different models shown above indicate that model 5 is the best model to represent the stated preference of the education purpose trip makers. The utilities of the available modes with the statistically significant values of the parameters in model 5 are shown as follows:

U_{Bus}= -0.365* IVTTIME - 0.032* OVTTIME - 0.135* TTCOST

U_{taxi} =0.547- 0.365* IVTTIME - 0.032* OVTTIME-0.135* TTCOST-0.938 Age_ctaxi (2)

U_{pcar} = -2.218 - 0.365* IVTTIME - 0.032* OVTTIME - 0.135* TTCOST

$U_{contract}$= -7.252 -0.365* IVTTIME - 0.032* OVTTIME - 0.135* TTCOST-3.079*Stype_ccontract(2)

U_{walk} = 7.822 - 0.365* IVTTIME - 0.032* OVTTIME - 0.135* TTCOST

4.6.2. Validation of revealed preference model of HBE trips

The validation of the most fitting model was done by informal test of basic parameters sign. Moreover validation of the model was checked by determining the prediction capacity of the model. The validation of the most fitting model is assessed using samples that were collected for validation purpose. These data were used to assess how well the model fits the data by determining the prediction capability of the model.

The prediction capability = Number of correctly predicted modes *100

Total number of validation samples**.**

The prediction capacity of the most fitting model for non-home based work related trips is shown below in the 4.42.

Table 4.42: Prediction capacity of model best fitting model

ID	Available alternatives	Utility	Exponent	Probability of choosing	Predicted choice	Chosen mode	Predicted vs chosen mode
886	1	-9.264	9.48E-05	0.007585	0	0	
886	2	-4.394	0.012351	0.988475	1	1	Similar
886	4	-20.055	1.95E-09	1.57E-07	0	0	
887	1	-9.264	9.48E-05	0.007585	0	1	Not similar
887	2	-4.394	0.012351	0.988475	1	0	
887	4	-23.793	4.64E-11	3.73E-09	0	0	
906	1	-9.264	9.48E-05	0.004228	0	1	Not similar
906	2	-4.394	0.012351	0.551031	1	0	
906	3	-4.6083	0.009969	0.444741	0	0	
917	1	-9.264	9.48E-05	0.007585	0	0	

917	2	-4.394	0.012351	0.988475	1	1	Similar
917	4	-31.269	2.63E-14	2.11E-12	0	0	
941	1	-9.264	9.48E-05	0.007585	0	0	
941	2	-4.394	0.012351	0.988475	1	1	Similar
941	4	-20.055	1.95E-09	1.57E-07	0	0	
1018	1	-9.264	9.48E-05	0.007585	0	0	
1018	2	-4.394	0.012351	0.988475	1	1	Similar
1018	4	-23.793	4.64E-11	3.73E-09	0	0	

The sample validation analysis of this most fitting model is shown above in the Table 4-42.Prediction capacity of this model is determined below. According to the collected validation data for the validation purpose of this model is shown below.

$$\text{The prediction capability} = \frac{36 * 100}{43} = 83.72\ \%$$

4.6.3. Application of revealed preference model of HBE trips to predict modal shift under different scenarios

The developed model can be used to predict the modal share of the bus for education purpose trips by applying different remedial action to develop the desirability of large buses which is supported to minimize the vast transportation problems engrained in the city. Moreover studies point out that increasing the attractiveness of the bus mode of transportation is environmentally friendly.

Increment of buses modal share can be introduced by reducing out of vehicle travel time, in vehicle travel time and total travel cost. Accordingly different scenarios are shown below in the table 4.43. The effects of decreasing out of vehicle travel time, in vehicle travel time and total travel cost of buses were determined using the most fitting model and the data collected for validation purposes. The average of out of vehicle travel time, in vehicle travel time and total travel cost of bus mode of the collected samples for validation purpose are 23.25 minute, 20 minute and 4.85 ETB respectively. At these values, using the developed model, the resulted modal share of buses were 42.44%. Different scenarios are shown below in the table 4.43.

Table 4.43: Application of the developed model for home based education trips

TTCost reduction	**Out of vehicle travel reduction**				**IVTtime reduction**				
	0%	10%	30%	50%		0%	10%	30%	50%
0%	42 %	43%	45%	49%	0%	42%	46%	50%	55%
10%	45%	46%	48%	50%	10%	43%	47%	50%	58%
20%	47%	48%	51%	53%	20%	44%	48%	55%	59%
30%	48%	49%	52%	55%	30%	46%	49%	56%	60%
40%	49%	51%	53%	56%	40%	48%	50%	57%	62%
50%	52%	54%	55%	59%	50%	50%	52%	58%	66%

According to the results shown in Table 4-43 above, for example, a scenario resulted in reducing 50% of out of vehicle travel time and keeping the TTC the same, and another scenario resulted in reducing 40% of TTC and keeping out of vehicle travel time the same result in similar increment of 7% in modal share to the bus. This indicated that total travel cost has significantly more effect than out of vehicle travel time in the modal preference of education purpose trip makers. Reducing 30% of IVTT and keeping the TTC the same, and another scenario resulted in reducing 50% of TTC and keeping the IVTT results in the same result of additional 8% modal share to bus. This implies that in vehicle travel time has more sensitive attribute over total travel cost to increase the modal share of the bus in for the education purpose trips. The leading increment of bus modal share was attained by reducing 50 % of in vehicle travel time and at the same time reducing 50% of TTC. Generally, the scenario analyses examine the trip makers' sensitivity towards different variables will guide policy makers and transport planners which remedial actions are more efficient and which actions to considered as policies, in increasing the modal share of large buses to minimize the transportation problems rooted in the city and also to make transportation system environmentally friendly. As a result, policy makers and transport planners can consider different scenarios of mode choice analysis determined in the table 4.43 during transport planning activities.

4.7. Trip makers concern towards BRT system

Household survey of the trip makers in the study area assess their concern towards a newly introducing transportation system, BRT.Their concern of trip makers to wards BRT bus service is discussed in detail below in the table 4.48.Respondents concern that this transportation service may causes traffic accident due to its higher speed.

Table 4.44: Trip makers concern towards newly introducing BRT system

No.	Trip makers concern	Trip makers gender		Trip makers age		No of trip makers
		Male	Female	<=35	>35	
1	Long bus waiting queue and frequency	53	71	35	89	124
2	Sexual harassment and suffocation in the bus	21	106	91	36	127
3	Car accident	16	23	11	18	39
4	Traffic congestion	35	12	29	19	47
5	Displacement from work place	7	6	3	10	13
6	No concern	32	18	43	7	50

Moreover, most respondents, especially woman are concerned about sexual harassment and in vehicle suffocation which is the most serious problem of public transportation due to loading commuters beyond the capacity of the vehicle. Also some respondents are concerned of about idling from their work because to displacements from their work place for the purpose of right of way of the road. Additionally, large number of respondents is concerned about the successful implementation of the project due to a long time project delay. It is not small in number of respondents that are concerned about the practical implementation of the designed speed and determined frequency of the BRT bus.

Therefore the city transport concerning authority should work in detail with the concerns of the trip makers for the success of the newly introducing public transportation service.

CHAPTER FIVE: CONCLUSION AND RECOMMENDATION

5.1. Conclusion

The aim of this research is to determine the effect of newly introducing bus rapid transit on trip makers modal shift interest to transit transport. In addition the study investigated target populations concern towards this system, in the case of Addis Ababa city around *Wingate* to *Autobistera* corridor. To meet the main objective of this research mode choice model was developed for the specified trip purpose under both revealed and stated preference approach.

- Revealed preference approach survey data analysis shows that minibus taxi mode has an uppermost modal share followed by bus mode, for all trip purposes.
- For the stated preference approach, survey data analysis shows 82.61%, 88.33%, 84.17% and 76.36% of respondents are willing to change their modal preference to BRT bus under HBW, HBO, NHBW and HBE trip purposes respectively.
- Result of the model estimation indicates in vehicle travel time, waiting time, total travel cost, age interacted with taxi and monthly income level interacted with taxi and ride share as statistically significant factpors for HBW trips.
- Many studies comprised waiting time in out of vehicle travel time which is separetly significant in this study.
- For HBO trip purpose, total travel cost, total travel time and family monthly income interaction with ride share mode are identified as statistically significant variables.
- In NHBW tip purpose, validated significant variables include waiting time, in vehicle travel time, total travel cost, marriage status interaction with taxi and family income interaction with ride share.
- HBE trip included in vehicle travel time, out of vehicle travel time, total travel cost, age variable interaction with taxi mode and school type variable interaction with contract (lada) mode.
- In the stated preference models, the in-vehicle travel time, waiting time and total travel cost are the only factors that are found to be statistically significant.
- This study concluded that, factors that affect mode choice are different for each specific trip purposes.

- The result of the study also shows that travellers have concerns on service quality of the newly introducing public transportation system, BRT.Their concern included sexual harassment, theft, in vehicle suffocation, traffic accident, congestion, displacement from work place, long bus waiting queue.
- Generally the researcher concluded that, even though travellers have many concerns towards BRT bus most of them are positively approaches the system to divert their modal preference to the bus.
- Averages of 82.87% travellers are willing to divert their modal choice to the newly introducing BRT system.

5.2. Recommendation

The researcher recommendations the following:

- During city transport planning, it is recommended to develop mode choice model to consider trip makers preference for the whole city, considering trip purposes and the whole combinations of modes.
- In the Addis Ababa city, mostly transport planning is traditional. Developed models for the specific trips purposes in study can be used as reference rather than traditional transport planning.
- Policy maker can use this research work as an initial model for further development of mode choice analysis.
- The researcher recommends extending BRT system to another part of Addis Ababa city.
- The researchers can validate the model by collecting new data with similar study to assess the interest and willing of travellers living in another area towards the newly introducing bus rapid transit system.
- The city transport concerning authority should work in detail with the investigated concerns of the trip makers for the success of the newly introducing public transportation service, BRT.

5.3. Future research areas

- The future research can focus on modal choice model by including other trip purposes with different independent variables and methods of modelling.
- Variables including to comfort, safety, and reliability are Qualitative variables that can affect travellers' modal preference. Hence, further studies are recommended to include these variables in mode choice assessment related studies.
- The researchers are encouraged to complete the rest of four steps of urban transport planning process: trip distribution, model choice and trip assignment modelling.

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APPENDIX-A

አዲስ አበባ ዩኒቨርሲቲ

አዲስ አበባ የቴክኖሎጂ ተቋም

የሲቪል እና የኢንቫይሮመንታል ምህንድስና ትምህርት ቤት

<u>መጠይቅ (ለሰራተኞች)</u>

"አዲስ አበባ ዉስጥ የአዉቶቢስ ፈጣን መጓጓዣ ተጽዕኖ በተጓዦች የመጓጓዣ አማራጭ ለዉጥ ወደ አዉቶቡስ " በሚል ርዕስ ለሚሰራዉ የመመረቂያ ጽሁፍ የተዘጋጀ መጠይቅ፡፡ይህ መጠይቅ በአዲስ አበባ ዉስጥ ያለውን የትራንስፖርት ሁኔታ እና ሰራተኞች የመጓጓዣ አይነት ሲመርጡ ተፅዕኖ ሊያሳድሩ የሚችሉ ነገሮችን ሂሳባዊ ሞዴል ለመስራት የተዘጋጀ ነዉ፡፡እንዲሁም እየተገነባ ባለዉ የአዉቶቢስ ፈጣን መጓጓዣ ላይ ያሎትን ፍላጎትና ስጋት በመዳሰስ ጥናት ለማድረግ ያለመ ነው፡፡ጥያቄዎቹን ሲመልሱ ስም የማይገልጹ ሲሆን መረጃዉ የተፈለገዉ ለጥናት አላማ ብቻ በመሆኑ በታማኝነት ትክክለኛዉን መረጃ እንዲሰጡን ስንጠይቅ ለጥናቱ ትክክለኛነትና ዉጤታማነት እርሶ የጀርባ አጥንት በመሆኖ ነዉ፡፡

ይህን መጠይቅ ለመሙላት የተጋበዙት ሰዎች የሚቀጥሉትን ሁኔታዎች የሚያሟሉ መሆን አለባቸዉ፡-

- ***ሰራተኞች*** መሆን አለባቸዉ፡፡
- ከሚሰሩበት መስሪያ ቤት የመጓጓዣ አገልግሎት የሌላቸው መሆን አለባቸዉ፡፡
- በአብዛኛዉ ከ12፡00 እስከ 4፡00 ሰዓት ከቤት የሚወጡ መሆን አለባቸዉ፡፡
- የጉዞ መስመራቸዉ ከጄኔራል ዊንጌት በፓስተር አደባባይ ወደ አዉቶቢስ ተራ ወይም አልፎ የሚሄድ መሆን አለበት፡፡

መመሪያ፡- በመረጡት ሳጥን ዉስጥ (√) ምልክት ያኑሩ፡፡

የመልስ ሰጪዉ ኮድ (የቤት ቁጥር) …………..

አዘጋጅ-ነፃነት ካሣሁን

አማካሪ-ሮብዓም ሰለሞን (ዶ/ር)

ረዳት አማካሪ- ታምሩ ጥላሁን

ክፍል1፡ የተጓዥ ማህበራዊና ኢኮኖሚያዊ መረጃ

1. ጾታ   ሀ. ወንድ [ ]   ለ. ሴት [ ]
2. እድሜ…………ዓመት
3. በቤተሰዎ ዉስጥ ስንት ሰዉ በቋሚነት ይኖራል (የቤተ-ሰብ አባላት ብዛት)………….በቁጥር
4. የጋቢቻ ሁኔታ ሀ. ያላገባ/ች [ ] ለ. ያገባ/ች [ ] ሐ. የትዳር አጋር የሞተበት/ባት [ ] መ. የተፋታ/ታች [ ]
5. የትምህርት ደረጃ

   ሀ. አንደኛ ደረጃ ያጠናቀቀና ከዚያ በታች [ ]   ለ. ሁለተኛ ደረጃ [ ]   ሐ. ሰርተፊኬትና ዲፕሎማ [ ]

   መ. የመጀመሪያ ዲግሪ [ ]   ሠ. ሁለተኛ ዲግሪ ያጠናቀቀና ከዚያ በላይ [ ]

6. ወርኃዊ የቤተ-ሰብዎ የገቢ መጠን በብር

ሀ. ከ2500 በታች [ ] ለ. ከ2501-5000 [ ] ሐ. ከ5001-10000 [ ] መ. ከ10001-20000 [ ] ሠ. ከ 20001 በላይ [ ]

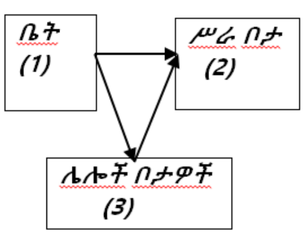
7. የተሽከርካሪ ብዛት በቤተ-ሰብዎ ውስጥ ሀ. የለም [ ] ለ. አንድ [ ] ሐ. ሁለት [ ] መ. ከሀለት በላይ [ ]
8. መተዳደሪያ የስራ አይነት

ሀ. የመንግስት ተቀጣሪ [ ]   ሐ. መንግስታዊ ያልሆኑና ዓለም አቀፋዊ ድርጂት ሰራተኛ (NGO) [ ]

ለ. የግል መስሪያ ቤት ተቀጣሪ [ ]   መ. የግል ስራ [ ]   ሠ. ሌላ ሥራ [ ]……………….

ክፍል 2፡ የጉዞና የመጓጓዣ አማራጮች ባህሪያት

- የጉዞዉ ***መነሻ ቤት*** እና የጉዞዉ ***መድረሻ ደግሞ ሥራ*** ቦታ መሆን ያለበት ሲሆን ከሚቀጥለዉ የጉዞ መስመር አማራጭ አብዛኛዉን ጊዜ የሚጠቀሙትን መርጠዉ ጥያቄዎቹን ይመልሱ።
- ልሎች ቦታዎች የሚለዉ ወደ ሥራ ቦታ ሲሄዱ ልጅ ለማድረስት/ቤት፣ገበያ እና ሌሎች ቦታዎች የሚሄዱ ከሆነ ለማመልከት ነዉ።
- ከጄኔራል ዊንጌት አደባባይ አካባቢ እስከ ጀሞ ድረስ አገልግሎት ለመስጠት የአዉቶቡስ ፈጣን መጓጓዣ በግንባታ ላይ ይገኛል።
- የአዉቶቢስ ፈጣን መጓጓዣ ባህሪያት እንደሚቀጥለዉ *በሰንጠረዥ 3* ቀርቧል።



ምስል 1፡ የጉዞ አቅጣጫ

2.1 *ቤት ⟶ ሠራ ቦታ* (**1⟶ 2**)

ሰንጠረዥ 1፡-ቀጥታ ከቤት ወደ ሥራ ቦታ የሚደረግ የጉዞ ባህሪያት

ተ.ቁ	***የጉዞ ባህርያት***	***ከቤት ወደ ሥራ***
1	አብዛኛዉን ጊዜ የሚጠቀሙት የመጓጓዣ(የትራንስፖርት) አይነት	
2	በእግር እና / በባጃጅ ከቤት እስከ መሳፈሪያ ቦታ ድረስ የጉዞ ጊዜ በግምት (በደቂቃ)	

3	ከቤት እስከ መሳፈሪያ ቦታ ድረስ ባጃጅ/ሌላ ከተጠቀሙ የጉዞ ክፍያ (በብር)	
4	የመረጡት መጓጓዣ መጥቶ አስኪሳፈሩ የሚጠብቁት ጊዜ በግምት (በደቂቃ)	
5	አስከ ሥራ ቦታ በመጓጓዣዉ ዉስት ሆነዉ የጉዞ ቆይታ በግምት (በሰዓት/ደቂቃ)	
6	የመረጡት መጓጓዣ የጉዞ ክፍያ (በብር)	
7	የመረጡት የመጓጓዣአይነት የግል መኪና ከሆነ፡-	
7.1	ከቤት እስከ ሥራ ቦታ የጉዞ ቆይታ በግምት(በሰዓት/ደቂቃ)	
7.2	ከቤት እስከ ሥራ ቦታ ድረስ ያለዉ ርቀት በግምት (በ ኪ.ሜ)	
7.3	መኪናዎ የሚጠቀመዉ የነዳጅ አይነት	
7.4	መኪናዎ በ 1 ሊትር ነዳጅ የሚጓዘዉ ርቀት (በ ኪ.ሜ)	
7.5	አማካኝ የጥገና ወጪ በወር (በብር)	
7.6	ዓመታዊ የሰርቪስ ክፍያ(በብር)	
8	እስከ ሥራ ቦታዎ ድረስ በእግር የሚሄዱ ከሆነ የሚፈጅብዎት ጊዜ በግምት (በሰዓት/ደቂቃ)	
9	አሁን እየተጠቀሙ ካሉት የመጓጓዣ አይነት ወደ አዲሱ ፈጣን አዉቶቡስ ለመቀየር ያለዎት ፈቃደኛነት	
አንዛኛዉን ጊዜ የሚጠቀሙት የመጓጓዣ አይነት፡* አንበሳ አዉቶቡስ **[ሀ]** ፣ሸገር አዉቶቡስ **[ለ]** ፣ ሀይገር አዉቶቡስ **[ሐ]** ፣ሎንችን **[መ]** ፣ ሚኒ-ባስ ታክሲ **[ሠ]** . የግል መኪና **[ረ]** ፣ራይድ ሼር (Ride share) **[ሸ]** ፣ላዳ ታክሲ **[ቀ]** ፣በእግር **[በ]** ፣ ሌላ……………..**[ተ]**		
*ወደ አዲሱ ፈጣን የአዉቶቢስ አማራጭ ለመቀየር ያለዎት ፈቃደኛት**:-* አዎ **[1]**፣ አልቀይርም **[2]**		

2.2 ቤት ⟶ ሌላ ቦታ⟶ ሠራ ቦታ **(1 ⟶**3 **⟶2)**

ሰንጠረዥ 2፦ከቤት ወደ ሌሎች ቦታዎችና ወደ ሥራ ቦታ የሚደረግ የጉዞ ባህሪያት

ተ.ቁ	***የጉዞ ባህርያት***	***ከቤት ወደ ሌላ ቦታ***	***ከሌላ ቦታ ወደ ሥራ***
1	አብዛኛዉን ጊዜ የሚጠቀሙት የመጓጓዣ(የትራንስፖርት) አይነት		
2	በእግር እና / በባጃጅ ከቤት እስከ መሳፈሪያ ቦታ ድረስ በግምት የጉዞ ጊዜ (በደቂቃ)		
3	ከቤት እስከ መሳፈሪያ ቦታ ድረስ ባጃጅ/ሌላ ከተጠቀሙ የጉዞ ክፍያ (በብር)		
4	የመረጡት መጓጓዣ መጥቶ አስኪሳፈሩ የሚጠብቁት ጊዜ በግምት (በደቂቃ)		
5	በመጓጓዣዉ ዉስጥ ሆነዉ የጉዞ ቆይታ(በሰዓት/ደቂቃ)		
6	የመረጡት መጓጓዣ የጉዞ ክፍይ (በብር)		
7	የመረጡት የመጓጓዣአይነት የግል መኪና ከሆነ፡-		
7.1	በመኪና ዉስጥ ሆነዉ የጉዞ ቆይታ(በሰዓት/ደቂቃ)		
7.2	የጉዞ ርዝመትበግምት (በ ኪ.ሜ)		
7.3	መኪናዎ የሚጠቀመዉ የነዳጅ አይነት		
7.4	መኪናዎ በ 1 ሊትር ነዳጅ የሚጓዘዉ ርቀት (በ ኪ.ሜ)		
7.5	አማካኝ የጥገና ወጪ በወር (በብር)		
7.6	ዓመታዊ የሰርቪስ ክፍያ(በብር)		
8	በእግር ብቻ የሚሄዱ ከሆነ የሚፈጅብዎት ጊዜ (በሰዓት/ደቂቃ)		
9	አሁን እየተጠቀሙ ካሉት የመጓጓዣ አይነት ወደ አዲሱ ፈጣን አዉቶቡስ ለመቀየር ያለዎት ፈቃደኛነት		
አንዛኛዉን ጊዜ የሚጠቀሙት የመጓጓዣ አይነት፦* አንበሳ አዉቶቡስ **[ሀ]** ፣ሸገር አዉቶቡስ **[ለ]** ፣ ሀይገር አዉቶቡስ **[ሐ]** ፣ሎንችን **[መ]** ፣ ሚኒ-ባስ ታክሲ **[ሠ]** . የግል መኪና **[ረ]** ፣ራይድ ሼር (Ride share) **[ሸ]** ፣ላዳ ታክሲ **[ቀ]** ፣በእግር **[በ]** ፣ ሌላ…………….. **[ተ]**			
*ወደ አዲሱ ፈጣን የአዉቶቢስ አማራጭ ለመቀየር ያለዎት ፈቃደኛት**:-* አዎ **[1]**፣ አልቀይርም **[2]**			

2.3 የአዉቶቡስ ፈጣን መጓጓዣ(BRT) ባህሪያት

ከጄኔራል ዊንጌት እስከ ጀሞ ድረስ አገልግሎት ለመስጠት የአዉቶቡስ ፈጣን መጓጓዣ በግንባታ ላይ ይገኛል።የዚህ አዉቶቡስ ፈጣን መጓጓዣ ባህሪያት እንደሚቀጥለዉ *በሰንጠረዥ 3* ቀርቧል።

ሰንጠረዥ 3፡ የአዉቶቡስ ፈጣን መጓጓዣ ባህሪያት

የጉዞ ባህሪያት	***አዲሱ የአዉቶቡስ ፈጣን መጓጓዣ ባህሪያት***
1. የጉዞ ርዝመት ከጄነራል ዊንጌት አደባባይ እስከ አዉቶቢስተራ (በደቂቃ)	15 ደቂቃ (16.92 ኪ.ሜ ፍጥነት በሰዓት ይጓዛል)
2. የጉዞ ክፍያ (በብርና በሳንቲም)	• ከሌሎች አውቶቡሶች ጋር ተመሳሳይ ክፍያ
3. አውቶቡሱ የሚመጣበት ድግግሞሽ ወይም አውቶቡሱን ቆመዉ የሚጠብቁበት ጊዜ (በደቂቃ)	• ጠዋት ከ12፡00-2፡00 ሰዓት በየ 6 ደቂቃ • ረፋድ ከ2፡00-5፡00 ሰዓት በየ 3 ደቂቃ • ቀን ከ5፡00-10፡00 ሰዓት በየ 6 ደቂቃ • ከሠዓት ከ10፡00-12፡00 ሰዓትበየ 3 ደቂቃ
4. የግል መኪናዎን በአዉቶቢሱ መነሻ ስፍራ አቁመዉ ወደ ስራ ለመሄድ ይችላሉ	በዊንጌት አደባባይ የመኪና ማቆሚያ

ምንጭ፡ አዲስ አበባ ትራንስፖርት ቢሮ

በግንባታ ላይ ያለዉን የአዉቶቡስ ፈጣን የመጓጓዣ አይነት ከተዘረዘሩት ባህሪያት አንጻር ለመጠቀም ስጋት ካለዎት?

………

ምስል 2፡ የአዉቶቡስ ፈጣን መጓጓዣ (BRT) መጫኛና ማዉረጃ (ስቴሽን)

ምንጭ፡ አዲስ አበባ ትራንስፖርት ቢሮ

Addis Ababa University

Addis Ababa Institute of Technology

School of Civil and Environmental Engineering

Questionnaire (For Workers)

Dear respondents,

This questionnaire is designed to collect required data for a research titled with '***Effect of Bus Rapid Transit System on a Modal Shift to Bus: Case Study Addis Ababa City'.*** It is prepared to assess transportation system situations in Addis Ababa city, following Winget to Autobis Tera corridor. Also factors that affect mode choice of workers in order to develop modal split model will be identified. Another purpose of this questionnaire is to examine travelers' interest towards a newly introducing Bus rapid transit system which is now under construction. Therefore, you are kindly requested to read the questions carefully and give a real response. Since the response that you give will not be used for any other purpose other than this scientific research please be free and give your honest response.

The respondent should satisfy the following condition.

- The respondent should be **worker**.
- The respondent should not have company provided transport service.
- The respondent should leave home 12:00-4:00, local time.
- The respondent trip direction should be from Wingate to Autobistera.

Instruction: Tick (√) for your choice of the following questions.

Prepared by: Netsanet Kassahun

Advisor: Robeam Solomon (Dr.)

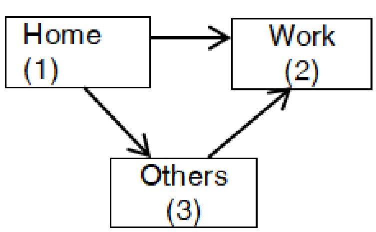
Co-Advisor: Tamiru Tilahun

Section 1፡ Travelers Socio-Economic information

1. Gender 1. Male [ ] 2. Female [ ]
2. Age…………years
3. Family members per house hold ………. in number
4. Marital Status
   1. Married [ ] 2. Single [ ] 3. Widowed [ ] 4. Divorced [ ]
5. Educational level
   1. Primary school and below [ ] 2. Secondary School [ ] 3. First Degree [ ]
   4. Second degree and above [ ] 5. Certificate and Diploma [ ]
6. Family monthly income level in birr (ETB)
   1. Less than 2500 ETB [ ] 2. 2501-5000 ETB 3. 5001-10000 ETB [ ]
   4. 10001-20000 ETB [ ] 5. Greater than 20001 ETB [ ]
7. Car ownership per house hold?
   1. Zero [ ] 2. One [ ] 3. Two [ ] 4 Above 2 [ ]
8. Occupational status
   1. Government employee [ ] 2. Private organization Employee [ ]

   3. NGO and International Organization employee [ ] 4.Self-Employed [ ] 5. Other Employee [ ]

Section 2፡ Trip and mode characteristics



2.1.Home ⟶Work (1⟶ 2)

Table 1፡ Home to Work trip characteristics

No.	Trip characteristics	Home to Work trip
1	Alternative you use most of the time	
2	Walk time and access time from home to nearby station in minutes(if you use to access station)	
3	Access cost (if you use other modes like Bajaj) in Birr and Cents	

4	Waiting time to get alternative you use, in minutes	
5	In vehicle travel time, in minute	
6	Fare, in birr	
7	If you are using private car,	
7.1	Travel time, in minutes	
7.2	Travel distance, km	
7.3	Type of fuel	
7.4	How many kilometers your car travel with 1 liter of fuel	
7.5	Maintenance cost	
7.6	Annual service cost	
8	Approximate time (hour / min) if you walk to work	
9	Your willingness to switch from the type of transportation you are currently using to the BRT	
Type of transportation you use most of the time*: Sheger bus(a), Higer bus(b), Lonchin(c), Minibus taxi(d), Private car (e), Ride share car (f), Lada taxi(g), Walk(h), Others (i)		
Your willingness to divert to the BRT bus** :- Yes(1), No (2)		

2.2. Home ⟶ Others ⟶ Work (1 ⟶ 3 ⟶ 2)

Table 2 : Travel characteristics from home to other places and to work place

No	Ttip Characteristics	Home to Others	Others to Work
1	Alternative you use most of the time		
2	Walk time and access time from home to nearby station in minutes(if you use to access station)		
3	Access cost (if you use other modes like Bajaj) in Birr and Cents		
4	Waiting time to get alternative you use, in minutes		
5	In vehicle travel time, in minute		
6	Fare, in birr		
7	If you are using private car		
7.1	Travel time, in minutes		
7.2	Travel distance, km		
7.3	Type of fuel		
7.4	How many kilometers your car travel with 1 liter of fuel		
7.5	Maintenance cost		
7.6	Annual service cost		
8	Approximate time (hour / min) if you walk to work		

9	Your willingness to switch from the type of transportation you are currently using to the BRT		
Type of transportation you use most of the time*: Sheger bus(a), Higer bus(b), Lonchin(c), Minibus taxi(d), Private car (e), Ride share car (f), Lada taxi(g), Walk(h), Others (i)			
Your willingness to divert to the BRT bus** :- Yes(1), No (2)			

2.3. Bus rapid transit (BRT) characteristics

The bus transit corridor from General Wingate to Jemo is under construction. The characteristics of this bus are shown in Table 3 as follows.

Table 3 : Bus rapid transit (BRT) characteristics

Variables	Bus rapid transit (BRT) characteristics
5. Travel distance from General Wingate Square to Bus (min)	15 minute (speed-16.92 km/hr)
16 Travel fare (in ETB)	Same travel fare as other buses
17 Frequency of bus arrival or waiting time (in minutes)	• Morning 6:00-8:00 am by 6 min. • Late morning 8:00-11:00 am by 3 min • Noon 11:00 am-4:00 pm by 6 min. • Afternoon 4:00-6:00 pm by 3 min.
18 Park and drive service	Nearby general Winget square

Do you have a concern to use the bus rapid transit under construction, in light of the characteristics listed in the table above?..

Figure 2 : BRT Loading and Uploading Station

Source: Addis Ababa Transport Bureau

አዲስ አበባ ዩኒቨርሲት

አዲስ አበባ የቴክኖሎጂ ተቋም

የሲቪል እና የኢንቫይሮመንታል ምህንድስና ትምህርት ቤት

<u>መጠይቅ (ለተማሪዎች)</u>

"አዲስ አበባ ዉስጥ የአዉቶቢስ ፈጣን መጓጓዣ ተጽዕኖ በተጓዦች የመጓጓዣ አማራጭ ለዉጥ ወደ አዉቶቢስ" በሚል ርዕስ ለሚሰራዉ የመመረቂያ ጽሁፍ የተዘጋጀ መጠይቅ።ይህ መጠይቅ በአዲስ አበባ ዉስጥ ከዊንጌት እስከ አዉቶቢስተራ ያለውን የትራንስፖርት ሁኔታ ለማጥናት እና ተማሪዎች የመጓጓዣ አይነት ሲመርጡ ተፅእኖ ሊያሳድሩ የሚችሉ ምክኒያቶችን ሂሳባዊ ሞዴል ለመስራት የተዘጋጀ ነዉ።እንዲሁም እየተገነባ ባለዉ የአዉቶቢስ ፈጣን መጓጓዣ ላይ ያሉትን ፍላጎትና ስጋት በመዳሰስ ጥናት ለማድረግ ያለመ ነው።ጥያቄዎቹን ሲመልሱ ስም የማይገልጹ ሲሆን መረጃዉ የተፈለገዉ ለጥናት አላማ ብቻ በመሆኑ በታማኝነት ትክክለኛዉን መረጃ እንዲሰጡን ስንጠይቅ ለጥናቱ ትክክለኛነትና ዉጤታማነት ዕርሶ የጀርባ አጥንት በመሆኖ ነዉ።

ይህን መጠይቅ ለመሙላት የተጋበዙት ሰዎች የሚቀጥሉትን ሁኔታዎች የሚያሟሉ መሆን አለባቸዉ፡-

- ***ተማሪዎች*** መሆን አለባቸዉ።
- ከሚማሩበት ትምህርት ቤት የመጓጓዣ አገልግሎት የሌላቸው መሆን አለባቸዉ።
- በአብዛኛዉ ከጠዋቱ 12፡00 እስከ 4፡00 ሰዓት ከቤት የሚወጡ መሆን አለባቸዉ።
- የጉዞ መስመራቸዉ ከጄኔራል ዊንጌት በፓስተር አደባባይ ወደ አዉቶቢስ ተራ ወይም አልፎ የሚሄድ መሆን አለበት።

መመሪያ፡- በመረጡት ሳጥን ዉስጥ (√) ምልክት ያኑሩ።

የመልስ ሰጪዉ ኮድ (የቤት ቁጥር) …………..

አዘጋጅ-ነፃነት ካሣሁን

አማካሪ-ሮብዓም ሰለሞን (ዶ/ር)

ረዳት አማካሪ-ታምሩ ጥላሁን

ክፍል 1፡ የተጓዥ ማህበራዊና ኢኮኖሚያዊ መረጃ

1. ጾታ ሀ.ወንድ [ ] ለ. ሴት [ ]
2. እድሜ…………ዓመት
3. የቤተሰዎ ዉስጥ ስንት ሰዉ በቋሚነት ይኖራል (የቤተ-ሰብ ብዛት)…………..
4. የሚማሩበትን የትምህርት ቤት አይነት ይምረጡ።

   ሀ. የመንግስት [ ] ለ. የግል [ ]

5. የትምህርት ደረጃ

   ሀ. አንደኛ ደረጃ ያጠናቀቀና ከዚያ በታች [ ] ለ. ሁለተኛ ደረጃ [ ] ሐ. ሰርተፊኬትና ዲፕሎማ [ ]

   መ. የመጀመሪያ ዲግሪ [ ] ሠ. ሁለተኛ ዲግሪና ከዚያ በላይ [ ]

6. ወርኃዊ የቤተ-ሰብዎ የገቢ መጠን በብር ቀጥሎ ከተዘረዘሩት አማራጮች ዉስጥ አንዱን ይምረጥ

   ሀ. ከ2500 በታች [ ] ለ. ከ2501-5000 [ ] ሐ. ከ5001-10000 [ ]

   መ.ከ10001-20000 [ ] ሠ. ከ 20001 በላይ [ ]

7. በቤተ-ሰብዎ ዉስጥ የሚገኝ የተሽከርካሪብዛት ስንት ነዉ?

   ሀ. የለም [ ] ለ. አንድ [ ] ሐ. ሁለት [ ] መ. ከሀለት በላይ [ ]

ክፍል 2፡ የጉዞና የመጓጓዣ ባህሪያት

1. በአካባቢዎ ሊያገኙ የሚችሉት የመጓጓዣ አይነቶች ቀጥሎ ከተዘረዘሩት ዉስጥ ይምረጡ ***(ከአንድ በላይ መምረጥ ይቻላል***)።

   ሀ. አንበሳ አዉቶቢስ [ ] ለ. ሸገርአዉቶቢስ [ ] ሐ. ሀይገር ባስ [ ] መ. ሚኒባስ ታክሲ [ ]

   ሠ.በግልመኪና(የቤተ-ሰብ) [ ] ረ. ኮንትራት መኪናዎች [ ] ሸ. ራይድ ሼር ቀ. ላዳ ታክሲ

   በ. ሌለች አማራጮች ካሉ በዝርዝር ይጥቀሱ………………………………………………..

2. ከታች ከተዘረዘሩት አማራጮች ውስጥ አብዛኛውን ጊዜ ከቤት ወደ ትምህርት ቤት ለመሄድ የሚጠቀሙበትን

   አማራጭ ብቻ መርጠው ጥያቄዎቹን ይመልሱ ***(አንድ ብቻ ይምረጡ)*** ::

ሀ. ሸገር አዉቶቢስ [ ] አንበሳ አዉቶቢስ [ ] ሀይገር አዉቶቢስ [ ] ሎንችን [ ]

- አማራጩን ለምን መረጠ?

  …………………………………………………………………………………………………

- በእግር እና / ወይም በባጃጅ ከቤትዎ እስከ አውቶቢስ መሳፈሪያ ድረስ የሚጓዙበት ጊዜ በግምት ስንት ደቂቃ ይሆናል?…………………………..ደቂቃ
- ከቤትዎ እስከ አውቶቡስ መሳፈሪያ ድረስ ባጃጅ ከተጠቀሙ ምን ያህል ይከፍላሉ (በብር እና በሳንቲም) ?……………….
- አውቶቢስ መጥቶ እስኪሳፈሩ ድረስ የሚጠብቁበት ጊዜ በግምት ስንት ደቂቃ ይሆናል ……………………………….ደቂቃ?
- በአውቶቢስ ውስጥ ሆነው ጠቅላላ የጉዞ ጊዜ እስከ ትምህርት ቤት ድረስ በግምት ስንት ይሆናል………..ሰዓትና …………ደቂቃ ?
- የአውቶቡስ ክፍያ ስንት ብር ነዉ?…………………………………………

ለ. ሚኒባስ ታክሲ []

- አማራጩን ለምን መረጡ? ……………………………………………………………………………………………….
- በእግር እና / ወይም በባጃጅ ከቤትዎ እስከ ታክሲ መሳፈሪያ ድረስ የሚጓዙበት ጊዜ በግምት ስንት ደቂቃ ይሆናል……………… ደቂቃ?
- ከቤትዎ እስከ ታክሲ መሳፈሪያ ድረስ ባጃጅ ከተጠቀሙ ምን ያህል ይከፍላሉ ……………………(በብር እና በሳንቲም)?
- ታክሲ መጥቶ እስኪሳፈሩ ድረስ የሚጠብቁበት ጊዜ በግምት ስንት ደቂቃ ይሆናል…………………………….ደቂቃ?
- ታክሲ ውስጥ ሆነው ጠቅላላ የጉዞ ጊዜ እስከ ትምህርት ቤት ድረስ በግምት ስንት ደቂቃ ይሆናል……………….ደቂቃ?
- የታክሲ ክፍያ በብርና በሳንቲም ስንት ነዉ?……………………………………………………

ሐ. በግል መኪና ከቤተሰብ ጋር []

- በመኪና ውስጥ ሆነው ጠቅላላ የጉዞ ቆይታ እስከ ትምህርት ቤት በግምት ምን ያህል ነው (በሰአት/በደቂቃ)?..............
- መኪናዎት ምን አይነት ነዳጅ ይጠቀማል? ……………………………………
- በ 1 ሊትር ነዳጅ መኪናዎ ምን ያህል ርቀት ይጓዛል ………..……………………..ኪ.ሜ
- አማካኝ የጥገና ወጪ በወር ምን ያህል ነው(በብር)?.......................
- በአንድ የሰርቪስ ጊዜ ስንት ይከፍላሉ (በብር)?………………

መ. በኮንትራት መኪና[ ]

- አማራጩን ለምን መረጡ?
  ………………………………………………………………………………………………….
- ከቤት ትምህርት ቤት ለመድረስ ምን ያህል ጊዜ ያስፈልጋል?....................ሰዐትና……….ደቂቃ
- የወር የኮንትራት ክፍያ ስንት ነዉ (በብር) ? …………….

ሠ. በግል መኪናዎች ከፍለዉ (Ride share) [ ]   ላዳ ታክሲ [ ]

- አማራጩን ለምን መረጡ?
  ………………………………………………………………………………………………….
- በእግር እና/ ወይም በባጃጅ ከቤትዎ መኪናዉን እስከሚያገኙበት ስፍራ ድረስ የሚጓዙበት ጊዜ በግምት ስንት ደቂቃ ይሆናል?……………….
- ከቤትዎ እስከ መኪና መሳፈሪያ ድረስ ባጃጅ ከተጠቀሙ ምን ያህል ይከፍላሉ (በብር እና በሳንቲም)? ………….........
- መኪናዉን የሚጠብቁበት ጊዜ በግምት ስንት ደቂቃ ይሆናል? ……………………………………………….
- በመኪና ውስጥ ሆነው ጠቅላላ የጉዞ ጊዜ እስከ ትምህርት ቤትዎ ድረስ በግምት ስንት ደቂቃ ይሆናል?…………
- የመኪናዉ የጉዞ ክፍያ በብርና በሳንቲም ስንት ነው? ……………………………………………….
- መኪናዉን ቤትዎ ድረስ የሚጠሩ ከሆነ በመኪና ውስጥሆነው ጠቅላላ የጉዞ ጊዜ እስከ ትምህርት ቤትዎ ድረስ በግምት ስንት ደቂቃ ይሆናል?..................
- መኪናዉን ቤትዎ ድረስ የሚጠሩ ከሆነ አጠቃላይ የጉዞ ክፍያ በብርና በሳንቲም ስንት ነው?...............................

ረ. በእግር [ ] …………ደቂቃ

3. የአዉቶቢስ ፈጣን መጓጓዣ (BRT)

ከጄኔራል ዊንጌት እስከ ጀሞ ድረስ አገልግሎት ለመስጠት የአዉቶቢስ ፈጣን መጓጓዣ በግንባታ ላይ ይገኛል፡፡የዚህ የአዉቶቢስ ፈጣን መጓጓዣ ባህሪያት ከታች ***በሰንጠረዥ 1*** ቀርቧል፡፡

ሰንጠረዥ 1፡ የአዉቶቢስ ፈጣን መጓጓዣ ባህሪያት

የጉዞ ባህርያት	***አዲሱ የአዉቶቢስ ፈጣን መጓጓዣ ባህሪያት***
1. የጉዞ ርዝመት ከጄነራልዊንጌት እስከ አዉቶቢስተራ በደቂቃ	15 ደቂቃ (16.92 ኪ.ሜ ፍጥነት በሰዓት ይጓዛል)
2. የጉዞ ክፍያ በብርና በሳንቲም	ከነባር ባሶች ጋር ተመሳሳይ ነዉ
3. በየስንት ደቂቃ አውቶቡስ ይመጣል	• ጠዋት ከ12፡00-2፡00 ሰዓትበየ 6 ደቂቃ • ረፋድ ከ2፡00-5፡00 ሰዓትበየ 3 ደቂቃ • ቀን ከ5፡00-10፡00 ሰዓትበየ 6ደቂቃ • ከሠዓት ከ10፡00-12፡00 ሰዓትበየ 3 ደቂቃ
4. የግል መኪናዎን በአዉቶቢሱ መነሻ ስፍራ አቁመዉ ወደ ስር ለመሄድ ይችላሉ	በዊንጌት አደባባይ

ምንጭ፡ አዲስ አበባ ትራንስፖርት ቢሮ

በቅርቡ እንደሚጀምር የሚጠበቀዉ በግንባታ ላይ የሚገኘዉ የአዉቶቢስ ፈጣን መጓጓዣ ባህሪያትን ታሳቢ በማድረግ ***ከቤት ወደ ትምህርት ቤት*** ለመሄድ አሁን እየተጠቀሙ ካሉት የመጓጓዣ አማራጭ ወደ አዲሱ የአዉቶቢስ አማራጭ ለመቀየር ፈቃደኛ ይሆናሉ?

1. አዎን [ ]   2. አይ (አልቀይርም) [ ]

4. አዲሱን የአዉቶቢስ ስፈጣን የመጓጓዣ አይነት ከተዘረሀሩት ባህሪያት አንጻር ለመጠቀም ስጋት የሚሆንብዎት ነገር ካለ በዘርዝር ያስቀምጡ፡፡……………………………………………………………………………………………

ምስል 1፡ የአዉቶቢስ ፈጣን መጓጓዣ(BRT) መጫኛና ማዉረጃ (ስቴሽን)

ምንጭ፡ አዲስ አበባ ትራንስፖርት ቢሮ

Addis Ababa University

Addis Ababa Institute of Technology

School of Civil and Environmental Engineering

Questionnaire (For students)

Dear respondents,

This questionnaire is designed to collect required data for a research titled with '***Effect of Bus Rapid Transit System on a Modal Shift to Bus: Case Study Addis Ababa City'.*** It is prepared to assess transportation systems situation in Addis Ababa city, following Winget to Autobis Tera corridor. Also factors that affect mode choice of students in order to develop modal split model will be identified. Another purpose of this questionnaire is to examine travelers' interest towards a newly introducing Bus rapid transit system which is now under construction. Therefore, you are kindly requested to read the questions carefully and give a real data. Since the response that you give will not be used for any other purpose other than this scientific research please be free and give your honest response.

The respondent should satisfy the following condition.

- The respondent should be **student.**
- The respondent should not have school provided transport service.
- Respondents should usually leave home from morning 6:00 am to 10:00 am.
- The respondent trip direction should be from Wingate to Autobistera.

Instruction: Tick (√) for your choice of the following questions.

Prepared by: Netsanet Kassahun

Advisor: Robeam Solomon (Dr.)

Co-Advisor: Tamiru Tilahun

Section 1: Travelers Socio-Economic information

1. Gender 1. Male [ ] 2. Female [ ]
2. Age…………years
3. Family members per house hold in number……….
4. School type

   1. Government School [ ] 2. Private School [ ]

5. Educational level

   2. Primary school and below [ ] 3. Certificate and Diploma [ ] 4. First Degree [ ]
   3. Secondary School [ ] 5. Second degree and above [ ]

6. Car ownership per house hold?

   2. Zero [ ] 2. One [ ] 3. Two [ ] 4. Above 2 [ ]

Section 2: Trip and available mode characteristics

7. What are the available transport modes for you to travel to school (More than one can be selected)?

   1. Anbessa Bus [ ] 4. Minibus tax [ ] 7. Contract car [ ]
   2. Sheger Bus [ ] 5. Private car as driver [ ] 8. Ride share car [ ]
   3. Higer Bus [ ] 6. Ride share [ ] 9. Others………..

8. Which mode of transportation do you prefer mostly to go to school from your home (select only one option)? ……………………………………….

A. Sheger Bus [ ] Anbessa Bus [ ] Higer bus [ ]

- Why did you choose the option? ....
- Estimate Walk time and/ access time (if you use other modes like bajaj) from home to arrive at a nearby bus station in minutes? …………………………
- Estimate Access cost to arrive at bus station (if you use other modes like Bajaj) in Birr and Cents?..…………… …………
- Estimate Waiting time for bus in minutes? ………………………………...
- Estimate In vehicle (bus) travel time in minutes? ……………………….
- Trip fare of bus, in Birr……………………………………………………

B. Minibus taxi [ ]

- Why did you choose the option? ....
- Estimate Walk time and/ access time (if you use other modes like bajaj) from home to arrive at a nearby taxi station in minutes? …………
- Estimate Access cost to arrive at taxi station (if you use other modes like Bajaj) in Birr and Cents?

  …………..
- Estimate Waiting time for minibus taxi, in minutes? ………………………………...
- Estimate In vehicle (taxi) travel time, in minutes? ……………………
- Trip fare in Birr and Cents? ………………………………………………………

C. Private car as driver [ ]

- Estimate In vehicle (Private car) travel time in minutes? ....
- Approximate distance from home to school, in km………….
- What type of fuel your cars consume? ……………………………………
- Estimate how many kilometers you travel with 1 liter fuel? ……………………..
- Average maintenance cost? ....
- How much do you pay per each service, in Birr? ....….

D. Contract car [ ]

- Why did you choose the option? ....
- How long does it take to get school from home?
- What is the monthly contract fee (in ETB)?

E. Ride share car [ ]   Lada taxi [ ]

- Why did you choose the option? ....
- Estimate Walk and/ access time (if you use other modes like bajaj) to access ride? ……………….
- Estimate Access cost to arrive at ride station (if you use other modes like Bajaj) in Birr and Cents? …………...
- Estimate Waiting time for ride in minute? ………………………………………………
- Estimate In vehicle (ride) travel time in minutes? …………
- Estimate Trip fare in Birr and Cents? ………………………………………………
- Estimate general travel time in minutes if you call ride to your home? ....
- Estimate general trip fare in birr and cents if you call ride to your home? ....

E. Bus rapid transit (BRT)

The characteristics of stated Bus rapid transit which is now under construction is shown below in table 1.

Table 1፡ Bus rapid transit systems trip characteristics

Trip characteristics	Trip characteristics detail
1. In vehicle (bus) travel time from general Wingate to Autobus tera in minutes	15 minutes (Speed- 16.92 km/hr)_
2. Trip fare from general Winget to Autobus tera in birr	Similar to other Buses fare
3. Arrival frequency of bus፣ in minutes	•Morning 6፡00-8፡00 am by 6 min. •Late morning 8፡00-11፡00 am by 3 min. •Noon 11፡00 am-4፡00 pm by 6 min. •After noon 4፡00-6፡00 pm by 3 min.
4. Park and drive service	Nearby general Winget square

Source: Addis Ababa Transport Bureau

Are you willing to shift your current mode choice to Bus Rapid Transit with the above listed trip attributes for trips to school from general winget to Autobis tera which will start providing service in the near future?

1. Yes [ ]   2. No [ ]

5. What are your concerns to use bus rapid transit for?
   ………

Figure 1: BRT Loading and Uploading Station

Source: Addis Ababa Transport Bureau

APPENDIX-B

Table B-1: Critical chi-squared (χ 2) values for selected level of confidence by number of restrictions.

Level of Confidence	Number of Restrictions								
	1	2	3	4	5	7	10	12	15
90%	2.71	4.61	6.25	7.78	9.24	12.01	15.99	18.54	22.31
95%	3.84	5.99	7.81	9.49	11.07	14.06	18.31	21.02	25.00
99%	6.63	9.21	11.34	13.28	15.09	18.48	23.21	26.21	30.58
99.5%	7.88	10.60	12.84	14.86	16.75	20.28	25.19	28.30	32.80
99.9%	10.83	13.82	16.27	18.47	20.51	24.32	29.59	32.91	37.70

Source: (Koppleman & Chandra, 2006)

APPENDIX-C

I. Revealed preference model estimation results

Case Processing Summary

		N	Percent
Cases available in analysis	Event[a]	154	31.2%
	Censored	339	68.8%
	Total	493	100.0%
Cases dropped	Cases with missing values	0	0.0%
	Cases with negative time	0	0.0%
	Censored cases before the earliest event in a stratum	0	0.0%
	Total	0	0.0%
Total		493	100.0%

a. Dependent Variable: T

Base model

Omnibus Tests of Model Coefficients

-2 Log Likelihood
356.209

Omnibus Tests of Model Coefficients[a]

-2 Log Likelihood	Overall (score)			Change From Previous Step			Change From Previous Block		
	Chi-square	df	Sig.	Chi-square	df	Sig.	Chi-square	df	Sig.
245.010	103.405	3	.000	111.199	3	.000	111.199	3	.000

Variables in the Equation

	B	SE	Wald	df	Sig.	Exp(B)	95.0% CI for Exp(B)	
							Lower	Upper
dtaxi	-.376	.191	3.857	1	.050	.687	.472	.999
dpcar	-3.259	.615	28.053	1	.000	.038	.012	.128
drshare	1.653	.350	22.285	1	.000	5.224	2.630	10.377

Model 1: Developed by adding total travel time and total travel cost over base model

Omnibus Tests of Model Coefficients[a]

-2 Log Likelihood	Overall (score)			Change From Previous Step			Change From Previous Block		
	Chi-square	Df	Sig.	Chi-square	df	Sig.	Chi-square	df	Sig.
235.556	110.718	5	.000	120.653	5	.000	120.653	5	.000

Variables in the Equation

	B	SE	Wald	df	Sig.	Exp(B)	95.0% CI for Exp(B)	
							Lower	Upper
dtaxi	.138	.344	.161	1	.688	1.148	.585	2.254
dpcar	-2.876	1.021	7.939	1	.005	.056	.008	.417
drshare	-1.142	2.077	.302	1	.582	.319	.005	18.709
TTTIME	-.049	.023	4.559	1	.033	.952	.910	.996
TTCOST	-.041	.019	4.802	1	.028	.960	.926	.996

Model 2: Developed by adding Age-Taxi variable to model 1

Omnibus Tests of Model Coefficients[a]

-2 Log Likelihood	Overall (score)			Change From Previous Step			Change From Previous Block		
	Chi-square	df	Sig.	Chi-square	df	Sig.	Chi-square	df	Sig.
223.659	121.168	8	.000	132.550	8	.000	132.550	8	.000

Variables in the Equation[b]

	B	SE	Wald	df	Sig.	Exp(B)
dtaxi	-.473	.577	.674	1	.412	.623
dpcar	-2.858	1.048	7.433	1	.006	.057
drshare	-.848	2.096	.164	1	.686	.428
TTTIME	-.054	.024	4.841	1	.028	.948
TTCOST	-.039	.019	4.505	1	.034	.961
Age_taxi			11.100	3[a]	.011	
Age_taxi(2)	-.937	1.119	.701	1	.402	.392
Age_taxi(3)	-.252	.577	.190	1	.663	.777
Age_taxi(4)	-1.584	.621	6.503	1	.011	.205

Model 3: Developed by add Age-Rshare interaction to model 2

Omnibus Tests of Model Coefficients[a]

-2 Log Likelihood	Overall (score)			Change From Previous Step			Change From Previous Block		
	Chi-square	df	Sig.	Chi-square	df	Sig.	Chi-square	df	Sig.
214.782	127.604	11	.000	141.427	11	.000	141.427	11	.000

Variables in the Equation[b]

	B	SE	Wald	Df	Sig.	Exp(B)	95.0% CI for Exp(B)	
							Lower	Upper
dtaxi	.747	.632	1.396	1	.237	2.110	.611	7.287
dpcar	3.251	1.113	8.526	1	.004	25.821	2.912	228.959
drshare	3.654	2.690	1.846	1	.174	38.632	.198	7524.694
TTTIME	-.055	.026	4.553	1	.033	.947	.901	.996
TTCOST	-.052	.021	5.976	1	.014	.949	.910	.990
Age_taxi			14.630	3[a]	.002			
Age_taxi(2)	-.843	1.257	.449	1	.503	.431	.037	5.062
Age_taxi(3)	-.423	.637	.440	1	.507	.655	.188	2.285
Age_taxi(4)	-1.985	.676	8.629	1	.003	.137	.037	.517
Age_rshare			6.267	3[a]	.099			
Age_rshare(2)	-.031	1.567	.000	1	.984	.969	.045	20.904
Age_rshare(3)	-1.154	1.028	1.260	1	.262	.315	.042	2.366
Age_rshare(4)	-3.320	1.411	5.535	1	.019	.036	.002	.575

Model 4: Developed by add Family income -Rshare interaction to model 3.

Omnibus Tests of Model Coefficients[a]

-2 Log Likelihood	Overall (score)			Change From Previous Step			Change From Previous Block		
	Chi-square	df	Sig.	Chi-square	df	Sig.	Chi-square	df	Sig.
199.954	131.835	15	.000	156.254	15	.000	156.254	15	.000

Variables in the Equation

	B	SE	Wald	df	Sig.	Exp(B)	95.0% CI for Exp(B)	
							Lower	Upper
TTCost	-.069	.026	7.052	1	.008	.933	.887	.982
TTTime	-.053	.026	4.166	1	.041	.949	.902	.998
CTaxi	-.795	.633	1.575	1	.210	.452	.131	1.563
CPcar	-3.783	1.202	9.902	1	.002	.023	.002	.240
CRshare	-7.315	3.403	4.622	1	.032	.001	.000	.524
Age_taxi			14.484	3[a]	.002			
Age_taxi(2)	-1.034	1.210	.730	1	.393	.355	.033	3.811
Age_taxi(3)	-.421	.637	.438	1	.508	.656	.188	2.285
Age_taxi(4)	-1.965	.673	8.511	1	.004	.140	.037	.525
Age_rshare			3.073	3[a]	.380			
Age_rshare(2)	-.208	1.664	.016	1	.901	.813	.031	21.198
Age_rshare(3)	-1.326	1.113	1.420	1	.233	.266	.030	2.352
Age_rshare(4)	-2.447	1.529	2.561	1	.110	.087	.004	1.733
Fincome_rsh			7.827	4[a]	.098			
Fincome_rsh(2)	-1.799	1.110	2.627	1	.105	.165	.019	1.457
Fincome_rsh(3)	-3.580	1.342	7.112	1	.008	.028	.002	.387
Fincome_rsh(4)	-13.351	239.744	.003	1	.956	.000	.000	1.870E+198
Fincome_rsh(5)	-1.220	1.038	1.382	1	.240	.295	.039	2.257

Model 5: Replace total travel time with out of vehicle and in vehicle travel time, in the model model 5 was developed.

Omnibus Tests of Model Coefficients[a]

-2 Log Likelihood	Overall (score)			Change From Previous Step			Change From Previous Block		
	Chi-square	Df	Sig.	Chi-square	df	Sig.	Chi-square	df	Sig.
199.954	131.835	15	.000	156.254	15	.000	156.254	15	.000

Variables in the Equation

	B	SE	Wald	df	Sig.	Exp(B)	95.0% CI for Exp(B)	
							Lower	Upper
OVTTIME	-.371	.144	6.599	1	.010	.690	.520	.916
IVTTIME	-.053	.026	4.166	1	.041	.949	.902	.998
TTCost	-.069	.026	7.052	1	.008	.933	.887	.982
CTaxi	2.068	1.332	2.411	1	.120	7.908	.581	107.530
CPcar	5.759	3.702	2.419	1	.120	316.900	.224	449148.414
CRshare			.	0[a]	.			
Age_taxi			14.484	3[a]	.002			
Age_taxi(2)	-1.034	1.210	.730	1	.393	.355	.033	3.811
Age_taxi(3)	-.421	.637	.438	1	.508	.656	.188	2.285
Age_taxi(4)	-1.965	.673	8.511	1	.004	.140	.037	.525
Age_rshare			3.073	3[a]	.380			
Age_rshare(2)	-.208	1.664	.016	1	.901	.813	.031	21.198
Age_rshare(3)	-1.326	1.113	1.420	1	.233	.266	.030	2.352
Age_rshare(4)	-2.447	1.529	2.561	1	.110	.087	.004	1.733
Fincome_rsh			7.827	4[a]	.098			
Fincome_rsh(2)	-1.799	1.110	2.627	1	.105	.165	.019	1.457
Fincome_rsh(3)	-3.580	1.342	7.112	1	.008	.028	.002	.387
Fincome_rsh(4)	-13.351	239.744	.003	1	.956	.000	.000	1.646
Fincome_rsh(5)	-1.220	1.038	1.382	1	.240	.295	.039	2.257

Model 6: Replace out of vehicle travel time with waiting time and access time in the model **5.**

Omnibus Tests of Model Coefficients[a]

-2 Log Likelihood	Overall (score)			Change From Previous Step			Change From Previous Block		
	Chi-square	Df	Sig.	Chi-square	df	Sig.	Chi-square	df	Sig.
191.484	133.839	16	.000	164.725	16	.000	164.725	16	.000

Variables in the Equation

	B	SE	Wald	df	Sig.	Exp(B)	95.0% CI for Exp(B)	
							Lower	Upper
ATIME	-.017	.211	.006	1	.937	.984	.650	1.488
IVTTIME	-.053	.026	4.076	1	.043	.949	.902	.998
WTIME	-.427	.149	8.265	1	.004	.652	.488	.873
TTCost	-.065	.026	6.030	1	.014	.937	.890	.987
CTaxi	2.551	1.369	3.472	1	.062	12.814	.876	187.390
CPcar	5.913	3.733	2.508	1	.113	369.640	.245	556579.262
CRshare			.	0[a]	.			
Age_taxi			14.035	3[a]	.003			
Age_taxi(2)	-1.088	1.220	.795	1	.373	.337	.031	3.683
Age_taxi(3)	-.415	.653	.404	1	.525	.660	.184	2.374
Age_taxi(4)	-1.953	.686	8.093	1	.004	.142	.037	.545
Age_rshare			2.622	3[a]	.454			
Age_rshare(2)	.411	1.821	.051	1	.821	1.508	.043	53.476
Age_rshare(3)	-1.000	1.235	.655	1	.418	.368	.033	4.138
Age_rshare(4)	-2.030	1.570	1.671	1	.196	.131	.006	2.850
Fincome_rsh			9.448	4[a]	.051			
Fincome_rsh(2)	-2.296	1.158	3.932	1	.047	.101	.010	.974
Fincome_rsh(3)	-4.318	1.465	8.689	1	.003	.013	.001	.235
Fincome_rsh(4)	-15.105	368.936	.002	1	.967	.000	.000	3.01
Fincome_rsh(5)	-1.403	1.144	1.506	1	.220	.246	.026	2.312

II. Home based work trips stated preference models.

Case Processing Summary

		N	Percent
Cases available in analysis	Event[a]	154	23.8%
	Censored	472	73.0%
	Total	626	96.8%
Cases dropped	Cases with missing values	0	0.0%
	Cases with negative time	0	0.0%
	Censored cases before the earliest event in a stratum	21	3.2%
	Total	21	3.2%
Total		647	100.0%

Base model

Omnibus Tests of Model Coefficients

-2 Log Likelihood
446.303

Omnibus Tests of Model Coefficients[a]

-2 Log Likelihood	Overall (score)			Change From Previous Step			Change From Previous Block		
	Chi-square	df	Sig.	Chi-square	df	Sig.	Chi-square	df	Sig.
118.129	345.036	4	.000	328.174	4	.000	328.174	4	.000

Variables in the Equation

	B	SE	Wald	df	Sig.	Exp(B)	95.0% CI for Exp(B)	
							Lower	Upper
CBUS	4.097	.714	32.934	1	.000	60.144	14.844	243.688
Ctaxi	3.691	.586	39.732	1	.000	40.096	12.724	126.349
Cpcar	-.538	.514	1.098	1	.295	.584	.213	1.597
Crshare	4.825	1.004	23.093	1	.000	124.548	17.408	891.104

Model 1: Adding travel time and cost relating variables to base model

Omnibus Tests of Model Coefficients[a]

-2 Log Likelihood	Overall (score)			Change From Previous Step			Change From Previous Block		
	Chi-square	df	Sig.	Chi-square	df	Sig.	Chi-square	df	Sig.
97.277	348.716	6	.000	349.026	6	.000	349.026	6	.000

Variables in the Equation

	B	SE	Wald	df	Sig.	Exp(B)	95.0% CI for Exp(B)	
							Lower	Upper
TTTime	-.075	.030	6.217	1	.013	.927	.874	.984
TTCost	-.172	.053	10.393	1	.001	.842	.759	.935
CBUS	4.028	.779	26.731	1	.000	56.163	12.197	258.611
Ctaxi	3.318	.650	26.066	1	.000	27.603	7.723	98.657
Cpcar	-5.015	1.412	12.613	1	.000	.007	.000	.106
Crshare	-10.484	4.270	6.027	1	.014	.000	.000	.121

Model 2: Replacing total travel time with out of vehicle and in vehicle travel time

Omnibus Tests of Model Coefficients[a]

-2 Log Likelihood	Overall (score)			Change From Previous Step			Change From Previous Block		
	Chi-square	df	Sig.	Chi-square	df	Sig.	Chi-square	df	Sig.
95.429	345.143	7	.000	348.101	7	.000	348.101	7	.000

Variables in the Equation

	B	SE	Wald	df	Sig.	Exp(B)	95.0% CI for Exp(B)	
							Lower	Upper
OVTTIME	-.078	.038	4.116	1	.042	.925	.858	.997
IVTTIME	-.144	.063	5.260	1	.022	.866	.766	.979
TTCost	-.191	.055	11.980	1	.001	.826	.741	.920
CBUS	2.661	.773	11.846	1	.001	14.315	3.145	65.153
Ctaxi	2.461	.749	10.808	1	.001	11.720	2.702	50.840
Cpcar	-6.558	1.735	14.292	1	.000	.001	.000	.043
Crshare	-12.445	4.440	7.856	1	.005	.000	.000	.024

Model 3: Replacing out of vehicle travel time with waiting time and access time.

Omnibus Tests of Model Coefficients[a]

-2 Log Likelihood	Overall (score)			Change From Previous Step			Change From Previous Block		
	Chi-square	df	Sig.	Chi-square	df	Sig.	Chi-square	df	Sig.
94.931	345.289	8	.000	348.599	8	.000	348.599	8	.000

Variables in the Equation

	B	SE	Wald	df	Sig.	Exp(B)	95.0% CI for Exp(B)	
							Lower	Upper
ATIME	.023	.109	.044	1	.835	1.023	.826	1.266
WTIME	-.088	.042	4.361	1	.037	.916	.843	.995
IVTTIME	-.146	.063	5.309	1	.021	.864	.763	.978
TTCost	-.187	.055	11.593	1	.001	.829	.745	.924
CBUS	2.670	.778	11.765	1	.001	14.442	3.141	66.417
Ctaxi	2.337	.754	9.610	1	.002	10.353	2.362	45.378
Cpcar	-6.638	1.747	14.429	1	.000	.001	.000	.040
Crshare	-12.124	4.409	7.562	1	.006	.000	.000	.031

III. Revealed preference model of Home based others trip

Case Processing Summary

		N	Percent
Cases available in analysis	Event[a]	116	32.3%
	Censored	243	67.7%
	Total	359	100.0%
Cases dropped	Cases with missing values	0	0.0%
	Cases with negative time	0	0.0%
	Censored cases before the earliest event in a stratum	0	0.0%
	Total	0	0.0%
Total		359	100.0%

Base model:

Omnibus Tests of Model Coefficients

-2 Log Likelihood
260.736

Omnibus Tests of Model Coefficients[a]

-2 Log Likelihood	Overall (score)			Change From Previous Step			Change From Previous Block		
	Chi-square	df	Sig.	Chi-square	df	Sig.	Chi-square	df	Sig.
181.460	75.054	3	.000	79.276	3	.000	79.276	3	.000

Variables in the Equation

	B	SE	Wald	df	Sig.	Exp(B)	95.0% CI for Exp(B)	
							Lower	Upper
ctaxi	-.773	.221	12.271	1	.000	.462	.299	.711
cpcar	-3.148	.771	16.668	1	.000	.043	.009	.195
crshare	1.446	.420	11.843	1	.001	4.247	1.864	9.678

Model 1: Add travel time and cost to base model.

Omnibus Tests of Model Coefficients[a]

-2 Log Likelihood	Overall (score)			Change From Previous Step			Change From Previous Block		
	Chi-square	df	Sig.	Chi-square	df	Sig.	Chi-square	df	Sig.
167.448	85.153	5	.000	93.288	5	.000	93.288	5	.000

Variables in the Equation

	B	SE	Wald	df	Sig.	Exp(B)	95.0% CI for Exp(B)	
							Lower	Upper
TTTIME	-.203	.078	6.696	1	.010	.817	.700	.952
TTCOST	-.095	.046	4.299	1	.038	.909	.831	.995
ctaxi	2.273	1.245	3.331	1	.068	9.704	.845	111.400
cpcar	1.601	2.933	.298	1	.585	4.956	.016	1553.989
crshare	1.745	3.926	.198	1	.657	5.724	.003	12565.867

Model 2: Add family income-ride share to model 1

Omnibus Tests of Model Coefficients[a]

-2 Log Likelihood	Overall (score)			Change From Previous Step			Change From Previous Block		
	Chi-square	df	Sig.	Chi-square	df	Sig.	Chi-square	df	Sig.
153.151	91.345	9	.000	107.585	9	.000	107.585	9	.000

Variables in the Equation[b]

	B	SE	Wald	df	Sig.	Exp(B)	95.0% CI for Exp(B)	
							Lower	Upper
TTTIME	-.198	.079	6.352	1	.012	.820	.703	.957
TTCOST	-.118	.051	5.376	1	.020	.889	.805	.982
ctaxi	2.136	1.250	2.921	1	.087	8.467	.731	8.078
cpcar	.717	3.028	.056	1	.813	2.049	.005	4.206
crshare	-1.943	4.287	.205	1	.650	.143	.000	3.790
Fminc_rshare			9.253	4[a]	.055			
Fminc_rshare(2)	-14.331	545.305	.001	1	.979	.000	.000	.
Fminc_rshare(3)	-3.739	1.414	6.990	1	.008	.024	.001	.380
Fminc_rshare(4)	-2.306	1.281	3.239	1	.072	.100	.008	1.228
Fminc_rshare(5)	-.126	1.164	.012	1	.914	.882	.090	8.629

Model 3: Replacing total travel time with out of vehicle and in vehicle travel time

Omnibus Tests of Model Coefficients[a]

-2 Log Likelihood	Overall (score)			Change From Previous Step			Change From Previous Block		
	Chi-square	df	Sig.	Chi-square	df	Sig.	Chi-square	df	Sig.
150.315	92.105	10	.000	110.421	10	.000	110.421	10	.000

Variables in the Equation[b]

	B	SE	Wald	df	Sig.	Exp(B)	95.0% CI for Exp(B)	
							Lower	Upper
OVTTIME	-.400	.175	5.247	1	.022	.670	.476	.944
IVTTIME	-.159	.083	3.664	1	.056	.853	.725	1.004

TTCOST	-.117	.052	5.102	1	.024	.890	.804	.985
ctaxi	3.828	1.937	3.907	1	.048	45.974	1.033	2046.592
cpcar	5.309	4.686	1.284	1	.257	202.162	.021	196.843
crshare	2.710	5.399	.252	1	.616	15.033	.000	591.040
Fminc_rshare			9.079	4[a]	.059			
Fminc_rshare(2)	-14.119	539.722	.001	1	.979	.000	.000	.
Fminc_rshare(3)	-3.541	1.362	6.755	1	.009	.029	.002	.419
Fminc_rshare(4)	-2.338	1.286	3.309	1	.069	.096	.008	1.199
Fminc_rshare(5)	-.139	1.170	.014	1	.905	.870	.088	8.625

Model 4: Replacing out of vehicle travel time with waiting and access time.

Omnibus Tests of Model Coefficients[a]

-2 Log Likelihood	Overall (score)			Change From Previous Step			Change From Previous Block		
	Chi-square	df	Sig.	Chi-square	df	Sig.	Chi-square	df	Sig.
158.065	86.029	11	.000	102.671	11	.000	102.671	11	.000

Variables in the Equation

	B	SE	Wald	df	Sig.	Exp(B)	95.0% CI for Exp(B)	
							Lower	Upper
ATIME	-.614	2.995	.042	1	.837	.541	.002	1.720
WTIME	-1.781	2.823	.398	1	.528	.168	.001	2.569
IVTTIME	-.092	.067	1.879	1	.170	.912	.800	1.040
TTCOST	-.127	.055	5.399	1	.020	.881	.791	.980
ctaxi	17.377	28.230	.379	1	.538	352.572	.000	4.000
cpcar	33.245	58.469	.323	1	.570	2749.600	.000	1.5658
crshare	30.078	58.513	.264	1	.607	13.215	.000	7.864
Fminc_rshare			9.717	4[a]	.045			
Fminc_rshare(2)	-5.428	5.630	.929	1	.335	.004	.000	2.385

Fminc_rshare(3)	-3.704	1.418	6.824	1	.009	.025	.002	.397
Fminc_rshare(4)	-2.487	1.314	3.584	1	.058	.083	.006	1.092
Fminc_rshare(5)	-.239	1.205	.039	1	.843	.787	.074	8.352

IV. Home based education trips.

Case Processing Summary

		N	Percent
Cases available in analysis	Event[a]	165	29.3%
	Censored	398	70.7%
	Total	563	100.0%
Cases dropped	Cases with missing values	0	0.0%
	Cases with negative time	0	0.0%
	Censored cases before the earliest event in a stratum	0	0.0%
	Total	0	0.0%
Total		563	100.0%

Base model: This model was developed for the constant parameter of available modes.

Omnibus Tests of Model Coefficients

-2 Log Likelihood
395.787

Omnibus Tests of Model Coefficients[a]

-2 Log Likelihood	Overall (score)			Change From Previous Step			Change From Previous Block		
	Chi-square	df	Sig.	Chi-square	df	Sig.	Chi-square	df	Sig.
383.150	13.411	4	.009	12.638	4	.013	12.638	4	.013

Variables in the Equation

	B	SE	Wald	df	Sig.	Exp(B)	95.0% CI for Exp(B)	
							Lower	Upper
Cpcar	-1.156	.340	11.569	1	.001	.315	.162	.613
Ccontract	-.473	.260	3.294	1	.070	.623	.374	1.038
Cwalk	-.075	.269	.078	1	.780	.927	.547	1.572
Ctaxi	-.337	.218	2.395	1	.122	.714	.466	1.094

Model 1: This model was developed by adding school travel time and travel cost over base model.

Omnibus Tests of Model Coefficients[a]

-2 Log Likelihood	Overall (score)			Change From Previous Step			Change From Previous Block		
	Chi-square	df	Sig.	Chi-square	df	Sig.	Chi-square	df	Sig.
363.070	30.577	6	.000	32.717	6	.000	32.717	6	.000

Variables in the Equation

	B	SE	Wald	df	Sig.	Exp(B)	95.0% CI for Exp(B)	
							Lower	Upper
TTTIME	-.035	.015	5.254	1	.022	.965	.937	.995
TTCOST	-.118	.046	6.626	1	.010	.889	.813	.972
Cpcar	-2.984	1.219	5.992	1	.014	.051	.005	.552
Ccontract	-6.532	2.736	5.700	1	.017	.001	.000	.310
Cwalk	1.289	.511	6.351	1	.012	3.628	1.332	9.885
Ctaxi	-.755	.267	7.975	1	.005	.470	.278	.794

Model 2: This model was developed by adding school type-contract interaction over model 1.

Omnibus Tests of Model Coefficients[a]

-2 Log Likelihood	Overall (score)			Change From Previous Step			Change From Previous Block		
	Chi-square	df	Sig.	Chi-square	df	Sig.	Chi-square	df	Sig.
358.961	34.273	7	.000	36.827	7	.000	36.827	7	.000

Variables in the Equation[b]

	B	SE	Wald	df	Sig.	Exp(B)	95.0% CI for Exp(B)	
							Lower	Upper
TTTIME	-.035	.015	5.037	1	.025	.966	.937	.996
TTCOST	-.120	.046	6.679	1	.010	.887	.810	.971
Cpcar	-3.020	1.233	5.995	1	.014	.049	.004	.547
Ccontract	-6.676	2.777	5.780	1	.016	.001	.000	.291
Cwalk	1.269	.515	6.064	1	.014	3.558	1.296	9.771
Ctaxi	-1.020	.299	11.632	1	.001	.361	.201	.648
Age_ctaxi			3.904	1[a]	.048			
Age_ctaxi(2)	-.804	.407	3.904	1	.048	.448	.202	.994

Model 3: This model was developed by adding school type-taxi interaction over model 2.

Omnibus Tests of Model Coefficients[a]

-2 Log Likelihood	Overall (score)			Change From Previous Step			Change From Previous Block		
	Chi-square	df	Sig.	Chi-square	df	Sig.	Chi-square	df	Sig.
354.153	38.372	8	.000	41.634	8	.000	41.634	8	.000

Variables in the Equation[b]

	B	SE	Wald	df	Sig.	Exp(B)	95.0% CI for Exp(B)	
							Lower	Upper
TTTIME	-.035	.016	5.003	1	.025	.965	.936	.996
TTCOST	-.119	.047	6.373	1	.012	.888	.809	.974
Cpcar	-2.877	1.254	5.266	1	.022	.056	.005	.657
Ccontract	-6.551	2.823	5.385	1	.020	.001	.000	.361
Cwalk	1.258	.520	5.860	1	.015	3.517	1.270	9.737
Ctaxi	-.393	.428	.842	1	.359	.675	.292	1.563
Age_ctaxi			3.872	1[a]	.049			
Age_ctaxi(2)	-.823	.418	3.872	1	.049	.439	.193	.997
Stype_ctaxi			4.505	1[a]	.034			
Stype_ctaxi(2)	.902	.425	4.505	1	.034	2.465	1.072	5.671

Model 4: This model was developed by adding school type-contract interaction over model 3.

Omnibus Tests of Model Coefficients[a]

-2 Log Likelihood	Overall (score)			Change From Previous Step			Change From Previous Block		
	Chi-square	df	Sig.	Chi-square	df	Sig.	Chi-square	df	Sig.
324.322	64.251	9	.000	71.466	9	.000	71.466	9	.000

Variables in the Equation[b]

	B	SE	Wald	df	Sig.	Exp(B)	95.0% CI for Exp(B)	
							Lower	Upper
TTTIME	-.036	.016	5.142	1	.023	.964	.934	.995
TTCOST	-.115	.051	5.140	1	.023	.891	.807	.984
Cpcar	-3.233	1.344	5.785	1	.016	.039	.003	.550
Ccontract	-7.607	3.047	6.234	1	.013	.000	.000	.195
Cwalk	1.304	.528	6.099	1	.014	3.686	1.309	10.378
Ctaxi	-.990	.473	4.387	1	.036	.372	.147	.938
Age_ctaxi			4.470	1[a]	.034			
Age_ctaxi(2)	-.887	.420	4.470	1	.034	.412	.181	.937
Stype_ctaxi			.045	1[a]	.832			
Stype_ctaxi(2)	.100	.470	.045	1	.832	1.105	.440	2.776
Stype_ccontract			22.168	1[a]	.000			
Stype_ccontract(2)	-3.059	.650	22.168	1	.000	.047	.013	.168

Model 5: This model was developed by replacing total travel time with out of vehicle and in vehicle travel time.

Omnibus Tests of Model Coefficients[a]

-2 Log Likelihood	Overall (score)			Change From Previous Step			Change From Previous Block		
	Chi-square	df	Sig.	Chi-square	df	Sig.	Chi-square	df	Sig.
318.309	69.175	10	.000	77.479	10	.000	77.479	10	.000

Variables in the Equation[b]

	B	SE	Wald	df	Sig.	Exp(B)
TTCOST	-.135	.055	6.056	1	.014	.873
IVTTIME	-.365	.147	6.162	1	.013	.694
OVTTIME	-.032	.016	3.901	1	.048	.969
Cpcar	-2.218	1.469	2.280	1	.131	.109
Ccontract	-7.252	3.220	5.073	1	.024	.001
Cwalk	7.830	2.972	6.942	1	.008	24.010
Ctaxi	.547	.816	.450	1	.503	1.728
Age_ctaxi			4.934	1[a]	.026	
Age_ctaxi(2)	-.938	.422	4.934	1	.026	.391
Stype_ctaxi			.064	1[a]	.800	
Stype_ctaxi(2)	.120	.475	.064	1	.800	1.128
Stype_ccontract			22.186	1[a]	.000	
Stype_ccontract(2)	-3.079	.654	22.186	1	.000	.046

Model 6: This model was developed by replacing out of vehicle with access and waiting time.

Omnibus Tests of Model Coefficients[a]

-2 Log Likelihood	Overall (score)			Change From Previous Step			Change From Previous Block		
	Chi-square	Df	Sig.	Chi-square	df	Sig.	Chi-square	df	Sig.
317.842	69.513	11	.000	77.945	11	.000	77.945	11	.000

Variables in the Equation[b]

	B	SE	Wald	df	Sig.	Exp(B)
WTIME	-.035	.017	4.161	1	.041	.966
ATIME	-.019	.065	.085	1	.771	.981
TTCOST	-.134	.055	5.984	1	.014	.874
IVTTIME	-.360	.147	6.013	1	.014	.698
Cpcar	-2.251	1.485	2.300	1	.129	.105
Ccontract	-7.230	3.208	5.081	1	.024	.001
Cwalk	7.822	2.962	6.976	1	.008	26.044
Ctaxi	.586	.850	.475	1	.491	1.796
Age_ctaxi			4.895	1[a]	.027	
Age_ctaxi(2)	-.935	.423	4.895	1	.027	.392
Stype_ctaxi			.058	1[a]	.810	
Stype_ctaxi(2)	.114	.476	.058	1	.810	1.121
Stype_ccontract			22.232	1[a]	.000	
Stype_ccontract(2)	-3.085	.654	22.232	1	.000	.046