ADDIS ABABA UNIVERSITY

SCHOOL OF GRADUATE STUDIES

Public Transport Mode Choice and its Determinants: The case of Megenagna-Ayat Corridor in Addis Ababa, Ethiopia

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May 2018

Addis Ababa, Ethiopia

Abstract

Transportation in today's world is the backbone of development for many countries. This is true, especially in urban cities. In fact, life is becoming impossible without transportation services. Provided all the positive outcomes transportation has to nations, it also impacts the environment and quality of life negatively if it is not planned and managed well. There are many means of transport available today containing a variety of trip purposes. Public transport is one of the most important parts of the transport system. Considering the positive effect on the environment and congestion public transport is considered the best means from land transport. In developing countries like Ethiopia, people's movements are highly dependent on public transport.

This study tries to analyze mode share among four major modes of public transport (i.e. Minibus, Higer bus, Anbessa bus and LRT) giving service in Addis Ababa, Ethiopia a study area from Megenagna to Ayat. It also identifies the most abandoned mode of transport. Accordingly, Minibus was the highest preferred mode while Anbessa bus was found to be the mode most individuals don't want to use.

Using a survey sample of 391, MNL model is used to analyze travelers' mode choice behavior. A statistical package, Stata 14, was used to develop the model. Based on the result; sex (with significance of 10% for Anbessa bus and 5% for LRT), monthly individual income (with significance of 1% for Higre bus and 5% for both Anbessa bus and LRT), daily trip frequency (with a significance of 1% for Higer bus and LRT), travel time, access time, waiting time and cost by distance (with significance level of 1% of the later four variables) were found to affect mode choice of public transport. Policy implications like subsidize Anbessa buses, improve its comfort and security and increase spatial expansion are drawn in order to increase use of large size public transports.

Keywords: Transportation, public transport, Mode choice, MNL

Acknowledgment

To God, who showed me His faithfulness and helped me throughout the work, goes my deepest gratitude. Secondly, I would like to thank my advisor Dr. Bikila Teklu for all the support, encouragement and providing opportunities for the work to come to end. Prof. Girma Gebresenbet, I can’t express enough of the respect and appreciation I have for the positive feedback and advice you have provided me with. Dr. David Ljungberg, I thank you for the kind help and constructive suggestion on work. This work would not have gone this far without the help of Raeed Ali who has been giving me guidance and putting a lot of effort from the beginning, thank you very much.

I would like to thank Addis Ababa University for sponsoring the M.Sc. program and Department of Energy and Technology for the facilities you have provided me in SLU. The Linnaeus-Palme program founders, thank you for providing the exchange program.

Many have been cooperating in providing data and collecting interviews. Abraham Yirga who helped me collecting questionnaire, Zelalem Birhanu for continuous encouragement, prayer and help I thank you with all my heart. Engineer Mohammed Hussien from AATPMO, Abyot Abera from ACBSE, Muluken Aseffa from ERC thank you for providing information valuable to the work with amazing hospitality.

My special thanks go to Wondmagegn Tafesse for helping me with research tools and technical writing and also for making my stay in Sweden very conducive. Ashenafi Daba, Taddese Ameante, and Techane Bosona I acknowledge your support.

Thank you to all family members and friends your prayers and advice have played an immeasurable role in this paperwork.

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List of Acronyms

AARTMA: Addis Ababa Road Traffic Management Agency

ACBSE: Anbessa City Bus Services Enterprise

ASClogit: Alternative Specific Conditional logit

ERC: Ethiopian Railway Corporation

Exp: Exponential

IIA: Independency of Irrelevant Alternative

LR: Likelihood Ratio

LRT: Light Rail Transit

MNL: Multinomial Logit model

1 Introduction

1.1 Background

People in urban areas use different modes of transportation to satisfy their travel demand. The types of land transportation modes that are currently used in Addis Ababa include Walking, Small Taxis, Mini-Buses, Anbessa City Bus, Lonchina, higer, Private vehicle as driver, Private vehicle as passenger, Company provided transport and the recently introduced LRT. From transportation modes mentioned above, the majority of the people in Addis Ababa city are public transport users.

Transportation plays a great role in the economic growth of a country by enabling raw material accessibility, increase the productivity of labor and raw material and by connecting people and things. As useful as it is in our day to day activity, transportation can be a big challenge if not planned and managed properly as reported by England World Business Council for Sustainable Development (2004). The challenges related to transportation include increased pollution, emission of greenhouse gases, congestion, the risk of death and serious injury. On the other hand, by travel demand that far exceeds supply, especially in developing countries is also known challenge urban cities are facing. Addis Ababa is no exception in struggling with these challenges. According to Ortuzar & Willumsen (2004) encouraging the use of public transport will advantage the traffic flow more since it transports more people with little space as compared to the private car.

Policy makers have a huge impact in minimizing those challenges and bringing a useful transportation system. Modeling is one of the tools that help this policymaker in making excellent decisions in transport planning. Modeling permits more intelligent management of the transport system. It also helps to improve decision making and planning in the transport field (Ortuzar & Willumsen, 2004)

One of the most widely used models in transportation is mode choice modeling. This is a model used to study people's behavior in selecting a mode of transportation among different alternatives. As one of the often-stated objectives of transport planning is to 'produce a plan which results in the best balance between all the available travel modes so that the movement demands of all sections of society can be met' (O'flaherty et al. 1997). The issue of mode choice is therefore probably the single most important element in transport planning and policy making as Ortuzar & Willumsen (2004) agree.

A developed mode choice model can be used as an input in the effort to predict future patronage levels for different scenarios; to understand passengers' preference to the different attributes of a public transport mode which could indicate how a new or improved mode would perform and to analyze policy variables relevant to the development of the transport system (Teshome, M. 2007). And so, using this model the impact of improvement of modes can be studied ahead of time.

1.2 Statement of the Problem

The demand for transportation is growing increasingly in urban cities like Addis Ababa. As the demand for transportation increases the issue of congestion, air pollution, noise and accidents will be inevitable. Delays, uncertainty, and stress levels are also beginning to take their toll on both individuals and society (Tilahun, 2014). These challenges increase as the mode choice of private car increases for means of transportation.

This is due to the fact that private cars use more space, more energy and are less safe than public transports as stated by O'Flaherty et al. (1997). According to Ortuzar & Willumsen (2004) encouraging the use of public transport will advantage the traffic flow more since it transports more people with little space as compared to the private car. Therefore, it is advisable to foster public transport usage than private cars.

In the same way, some means of public transport take more space than others in Addis Ababa city. From the modes addressed in this study, Minibus is small-sized while LRT is the biggest. Regardless of the contributions of Minibus taxi to congestion and environment, people still prefer to use them as a primary mode of transport. In fact, Minibus takes the highest share of public transport. Daily report from AATMA shows that on average there are 88.3% Minibuses, 2.4% Higer buses and 3.8% Anbessa buses and 8.7% other public transports fleet size in Addis Ababa city. Report from ERC shows that on average 120 trains give service in the east-west corridor of LRT on daily basis. These numbers indicate how much the city public transport system is relying on Minibuses.

With an introduction of the proper policy, the above-mentioned problems can be well addressed. Policies that enhance the use of relatively large sized public transport should be considered by decision makers. In order to do so, modeling can be used as a strong tool. Ortuzar & Willumsen (2004) agreed that Sound decisions are made by policymakers using modeling results.

One of the powerful models in transport engineering is the mode choice model. Using this model determinant factors that motivate people to choose modes of transport with its level of impact on the choice can be found. And this information is very crucial in determining the main parameters to consider in providing new public transport or improving current ones. Similarly, policy can be formulated considering the results from this model that can motivate people use large public transports.

1.3 Objectives

The major objective of the study was to examine the determinants of public transport mode choices and its policy implications in Megenagna-Ayat corridor of Addis Ababa, Ethiopia.

Specific objectives were to:

- Determine the current modal split (mode sharing) among the available modes of public transport in the study area.
- Study the reasons why individuals don't want to use or avoid certain mode of public transport.
- Identifying key socio-economic and mode attribute factors explaining public transport mode choice using a multinomial logit model.
- To make policy recommendations based on estimates of selected parameters that would improve the ridership and quality of public transport.

1.4 Research questions

1. What is the widely used and not used mode of public transport in the study area?
2. What major criteria do passengers consider in making choice among public transport modes?
3. How can the public transport be improved to attract more passengers?

1.5 Organization of the paper

This paper is comprised of six major topics. In the first part introduction to the work is presented with addressing general background, objectives, statement of problem and research questions. In part two the literature reviewed are summarized and presented in scientific manner. Part three discusses the methodology employed in conducting the paper. The tools used to materialize the study and basic procedures are all discussed within this chapter. The result will be presented and discussed in part four. The conclusions that are drawn out are explained in part five and finally, some recommendations are listed in the last section which is part six.

2 Literature review

2.1 General overview

Transportation is one of the basic societal demand that is incurred in this day and age. This is true especially in urban areas considering the tremendous increase in a number of vehicles using roads. The report from England World Business Counsel for Sustainable Development (2004) states that transportation plays a great role in economic growth of a country by enabling raw material accessibility, increase the productivity of labor and raw material and by connecting people and things. The report also argues that all the benefits people get out of transportation also comes with some prices that include increased pollution, emission of greenhouse gases, congestion, the risk of death and serious injury, noise and disruption of communities and ecosystems.

In order to satisfy their demand for mobility, people in urban areas use different types of modes of transportation. ‘In urban areas, there are mainly five passenger transport modes available: walking, cycle, motorcycle, private car and some form of public transport.’ (O’flaherty et al. 1997). In general, they can be categorized in to private transportation (consists of privately owned vehicles operated by owner for their personal use. Walking, bicycle, private cars), paratransit or for-hire transportation (is provided by operators and available to parties which hire them for individual or multiple trips. Taxi, dial–a–bus, jitney) and public transportation (mass transit/ urban transit) (Vuchic, 1999).

2.2 Public Transport

Public transportation is a transportation service that is available to the general public and that carries passengers to destinations for a fee (Meshesha, 2014). The mode is an essential component, especially for low-income groups. Public transportation or mass transit includes a system that is available for use to all people that are willing to pay the established fare. These modes operate on fixed routes and schedules. There are various modes of transportation that can be categorized under public transport. These modes of public transport include bus, light rail transit, metro, regional rail and other systems. Each mode of public transports have its own characteristics.

Vuchic (1999) stated that public transport or Transit modes are defined by their right of way (ROW), technology and types of operation. Among the categories, ROW is the most important element because it determines the performance/cost relation for the mode. Three ROW categories are (Vuchic, 1999):

C – urban street with mixed traffic: street transit modes mostly include buses, but also trolley buses and tramways/street cars.

B – partially separated tracks/lanes, usually in street medians: Requires more investment and has a higher performance than street transit. It includes light rail transit and semi-rapid bus.

A – paths used exclusively by transit vehicle: fully separated and physically protected. comprise rapid transit mode or metro system. Provide the highest performance mode of urban transportation.

ROW A is provided where routes are lightly traveled and large investment is not justifiable (for small cities and suburban areas). When passenger volume is higher and better service is needed category B will be more effective. Category B will be preferable for very large passenger volume which exists in big cities where there is no space for separate ROW on the surface.

Buses: are the most common transit mode. They operate on streets and have an extensive network of lines. They have been upgraded by providing exclusive bus lanes and providing bus preferential signals.

LRT: the most common mode of semi-rapid transit. Provide more attractive and permanent system than the bus at a much lower cost than metro systems.

Metro: have by far the highest performance – capacity, speed, reliability – of all transit modes. They require a huge investment in the beginning but in the long run, they provide efficient functioning and quality of life in large cities.

The high density of activities makes it necessary for high capacity modes of transport in cities because they are more economical, more energy efficient and require much less space than private cars. Moreover, public modes of transportation provide service for all persons while cars can only be used by those who own and can drive them.

Current passenger transport systems in New Zealand cities are overwhelmingly reliant on private cars. The future risks of this dependence on cars – increased social and economic costs and environmental impacts – mean that cost-effective and less-polluting alternatives must be found to efficiently serve the urban transport task. Faster and more convenient travel by public transport is needed to replace longer urban journeys and to maximize the efficient use of existing roads (Mees, Stone et al. 2010).

2.3 Advantages of Public Transport

As car ownership has increased, more and longer journeys have been made by car and fewer by public transport. Reduced travel by public transport means reduced revenue to the operators, who then reduce the service frequency, or increase the fare, or both. This leads to the loss of more passengers and increased travel by car. More car means more road congestion which makes travel by bus even slower and more unreliable, thus further encouraging car travel. Then the downward spiral of bus public transport usage continues. However, increasing car travel has created a number of serious detrimental consequences, of which the three most important are:

> Traffic congestion: this is a phenomenon found in most urban areas. Lost economic output, increased noise and visual pollution, increased journey times and journey unreliability, unacceptable driver stress and frustration are the effects of congestion.
>
> Energy consumption and air pollution: the relative energy consumption of different travel modes favors public transport as it consumes less energy. Additional air pollution results from increased car travel. It has been estimated that 88% of CO2 emissions, 48% of NOx and 37% of volatile organic compounds emanating from road vehicles.
>
> Safety: with increasing car travel, there is a greater risk of accidents, particularly to vulnerable users of the road system such as motorcyclists, pedal cyclists, and pedestrians. Greater use of public transport would have significant safety advantages.

It can be concluded that although car travel has brought many benefits to urban residents, it has already reached such a level that severe congestion extends beyond the traditional morning and evening peak periods and is resulting in ever increasing and unreliable travel times. Thus, it seems probable that if a satisfactory and reliable public transport service were to be introduced, for many journeys a transfer from car to public transport could be anticipated (O'Flaherty et al. 1997).

Jaiswal & Sharma (2012) agree that using public transportation has many advantages over private transportation in the city of Bhopal. Some of the advantages they discuss include that public transport:

- Ensure safety: riding a transit bus is 91 times safer than car travel in Bhopal city.
- Saves money: Studies have shown that public transport can save up to 2 to 3 times the money spent on private vehicles.
- Eases traffic congestion: Public transportation can help much to alleviate the city's crowded network of roads by providing transportation choices.

- Improves air quality: Public transportation helps promote cleaner air by reducing automobile use. For each kilometer traveled, fewer pollutants are emitted by transit vehicles than by a single-passenger automobile. (Buses emit 80 percent less carbon monoxide than a car.)
- Reduces energy consumption: Public transportation can significantly reduce dependency on petrol, reducing auto fuel consumption by 1.5 billion gallons annually.
- Fosters more livable communities

Public transport has plenty of advantages as listed above. However, the users are not fully satisfied with its performance and prefer to use other modes like private cars. People require some improvements in characteristics of public transports in order to use them. For an instant, Nurdden, Rahmat & Ismail (2008) found out that the travel time, travel cost reduction are the contributing factors that influence the model shift from car to public transport in Malaysia.

2.4 Desirable Operational Characteristics of Public Transport

According to O'Flaherty et al. (1997) in order to increase the usage of public transport, the following operational characteristics need to be met by public transports.

Convenience

- Direct service: the service needs to go to the destination(s) that travelers wish to reach, preferably without the need to interchange
- Frequency: must be adequate that wait times are adequately short
- Reliability: scheduled arrival times and scheduled line haul times must be consistently maintained
- The door to door journey must be comparable/competitive with that of the car
- Comfortable: adequate seating, acceptable standing passenger densities during peak periods
- Clean and easily accessible
- Stations/stops should be well designed with good waiting facility
- Any interchanging should be undertaken without steps and should involve short distance

Image

In the view of many people public transport, especially the bus, has an old-fashioned, antiquated, run-down image and this need to be improved.

Information

- Detail of service frequencies, times and fares (by route) should be readily available, clearly presented and kept up-to-date.
- 'Real-time' information should be available at stations/stops.
- Details of my pre-booking arrangement should be clearly presented.

Security

If many stations and bus stops are not staffed the feeling of safety when using public transport by travelers can be accentuated.

In order to achieve the above characteristics, some criteria need to be met. For example, the performances of a public bus transport systems are affected by several criteria, such as increasing the number of buses, number of bus stops, number of passengers, and changes along roadways (Eshetie, et al., 2013).

2.5 Public transport in Addis Ababa

"Mobility in the developing world is often characterized by travel demand that far exceeds supply" (Darido 2003). The transportation system of Addis Ababa is highly dependent on public transport and so it is very important. Its affordability than the rest of transports, infrastructure constraints, reduction in traffic congestion and pollution are the fundamental reasons that make public transport an important element of Addis Ababa life as discussed by Gebeyehu & Takano (2007). Due to high population growth and galloping urbanization, the demand for mass mobility is highly growing and this requires providing and improving urban public transport service according to Eshetie et al. (2013).

As Meshesha (2014) reported the first public transport service in Addis Abeba was Anbessa City Bus Service Enterprise. Currently, public transport including Anbessa buses, Higer mid-buses, Alliance buses, Minibus taxis, and Salon taxis altogether cover about 48 percent while private mode only 9 percent and walking estimated to be 43 percent (Meshesha, 2014). There are more than 10,000 minibus taxis that provide service with higher quality. Until 2009, Minibus taxis were not restricted in terms of the routes or areas in which they may operate. The operators used to determine the routes and hours they serve within the zoning system. The result is a demand-driven public transport system that operates without routes maps, timetables or central co-ordination. "The fares are controlled by the city government but are two to three times those of city buses" (Meshesha, 2014).

According to Aimero (2016), the prominent problems regarding public transport in the city of Addis Ababa include; shortage of service providers, low levels of safety, poor service quality, poor service accessibility, inappropriate vehicle type and size and lack of integrated network design. Moreover, the public transit transport service provision, that has critical financial constraints have made the Anbessa City Bus Service Enterprise unable to replace the old buses with new ones which in turn, has restricted its service quality and coverage (Ministry of Transport, 2011). In addition, the Ministry of Transport (2011) has considered In-sufficient public transport service provision and limited coverage to main roads only; Lack of standard public transport service provisions and rising transport fairs; Absence of stakeholder

coordination in the sector to be primary challenges in the city transportation. To tackle the challenges the government is engaging in lots of schemes. One is the LRT system project which according to Eshetie, et al. (2013) cannot fully substitute the bus service; and expansion of city roads and increasing the number of buses could not address the problem without efficient utilization and scheduling of buses.

2.6 Competency in Public Transport

Alternative modes of public transport can serve in a given route and this creates a competitive environment. A competitive environment can be created in a variety of ways.

a) Competition in the transport market: this occurs where there is no restriction on entry. Competition in the market can be between individual operators within a mode of transport, between groups of operators within a mode or between modes;
b) Competition for the transport market: where entry is restricted, it is possible to organise competition for the right to service individual routes, for the sole right to provide a whole network or to undertake particular functions as a subcontractor to a monopolist operator.

The absence of competition has enabled management, favored customers and organized labor interests to the appropriate part of the potential monopoly profit. It is now widely felt that the potential loss of patronage, earnings and, ultimately, employment resulting from a failure to respond to consumer demand in competitive markets is the most powerful means to force suppliers to respond to consumer requirements.

If modes are not able to penetrate the market they can end up being underutilized. In a study conducted for the city of Chennai, MRTS provided to minimize the problem occurred due to lack of transport turned out to be underutilized. From their research, Muthukannan & Thirumurthy (2008), found that;

- Less accessibility
- More cost and
- More travel and waiting time

to be the primary reasons for not using MRTS. On the other hand, if the waiting time is reduced by 25 % the MRTS system will get additional patronage up to 17000. To achieve the estimated patronage in MRTS the optimum cost of the ticket should be 23% less than the existing cost of the ticket and the optimum travel time in MRTS should be 25 % less than the existing travel time.

The various travel modes constituting the transport system are interrelated. Hence changing the level of service in one mode (e.g. providing improved facilities for the private car) has an impact upon the others. Thus, one of the often-stated objectives of transport planning is to produce a plan which results in the best balance between all the available travel modes so that the movement demands of all sections of society can be met (O'flaherty et al. 1997).

2.7 Mode Choice Modelling

The statement of a "model" typically begins with an observation or a proposition that one variable "is caused by" another, or "varies with another," or some qualitative statement about a relationship between a variable and one or more covariates that are expected to be related to the interesting one in question (Green, 2012). The main use of models in practice is for conditional forecasting: the model will produce estimates of dependent variable given a set of independent variables. A model is normally used to test a range of alternative plans for a range of possible assumptions about the future value of other variables. (Ortuzar & Willumsen 2004)

2.7.1 Aggregate and Disaggregate Model

When a model at base aims at representing the behavior of more than one individual such as in the case of aggregate or first generation models a certain degree of aggregation of the exogenous data (information about item other than the behavior of travelers) is inevitable. When the model at base attempt to represent the behavior of individuals such as in the case of disaggregate or second-generation models it is conceivable that exogenous information can be obtained and used for each traveler.

Aggregate models are criticized for their inflexibility, inaccuracy, and cost. In order to use disaggregate models statistical and econometrics skills are required with high level. 'Aggregate demand transport models are either based on observed relations of a group of travelers or on average relations at zonal level. Disaggregate demand models are based on observed choices made by individual travelers' (Ortuzar & Willumsen, 2004).

2.7.2 Discrete Choice Model

Discrete models are type of disaggregate models. Discrete choice models describe decision-makers' choices among alter-natives. The decision-makers can be people, households, firms, or any other decision-making unit, and the alternatives might represent competing products, courses of action, or any other options or items over which choices must be made (Train, 2002).

To fit within the discrete choice framework three properties of choice set should be satisfied. These include: the alternatives should be mutually exclusive; the choice must be exhaustive and the number of alternatives must be finite. According to Train (2002), the third condition is restrictive and it's this condition that defines the discrete choice model and differentiates it from the continuous model. This distinguishes their realm of application from that for regression models. With regression models, the dependent variable is continuous, which means that there is an infinite number of possible outcomes.

In discrete choice models, usually, the "dependent variable" is not a quantitative measure of some economic outcome, but rather an indicator of whether or not some outcome occurred (Green 2012). A discrete choice model would be used in these situations only if there are compelling reasons for doing so. In general, the researcher needs to consider the goals of the research and the capabilities of alternative methods when deciding whether to apply a discrete choice model. In general, discrete choice model postulates that 'the probability of individuals choosing a given option is a function of their socio-economic characteristic and the relative attractiveness of option' (Train 2002).

2.7.3 Utility Maximization Theory

The most common theoretical base or paradigm for generating a discrete-choice model is the random utility theory (Ortuzar & Willumsen, 2004). Discrete choice models are usually derived under an assumption of utility-maximizing behavior by the decision-maker (Train, 2002). Which assumes that individuals of a homogeneous population act rationally and have perfect information that they will always select the option that maximizes their net personal utility. The individuals are faced with a set of alternatives $A = A_1, A_2, \ldots. A_j$. The decision maker would obtain a certain level of utility (or profit) from each alternative. The utility that decision-maker n obtains from alternative j is Unj, j =1 ..., J.

Utility models that yield certain predictions of choice are called deterministic utility models (Koppelman & Bhat, 2006). For this type of model, the individual selects the alternative with the highest utility with no uncertainty of the decision process. The factors that are observable to the researcher are not taken to the utility function in deterministic approach. According to Koppelman and Bhat (2006), this model has three basic sources of error.

First, the attributes of the alternatives can be perceived differently for different individuals. Second, it's difficult for analyst to put the function individuals use to evaluate utility of each alternative accurately. Third, special cases of the decision maker can't be observed by the analyst.

In probabilistic mode choice model, the data and models used by analysts describe preferences and choice in terms of probabilities of choosing each alternative rather than predicting that an individual will choose a particular mode with certainty (Koppelman & Bhat, 2006). Thus, the utility function for this model has two components one component of the utility function represents the portion of the utility observed by the analyst, often called the deterministic (or observable) portion of the utility. The other component is the difference between the unknown utility used by the individual and the utility estimated by the analyst. The components are represented as equation 2.1 below:

$$Unj = Vnj + \varepsilon nj \tag{2.1}$$

The observable part of utility equation can be written as a general form, for an instant for four choices with a different combination of case-specific and alternative specific variables, shown in equation 2.2

$$\begin{aligned}
V_{walk} &= \beta_{01} + \beta_1 TT_{walk} + \beta_{21} MII + \beta_{31}\ MALE + \beta_{41}\ AGE \\
Vcardrive &= \beta_{02} + \beta_5 CostBii + \beta_1 TT + \beta_6 OVTBd + \beta_{22} MII + \beta_{42} AGE + \beta_7 twocar \\
V_{taxi} &= \beta_{03} + \beta_5 CostBii + \beta_1 TT + \beta_6 OVTBd \\
V_{Bus} &= \beta_{04} + \beta_5 CostBii + \beta_1 TT + \beta_6 OVTBd + \beta_{24} MII + \beta_{44} MALE + \beta_{84} CHILD + \beta_{94} PH + \beta_{104} CBD
\end{aligned} \tag{2.2}$$

Where εnj captures the factors that affect utility but are not included in Vnj. The researcher does not know $\varepsilon nj\ \forall j$ and therefore treats these terms as random. The joint density of the random vector $\varepsilon n = \varepsilon_{n1},...,\varepsilon_{nJ}$ is denoted $f\ (\varepsilon n)$ (Train, 2002). Then the probability to choose alternative i is represented as:

$$\begin{aligned} P_{ni} &= \Pr ob(U_{ni} \succ U_{nj \neq i}) \\ &= \Pr ob(V_{ni} + \varepsilon_{ni} \succ V_{nj} + \varepsilon_{nj} \forall j \neq i) \\ &= \Pr ob(\varepsilon_{nj} - \varepsilon_{ni} \succ V_{ni} - V_{nj} \forall j \neq i) \\ &= \Pr ob(\varepsilon_{nj} \succ \varepsilon_{ni} + (V_{ni} - V_{nj}) \forall j \neq i) \end{aligned} \tag{2.3}$$

Using the density *f (εn),* this cumulative probability can be rewritten as:

$$P_{ni} = \int I\ (\varepsilon nj - \varepsilon ni < Vni - Vnj\ \forall\ j = i)\ f\ (\varepsilon n) d\varepsilon n \tag{2.4}$$

where I (·) is the indicator function, equalling 1 when the term in parentheses is true and 0 otherwise. This is a multidimensional integral over the density of the unobserved portion of utility, f (εn). Different discrete choice models are obtained from different specifications of this density, that is, from different assumptions about the distribution of the unobserved portion of utility (Train, 2002). Among the models which are developed so far include Logit, GEV (generalized extreme value), probit, and mixed logit.

2.7.4 The Logit Model

By far the easiest and most widely used discrete choice model is logit. The logit model is obtained by assuming that each εnj is distributed independently, identically extreme value (Train, 2002). Gumbel distribution is selected because it has computational advantages in a context where maximization is important, closely approximates the normal distribution. The density for each unobserved component of utility is

$$f(\varepsilon nj) = e^{(-\varepsilon nj)} e^{-e^{-\varepsilon nj}} \tag{2.5}$$

and the cumulative distribution is

$$F\ (\varepsilon nj) = e^{-e^{-\varepsilon nj}} \tag{2.6}$$

Identically distributed hypothesis is essentially a homoscedasticity hypothesis, which means that the scale parameter of Gumbel distribution is the same for all the alternatives.

Independent distribution of the error term means the univariate distribution of the errors can be used. This independence means that the unobserved portion of utility for one alternative is un-related to the unobserved portion of utility for another alternative. Since the εs' are independent, this cumulative distribution over all j ≠ i is the product of the individual cumulative distributions: (Train, 2002).

$$P_{ni} / \varepsilon_{ni} = \prod_{j \neq i} e^{-e^{-(\varepsilon ni + Vni - Vnj)}} \quad (2.7)$$

Of course, εni is not given, and so the choice probability is the integral of Pni | εni overall values of εni weighted by its density

$$P_{ni} = \int (\prod_{j \neq i} e^{-e^{-(\varepsilon_{ni} + V_{ni} - V_{nj})}}) e^{\varepsilon ni} e^{-e^{-\varepsilon ni}} d\varepsilon ni \quad (2.8)$$

Some algebraic manipulation of this integral results in a succinct, closed-form expression:

$$Pni = \frac{e^{Vni}}{\sum_j e^{Vnj}} \quad (2.9)$$

This is called the logit model probability. The representative utility is usually specified to be linear in parameters: $Vnj = \beta' Xnj$

where Xnj is a vector of observed variables relating to alternative j. With this specification, the logit probabilities become:

$$P_{ni} = \frac{e^{\beta' X_{ni}}}{\sum_j e^{\beta' X_{ni}}} \quad (2.10)$$

2.7.5 Model Estimation

The maximum likelihood estimator is the most common class of parametric estimator so far according to Green (2012). The underlying philosophy of this class of estimators is the idea of “sample information.” When the density of a sample of observations is completely specified, apart from the unknown parameters, then the joint density of those observations (assuming they are independent), is the likelihood function. The maximum likelihood estimator (Green, 2012) is the function of the data that (as its name implies) maximizes the likelihood function (or, because it is usually more convenient, the log of the likelihood function). In discrete choice case, the likelihood function gives the joint probability for the observed sample observations, and the maximum likelihood estimator is the function of the sample information that makes the observed data most probable (at least by that criterion).

2.7.6 Responses for Change of Attributes

It's important to know the effect of change of the attributes that define the utility, on the probability of choice of alternatives. There are two basic means of estimating this response of logit model because of change of attributes according to Koppelman & Bhat, 2006 as discussed below:

Derivatives of Choice Probabilities: One measure "for evaluating the response to changes is to calculate the derivatives of the choice probabilities of each alternative with respect to the variable in question" (Koppelman & Bhat, 2006). The value of the derivative is largest at $P_i = ½$ and becomes smaller as P_i approaches 0 or 1. This means the response to a change in an attribute will be greatest when the choice probability for the alternative is 0.5.

Elasticities of Choice Probabilities: another means of measuring the change of choice probability with respect to change in the attribute value is elasticity. "In general, elasticity is defined as the percentage change in the response variable with respect to a one percent change in an explanatory variable. In this case, the elasticity is the proportional change in the probability divided by the proportional change in the attribute under consideration" (Koppelman & Bhat, 2006):

The elasticity concept is based on independent variables which are continuous variables like travel time and cost. But if the variables are discrete differentiating will be meaningful. And therefore, derivatives will not be calculated for ordinal variables. To study the change caused by these types of variable, calculate the change of incremental in each probability for a change of one-unit of an ordered variable or categorical shift for a categorical variable then use the differences to have the elasticities.

2.8 Overview of Similar Studies

Diagnostic Evaluation of Public Transport Mode in Addis Ababa

In order to diagnose the public transport in Addis Ababa Mintesnot Gebeyehu and Shin-ei Takano (2005) used two of model approaches using 750 respondents from inner-city residents, intermediate zones and expansion areas selected for the study. A questionnaire that addresses Socioeconomic variables, Demographic characteristics, travel pattern, mode attributes, satisfaction variables and bus condition data were used. The models used were ordered logit and binary logit model.

In an ordered logit model, individual reveals the strength of his or her preferences with respect to a single outcome and it was used to examine citizens' perception on bus condition. Three conditions of the bus that are presented for the study were fare, convenience, and frequency.

The dependent variable for order logit model is the ranking of each condition found from respondents. The rankings have four categories. For example, for a fare the categories are very costly, costly, less costly and not costly. Independent variables for this model are socioeconomic attributes and attributes related to mode.

From the model, bus mode is perceived costly with an increase of age, family size, bus fare, travel time, waiting time and number of bus transfer and for people who live in periphery zone. Male, people who have work and have high income don't feel bus is the costly mode of transport. In the same way increase of the variable age, monthly individual income, family size, no. of transfer, bus travel time and bus waiting time cause the mode to be perceived as inconvenient one. Male and those individuals who work perceive bus as a convenient mode. And also, with an increase of fare bus is considered convenient.

In a model describing frequency perception only four variables were significant which are; sex, no. of bus connection, travel time and waiting time. Male perceive bus to be less frequent. The number of bus connection and waiting time have a negative relationship with the perception of frequency. Travel time increase has a positive bus frequency.

Binary logit model is used to study the mode choice behavior of individuals between bus and taxi. Those who live in the periphery area and females tend to use the bus more than those in inner-city according to the model formulated. As age, income and waiting time increases the probability of using bus decreases. On the other hand increase, family size and travel time will increase the tendency of using the bus. Diagnosing the two models final summary of the mode choice has been made in the study. Mintesnot Gebeyehu and Shin-ei Takano (2005) have concluded that socio-economic as well as public transport mode related variables affect mode choice and perception of mode conditions positively or negatively. Expansion of bus service, improving bus frequency condition and strengthening of bus linkage should be the focus of policy as recommended by the paper.

Logit model of work trip mode choice for bole sub- city residents

With the objective of developing Multinomial Logit model which is based on disaggregate socioeconomic, mode and trip-related data, for work purpose trips a study has been made by Mekdim Teshome (2007) for Bole Sub-City residents. The different modes of road passenger transport considered in the model are Walking, Small Taxis, Mini-Buses, Anbessa City Bus, Lonchina, Private vehicle as driver, Private vehicle as passenger and Company provided transport. Household or Home Interview Survey was used as a data source in addition to secondary data that is used to create the level of service data.

Five model specifications were adopted in the model; base model having only mode related variables, Model 1 including income variable in addition to base model, Model 2 with an upgrading of Model 1 by adding variable peak hour, Model 3 and Model 4 which have different specifications of total travel time and cost including socioeconomic variables i.e. gender, age, Car and child ownership (indicating whether the individual has children and the no. of children they have) and trip-related variable cost by distance (CBD) to Model 2.

The values for the coefficients were estimated using the concept of maximum likelihood. If an exogenous sample of N decision makers is obtained for the purpose of estimation, since the Logit probabilities take a closed form, the traditional maximum-likelihood procedures can be applied. For independent mode choice among decision makers the probability of each person in the sample choosing the alternative that he was observed actually to choose (the likelihood function) is given as:

$$L(\beta) = \prod_{n=1}^{N} \prod_{i} (P_{ni})^{Yni} \tag{2.11}$$

Where, Y_{ni} = 1 if person n chose i and 0 otherwise.

The log-likelihood function is then:

$$LL(\beta) = \sum_{n=1}^{N} \sum_{i} Y_{ni} \ln P_{ni} \tag{2.12}$$

The estimator is the value of β that maximizes the function which is computed by setting the 1st derivative of the function zero. After proper estimation and calibration of the models using Stata required tests that are summarized in Table 1 below were performed.

Table 1: Model testing measures

Classification of tests	Fitness measures		Test description	Remark
Informal tests	Sign of variables		Comparing the sign of coefficient with theory, intuition and judgment.	Travel time and cost variables have negative signs in all the models.
	The difference in alternative specific parameters		The difference in magnitude of alternative specific parameters indicates the relative impact of increasing variable in the probability of mode.	Sound coefficient of income, automobile ownership and home ownership found for Automobile alternative which is higher.
Overall goodness of fit measures	Likelihood ratio index (rho-squared)		Similar to R^2 in regression and shows how well independent variables in a model explain the dependent variable.	The higher R^2 is taken as a better model.
Statistical tests	Individual parameter test	(Asymptotic t-test)	Used to test the significance of each variable in explaining the dependent variable.	With higher t-statistics, the null hypothesis that the corresponding variable has no significant impact on the model can be rejected.
	Test of the entire model	Likelihood ratio test	To test model with imposed restriction (setting some parameters zero)	
		Non-nested hypothesis tests	To test the impact of a variable that is explained as a function of another.	
Test of the model structure	IIA		Used to test the assumption of Independence of Irrelevant Alternative in a logit model.	

And from analysis and personal judgment model 3 has been selected as the optimal model and the utility function was determined:

Teshome (2007) has also shown that a continuous improvement in the model's explanatory power is observed as the model changes from being restricted to mode related variables to incorporating the socio-economic and trip-related variables.

Logit Model for School and Work Trip Mode Choice on Railway Route Corridor

Both revealed and stated preference logit model had been developed by Etsub Hailu (2015) to study the behavior of people on the selection of the mode of transport and show the modal shift factor to LRT for students and workers. Multinomial logit model (MNL) with linear in parameters utility was applied to understand the relationship between mode choice and characteristic of mode and decision makers. The alternatives under consideration for employees include; Taxi, Anbessa bus, Higer, company provided service, government service and walk. And it's the same for students except there is no company service rather school service is used and government/public service is also omitted.

Forward stepwise likelihood ratio method was used in the analysis of data using SPSS. In this method, the step starts with a model with no explanatory variable then at each step a predictor with largest score statistics whose significant value (0.05) is added to the model. The tests undertaken for the model include; Pseudo R-square, Likelihood ratio, Pearson and Deviance.

Work type, out of vehicle time, travel time and income were significant factors that affected work trip while out of vehicle time, travel time, sex and service cost were significant factors for a school trip. From the result of a stated preference for work trip current taxi users were 7.229 times more likely to prefer the train, Higer users were 12.65 more likely to use train and Anbessa bus users were 15.52 times more likely to prefer the train. For school trip current taxi users were 0.54 times less likely to prefer the train, Higer users were 0.32 less likely to use train and Anbessa bus users were 0.997 times less likely to prefer the train.

3 Methodology

3.1 Study Area

The study was carried out in part of Addis Ababa, is the capital city of Ethiopia (shown in Figure 1 below). The city is divided into 10 Sub-cities and 116 Woredas (*i.e. the smallest division of city municipality (districts) in Ethiopia*) as shown in Figure 1 below. The study area selected for this research is the corridor from Ayat to Megenagna following the East-West Light Rail Transit corridor in Addis Ababa. This corridor is located on the border between Yeka and Bole Sub-cities of the Addis Ababa. One side of the road that starts from Megenagna and heading to Ayat is Bole sub-city. While the other side that goes from Ayat to Megenagna is in Yeka Sub-city. The Woredas that fall under the study area are Woreda 6, 7, 8 and 10 from Bole sub-city and woreda 10, 11 and 13 from Yeka sub-city. The length of the corridor under the study is 7.9km.

Figure 1: Map of Addis Ababa

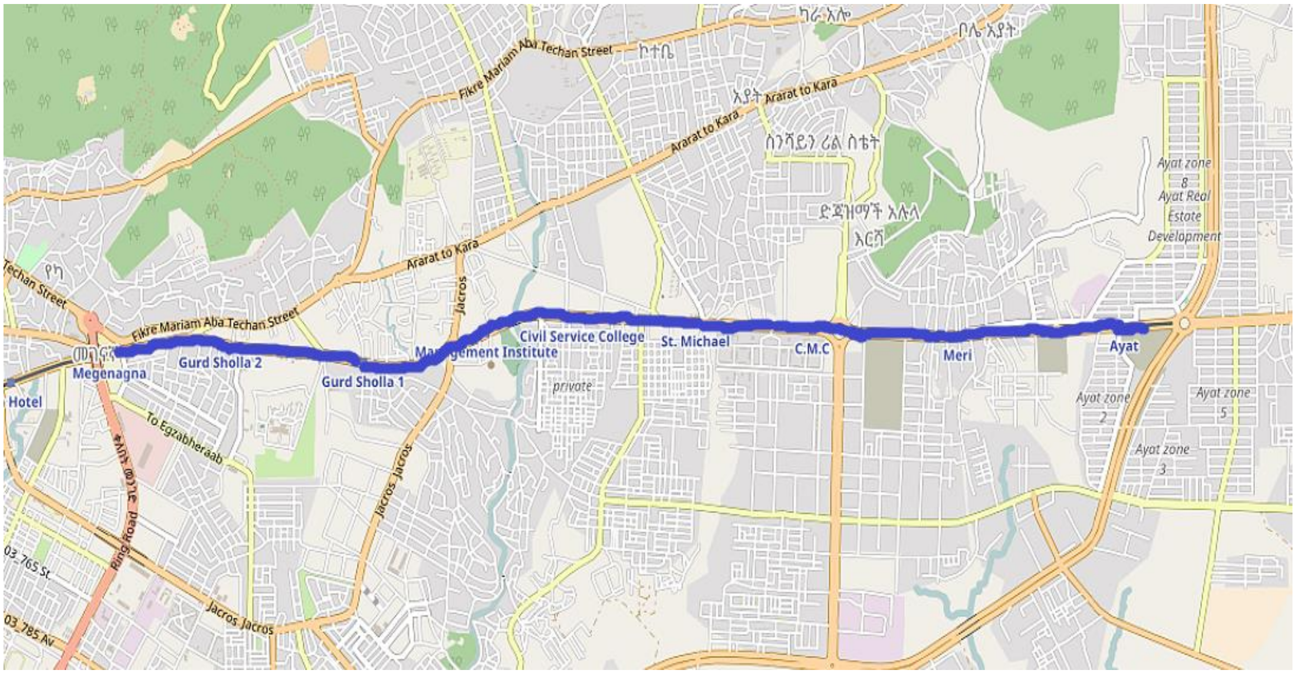

Figure 2: Corridor from Megenagna to Ayat

3.2 Study Design

An observational study approach is adopted for this research. The explanatory and analytical study, under observational study, are used to meet the objectives. The explanatory approach is used to find out highly utilized mode of transport and mostly abandoned mode of transport. The reason why people will not use some mode of transport will also be gathered from survey responses.

An analytical study is carried out to identify the association of the mode choice with different independent variables. The independent variables include some demographic features like age, income, family size etc. Trip characteristics and mode characteristics are also considered as a dependent variable for mode choice. The logit model is used to get the correlation between the mode choice and regressors. From the logit model the coefficients that determine the utility functions are estimated using the maximum likelihood estimation method. Stata 14 has been used as a tool both for the model and descriptive statistics.

3.3 Data Requirement

The data required for the research include the demographic data of public transport users in the study area. This demographic data includes Gender, age, family size and monthly income. The primary choice of the mode used to make their travel is collected together with travel time, waiting time, access time required to make the trip using the chosen mode.

The respondents were also asked for avoided modes of public transport and the reasons for avoiding them, in order to identify the least preferred mode. The capacity, frequency, fare, Operational characteristics of the modes of public transport are also collected. Individuals were also asked to rate the chosen public transport mode from safety, comfort and accessibility point of view. The rating was from one up to five, one being very poor and five very good.

3.4 Data Source

A questionnaire was used as a primary source of data to obtain the demographic data of respondents, mode preference for the trip, and travel time, waiting time etc. required for the trip. Six sets of reasons were also given to respondents to select the reason why they abandon the mode they don't use. Low speed, not safe, long waiting time, high fare, low comfort and no reason to use were the options provided with an open space free to include other reasons if there are any. The questionnaire used is attached in Appendix A.

Different kinds of literature have been studied as a secondary source of data to obtain what operational characters are required for public transport and to study methods to obtain the objectives.

The operational characteristics and other general data regarding the four modes of public transport under the consideration of the study (i.e. LRT, Anbessa bus, Higer bus and Minibus) are collected from Ethiopian Railway Corporation (ERC), ACBCE (Anbessa City Bus Service Enterprise) and Addis Ababa Traffic Management Agency (AATMA). These data are discussed as follows:

Minibus

Minibus is one of the public transport service that most of the city residents are highly dependent on. Relative to the other three modes of transport in this study Minibus have high fare and not affordable for low-income groups. A minibus has a capacity of holding 13 people per vehicle. With Minibus transport system there is no fixed time schedule and route which cause it to be difficult for researches. Travel speed, access time and waiting time are all collected from interviews as it was difficult to get a measured amount for this means. Travel speed is calculated as the distance from the origin to destination divided by travel time that took travelers to make the trip.

Figure 3: Minibus taxi public transport

Table 2: fare charge of a minibus taxi

Distance (km)	Cost(birr)
≤2.5	1.45
2.6 – 7	2.7
7.1 – 10	3.85
10.1 – 12	4
12.1 – 15	5

Higer bus

Higer bus is a midi-bus with total capacity 37 passengers, 27 passengers seating and 10 passengers standing as shown in Figure 4 below. Travel speed, access time and waiting time are all taken from respondents as it was difficult to get a measured amount for this means. The travel speed is calculated by dividing the distance by travel time both of which were collected from respondents who actually use Higher bus as a primary means of transport.

Figure 4: Higer bus public transport

The fare established for Higer bus is indicated in Table 3 below.

Table 3: Fare charge of Higer Bus

Distance (km)	Cost(birr)
≤4	1.5
4.1 – 6	2
6.1 – 8	2.55
8.1 – 9	3.05
9.1 – 10	3.55
10.1 – 12	4.05
12.1 – 13	4.55
13.1 – 15	5.05

Anbessa Bus

Anbessa-Bus service enterprise is a transportation system that gives service to the people which is owned by the federal government and is controlled by Addis Ababa city administration. It is the first public transport in Addis Ababa that started operation since 1935. There are 124 routes in total that serve in Addis Ababa city. In the route section that is under consideration of this study (from Hayat to Megenagna), there are five numbers that are at service. These Bus numbers include:

- Bus No. 49 from Megenagna to Hayat Chefe
- Bus No. 61 that starts from Legehar to Hayat Chefe
- Bus No. 83 from 6kilo to Hayat Chefe

- Bus No. 97 from Megenagna to Tafo roundabout
- Bus No. 101 from Megenagna to Tafo roundabout

Figure 5: Anbessa bus public transport

Unlike the above two modes waiting time for Anbessa bus is calculated from the schedule of the bus which is found from ACBS. Access time and travel speed are taken from respondents who actually use Anbessa as the means of primary choice. Overall operational characteristics of Anbessa bus is indicated in Table 4 below while the fare charges are shown in Table 5.

Table 4: operational characteristic of Anbessa Bus from Hayat to Megenagna

Item		**Statistic**
Days of operation		Mon-Sun
Times of operation		06:15 - 20:30
Number of routes in the study area		7 bus numbers
Vehicle capacity	Normal	100 (30 seating and 70 standing)
	Articulated	300 passengers (with relaxed space)
No. of vehicle	Normal	16
	Articulated	22
Max. distance between stations (m)		300m
Min. distance between stations (m)		500m
Average distance between stations (m)		400
Frequency		13 – 30 min
Average Speed (km/hr)		13.1

Table 5: Fare charge of Anbessa bus

Distance (km)	Cost(birr)
≤9	1.5
9 – 12	2
12 - 15	2.7
15 - 18	2.8
18 - 21	3.5
21 - 24	4.25
24 - 30	5
30 - 47	9

Light Rail Transit (LRT)

The LRT is owned and managed by the Ethiopian Railway Corporation. There are two large routes giving service in Addis Ababa. The first is the North-South route which starts from Menelik II square to Kality covering a total of 16.9km. This route gives service starting from September 20, 2015. There are 19 stations along this route. The second route, which is the focus of this study, starts from Ayat and ends at Torhayloch. It was launched on November 11, 2015, and runs 17.4km having 22 stations. Table 6 summarizes the operational characteristic of the LRT (EW direction) service.

The travel speed and fare of LRT are directly taken from ERC. The waiting time is also taken from ERC from the time schedule they have. Access time is taken as the time that takes respondents, who use LRT as their primary means of transport, to reach to the service from their homes. And the access time for LRT is calculated to be 10min.

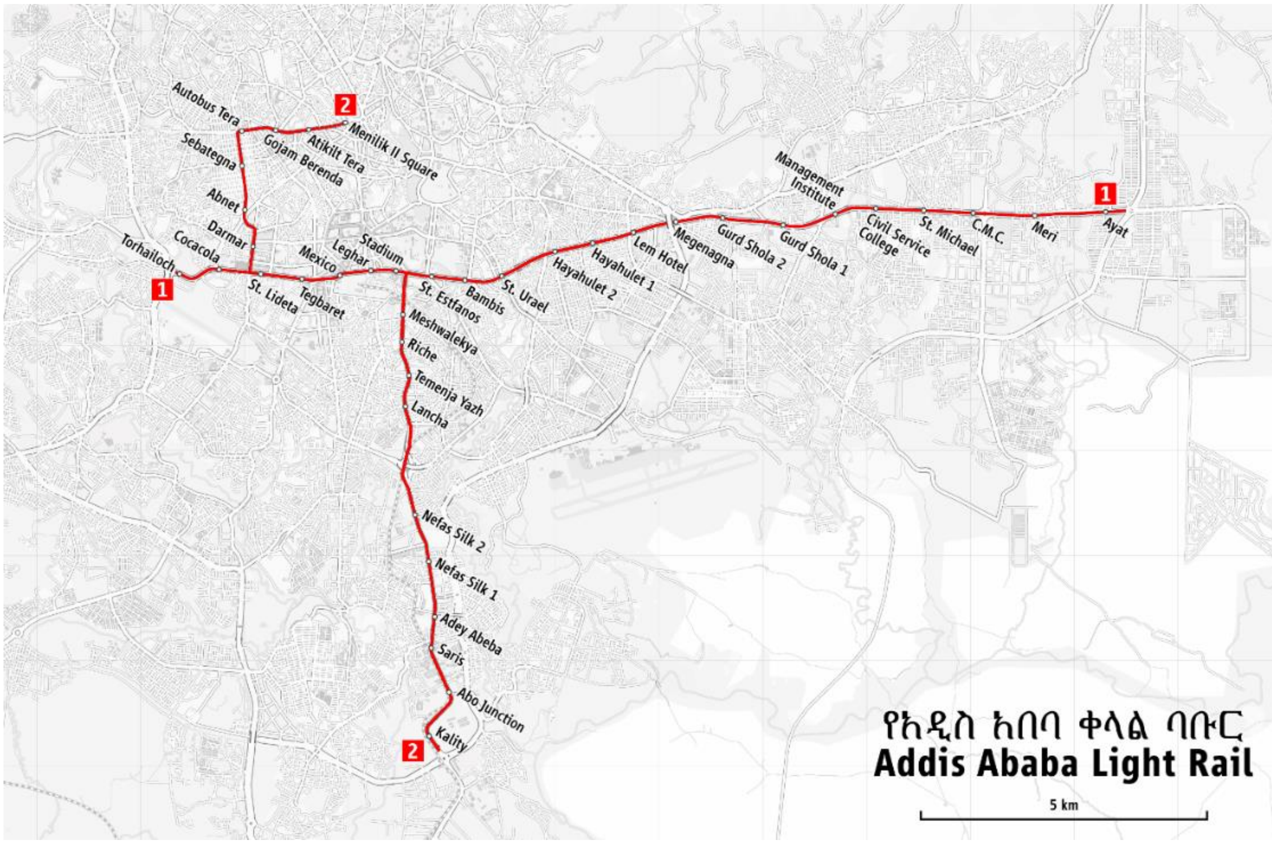

Figure 6: The East-West and South-North corridor of Addis Ababa light rail transit

Figure 7: Addis Ababa Light Rail Transit vehicle

Table 6: operational characteristics of the EW route of LRT

Item		Statistic
Days of operation		Mon-Sun
Times of operation	Peak Hour	07:00 - 19:00
	Flat Hour	6:00 - 07:00 & 19:00 - 22:00
Number of routes		2
Vehicle capacity	AW1 (no standing)	65
	AW2 (189 standing)	254
	AW3 (252 standing)	317
	Coupled	Twice of the above conditions
No. of vehicle	Peak Hour	8
	Flat Hour	6
No. of stations (from Ayat to Megenagna)		9
Max. distance between stations (m)		1260
Min. distance between stations (m)		445
Average distance between stations (m)		798.2
Frequency		15min
Average Speed (km/hr)	upward	19.9
	downward	19.2
Average number of passengers per day		62450

Table 7: Fare charge of LRT

No. of Station	Km	Fare charge (birr)
≤ 8	≤ 6.4	2
8 – 16	6.4 – 13.8	4
> 16	>13.8	6

3.5 Sampling Method

The questionnaires were randomly distributed to respondents at two stations in the study area. Megenagna and Ayat were the selected stations where questionnaires are distributed. Any individual in the station that use public transport has been selected randomly for the study.

3.6 Sample Size

Montgomery and Runger (2003) suggested that in situations where the sample size can be selected, we may choose n to be 100 (1 - α) % confident that the error is less than some specified value E using the following equation.

$$n = \left(\frac{Z_{\frac{\alpha}{2}}}{E}\right)^2 p(1-p) \qquad (3.1)$$

Where, n: sample size

Z: standard normal random variable

E: error

p: prthe oportion of the population

α: confidence coefficient.

In order to choose n use the fact that the sample size from the equation 3.1 above will always be a maximum for p = 0.5 [that is, p (1 - p) < 0.25 with equality for p = 0.5], and this can be used to obtain an upper bound on n. Then the equation is modified to:

$$n = \left(\frac{Z_{\frac{\alpha}{2}}}{E}\right)^2 0.25 \qquad (3.2)$$

For this research by taking a 95% confidence interval and the error term (E) 0.05 the sample size calculated will be:

$$n = \left(\frac{Z_{\frac{\alpha}{2}}}{E}\right)^2 0.25 = \left(\frac{1.96}{0.05}\right)^2 0.25 = 384.16 \qquad (3.3)$$

Accordingly, a sample size of 385 will be enough. But taking some error into consideration a sample of 470 questionnaires were distributed out of which 391 correctly filled samples were found and used for the study.

3.7 Model development

Data from the questionnaire were filtered and selected to fit MNL model. And the data were fed to Stata using long data set. This means a single case had to be inserted four times (i.e. no. of alternative public transport modes for the study) in order to deal with alternative specific variables. This is due to the nature of the logit model indicated in equation 3.4 below.

$$P_{ni} = \frac{e^{\beta' X_{ni}}}{\sum_j e^{\beta' X_{ni}}} \qquad (3.4)$$

The theory underlying logit model is utility maximization theory which assumes that a decision maker with a given set of alternatives will select an alternative that will maximize his utility. The utility function of each mode is given as a linear combination of independent variables as indicated in equation 3.4 as an exponential function. From this theory probability of choice of one alternative is not dependent only on the utility of alternative under consideration but also the utility of all available. Travel time, waiting time, access time and cost by distance are the alternative specific variables in the study. These variables vary along alternatives for a single individual. ASClogit command was used in Stata to fit the multinomial logit model considering these alternative specific variables and other case-specific variables.

4 Results and Discussion

4.1 General Descriptive Statistics

Out of the 391 data that are used in the study 249 were male and 142 females. The age range of the sample is 16 to 79 years. The first age category is labeled as a youth and is the age group between 16 and 22. 22% of the sample falls in this group. About 46% (highest percentage) of the survey covers age between 23 and 30 which are labeled as young adults. The next highest percentage group are adults that are between age 31 and 50 and account for about 26% of the sample. The rest 6% of the sample are seniors aged higher than 51. The statistics are listed in table 8 below.

About 55% of the study participants have a family size ranging from three to five. Beyond half of the surveyed people have income that can be categorized as lower middle and upper middle income, that is 1000 – 3000 and 3000 -5000, while 19 percent have lower income and the 14% have relatively higher income. The overall descriptive statistics are summarized and listed in Table 8 below.

Table 8: Summary of descriptive statistics

Parameter	Category	Label	Frequency	Percent (%)
Gender	Male		249	64
	Female		142	36
Age	≤22	Youth	87	22
	23 - 30	Young adults	179	46
	31 - 50	Adults	103	26
	≥51	Seniors	22	6
Family size	≤2	Small	100	25
	3 - 5	Medium	214	55
	≥ 6	Large	77	20
Income (Birr)	≤1000	Low	73	19
	1000 - 3000	Lower medium	150	38
	3000 - 5000	Medium	114	29
	5000 - 10000	Upper medium	46	12
	≥10000	High	8	2

Mode preference by passengers

From the interview result mode of public transport selected as a primary means of traveling are summarized in Table 9. It is indicated that the largest proportion (i.e. 52.7%) of the sample use Minibus as a primary mode of transport. The next widely used mode of public transport is LRT taking a 28.6 % share of the survey. Anbessa bus and Higer bus are the last two options selected. Table 9 describes these shares of public transport among the four alternatives.

Table 9: Share of each mode

Frequently used mode of Public transport	Frequency	Percentage (%)
Minibus	207	52.7
Higer bus	31	8.4
Anbessa bus	39	10.2
LRT	114	28.6
Total	391	100.0

Travel modes passengers do not want to use

In the survey individuals where asked the means of public transport that they are not willing to use. And Anbessa bus takes the highest percentage of respondent which is 39%. Then Higer bus follows with 34% share of respondents. While Minibus and LRT take 10% and 11% respectively. 6% of the respondents say that they don't have a means of transport that they don't want to use indicating that these passengers don't have any means of transport they avoid but their level of preference can be different.

Table 10: public Transport mode not used by individuals

Not used Mode	Frequency	Percentage
Minibus	50	10
Higer bus	170	34
Anbessa bus	195	39
LRT	55	11
None	30	6
Total	500	100.0%

When respondents were asked the mode of public transport, among the alternatives, they don't want to use the reasons behind were also requested together. Among the reasons that may cause passengers not to choose certain modes of transport, the respondents were provided with six options. And with this, the reasons behind avoiding each mode of public transport under study were studied and presented with charts below.

Minibus

Out of 50 trip makers who responded as they don't want to use Minibus as their mode of transport the highest amount of respondents which are 44% claim their reason to be high fare. As indicated in Figure 6, About 17% answered a long waiting time is their reason. Low speed and low security take 16% and 14%, of respondents. 91% of those who don't use Minibus are willing to use if these drawbacks are improved.

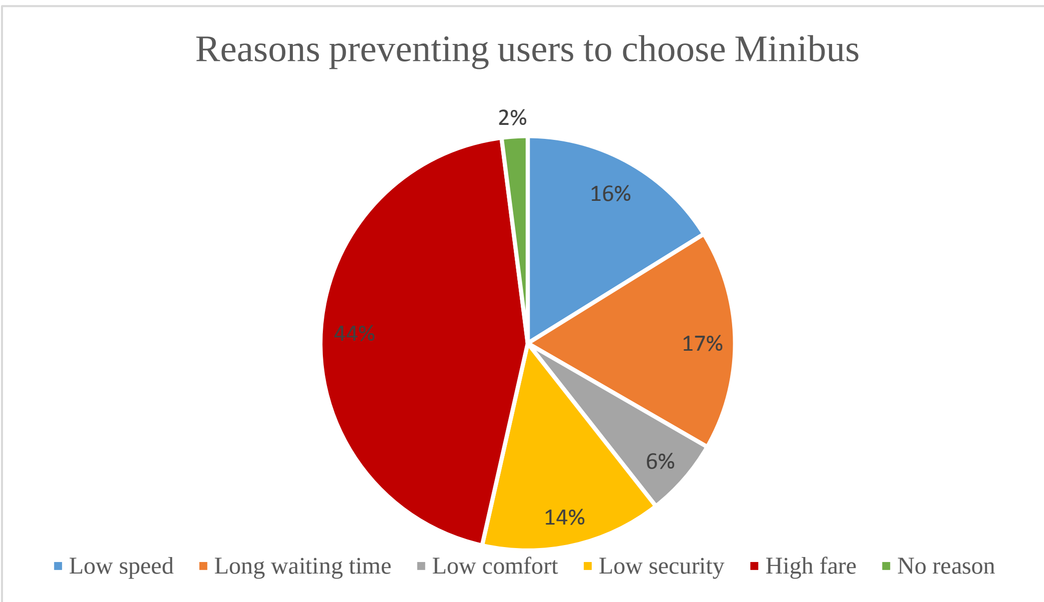

Figure 8: Reason behind not using Minibus

Higer bus

It is shown in Figure 9 that from 170 respondents who take Higer to be their least reference 36% claim the reason to be a low comfort. Low speed and Low security follow this having 23% and 21%. High fare takes the least percent of the reasons. Out of the individuals who don't use Higer bus 97% expressed their willingness to shift if the current challenges are resolved.

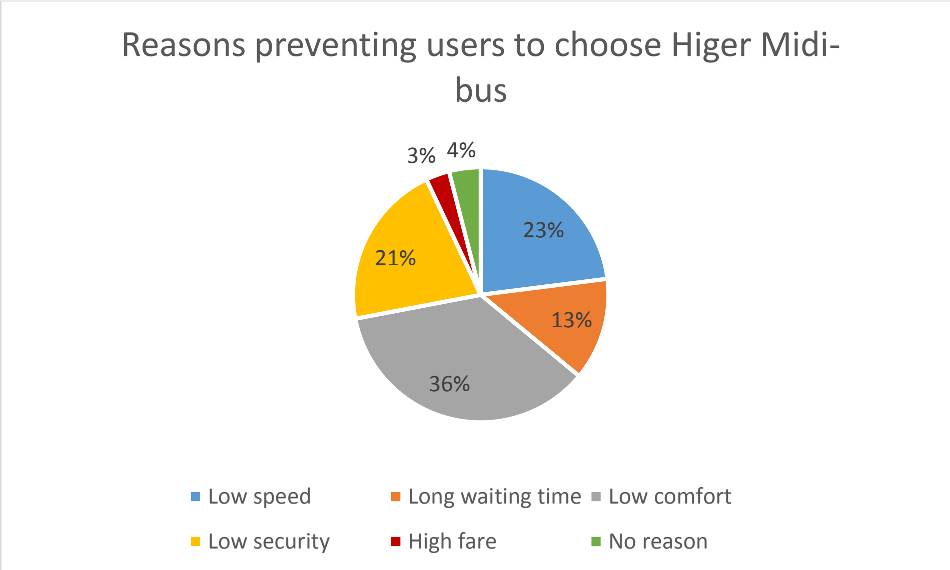

Figure 9: Reason behind not using Higer bus

Anbessa bus

The reasons for the 195 respondents who avoid public transport is mainly low comfort of the bus service. The next is 28% respondents who referred low speed for the reason not to use Anbessa bus. Almost equal to the previous proportion of respondent (i.e. 24%) say that Low security is the reason that prevents them from using Anbessa bus. Like expected those who answered fare take only 1% of the respondent for the reason to avoid Anbessa bus. 93% are willing to shift to this mode if improvements are guaranteed.

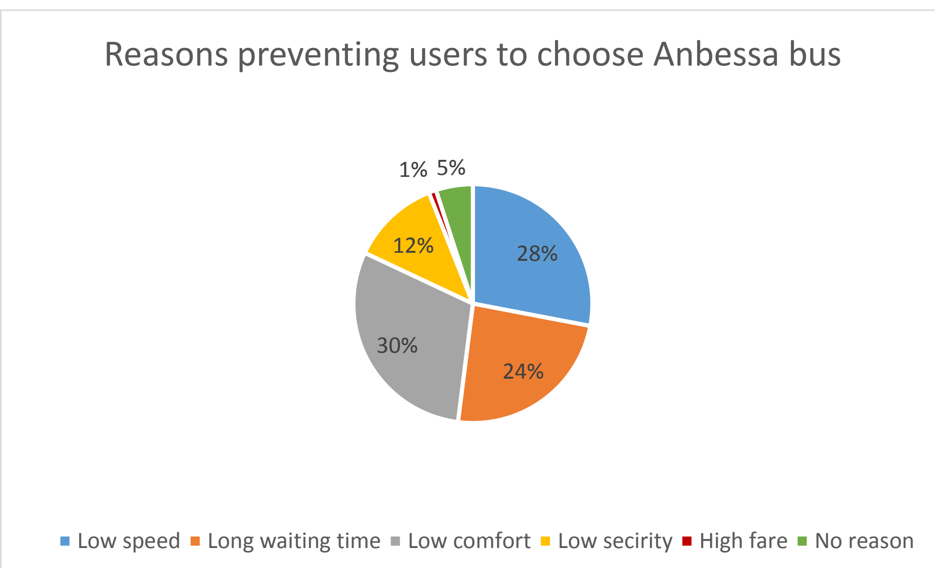

Figure 10: Reason behind not using Anbessa bus

LRT

The highest percent from 55 respondent who claim LRT as a mode of transport they don't want to use 27% responded low comfort to be the reason. 25% argued long waiting time to be the reason and this could be due to an insufficient amount of train in the area because in literature the waiting time for LRT seems to be good relative to the other modes but as the train is overpopulated people usually skip and wait until next vehicle arrives. 20% of respondents regarded security to be the reason not to choose the mode. If the above improvements are introduced for LRT 97% agreed that they would use the mode.

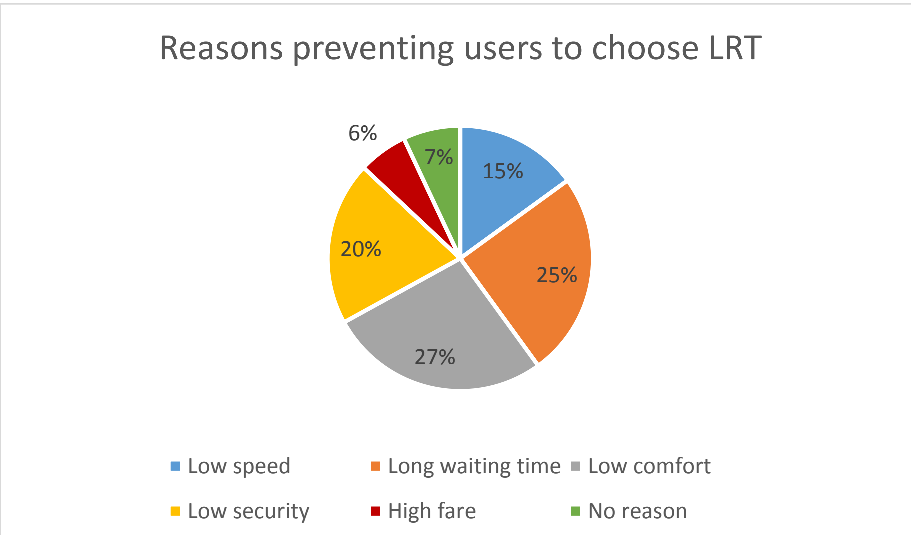

Figure 11: Reason behind not using LRT

4.2 Mode choice with demography

Gender wise mode selection: As shown in Figure 13 below from individuals that choose Minibus as a primary means of transport the proportion of male are 59.9% and female are 40.1%. In the same way from Higer bus users are 54.84% male and 45.16% female. For the two modes, the proportion of male and female passengers doesn't show a big difference. Even if the proportion of females is less in all modes (due to less female in the overall sample than male) the proportion difference is huge for the case of Anbessa bus and LRT. The first one having 74.36% male and 25.64% female while the latter one has 69.3% male and 30.7% female passengers. Anbessa bus contains the least proportion of females which is followed by LRT. From this, it is observed that female passengers tend not choosing Anbessa bus and LRT

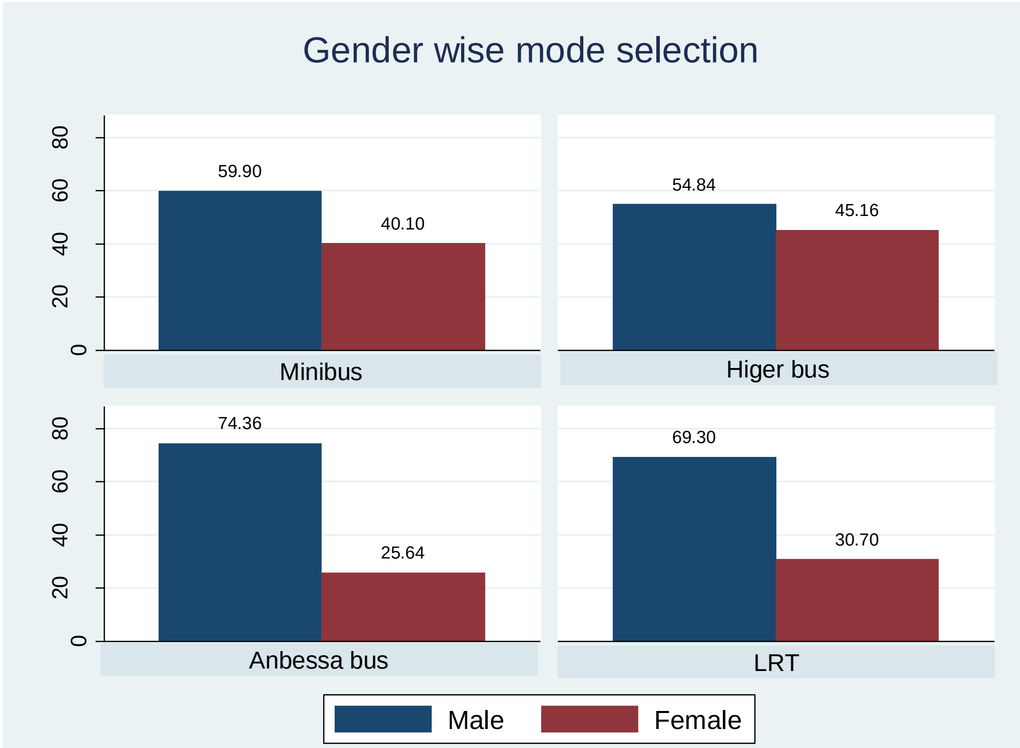

Figure 12: Mode selection with gender

Age wise Mode selection: Figure 14 shows young adults are the highest share of passengers for Minibus, Anbessa bus, and LRT. This proportion of young adults are extreme than the rest age categories for the case of Minibus when compared with the other three modes. Adults take the highest share for the case of Higer bus followed by young adult proportion having a very small difference from adult's percent. A similar distribution of age group is seen for Minibus, Anbessa bus and LRT from Figure 11. However, more senior proportions are observed for the case of Anbessa bus users than the rest modes and more youths are observed for the case of LRT.

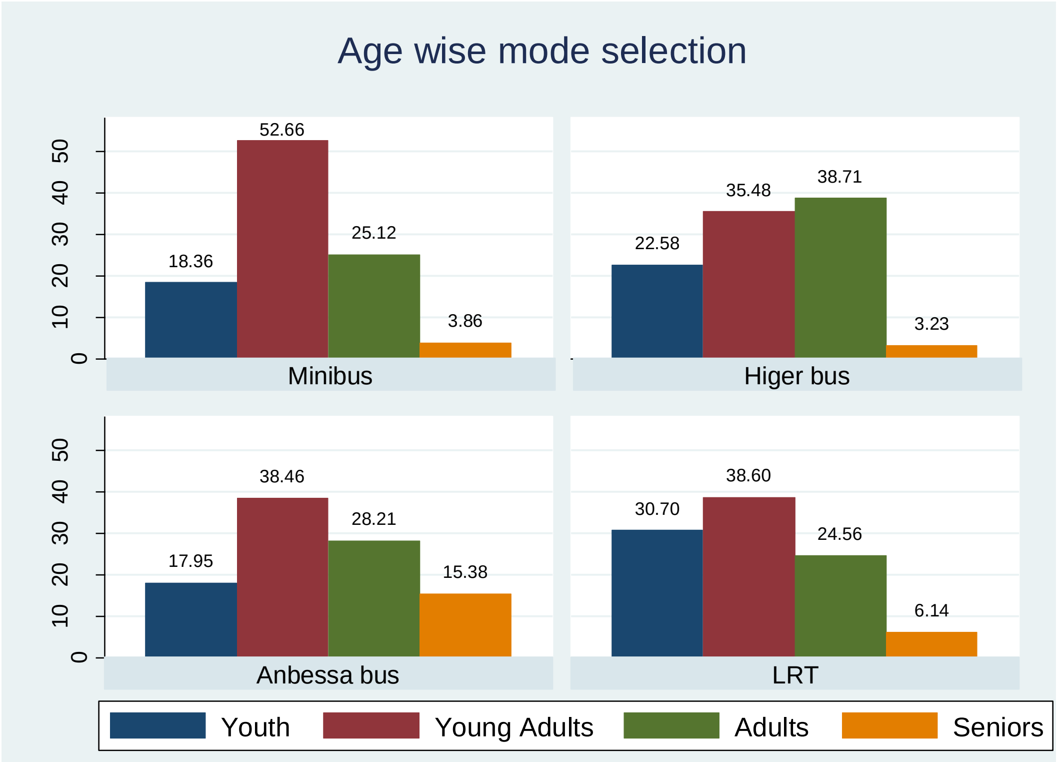

Figure 13: Mode selection with age

Family size and mode selection: mode selection doesn't change much with family size. The distribution is similar among the modes of transport as shown in Figure 15. But it is observed that a very small proportion of small family size and relatively large proportion of large family size is observed for Anbessa bus than the rest three modes. Which shows that individual with high family size prefers Anbessa than Minibus, Higer bus, and LRT.

Figure 14: Mode selection with family size

Monthly income and mode selection: Minibus and LRT are selected by all monthly income groups. While there is no percent of the high-income group that uses higher bus and Anbessa bus as shown in Figure 16. Medium income group takes the highest percent of Minibus users. Lower medium income group takes the highest proportion for the rest of the mode. This percent is very large for Anbessa bus users which shows that individuals with lower income prefer Anbessa bus. Higher bus contains a relatively highest proportion of the low-income group.

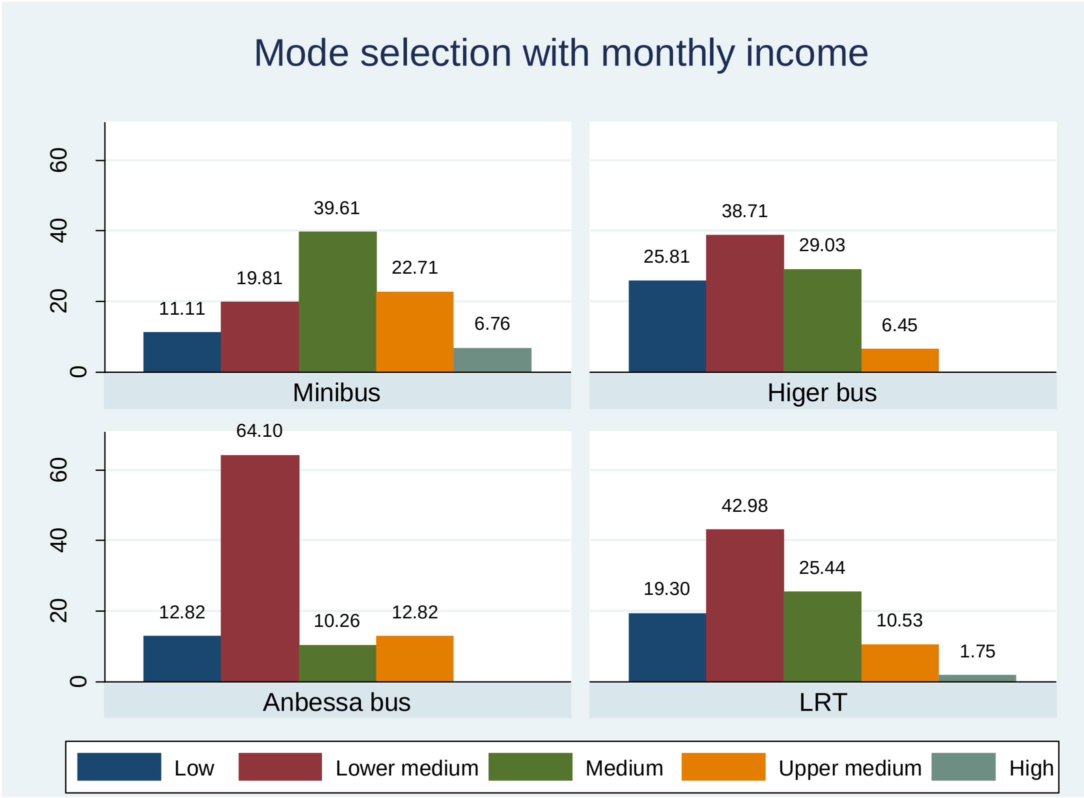

Figure 15: Mode selection with monthly income

Trip frequency mode selection: from Figure 17 below, individuals with high trip frequencies are observed to choose Anbessa bus and Minibus. While this proportion is lowest for the case of Higer bus and LRT users. At the same time, Higer bus and LRT have a relatively large proportion of low trip frequencies. Medium trips are also higher proportion for Anbessa bus. Low trip frequencies take the maximum proportion, compared with the rest three modes, for Higer bus.

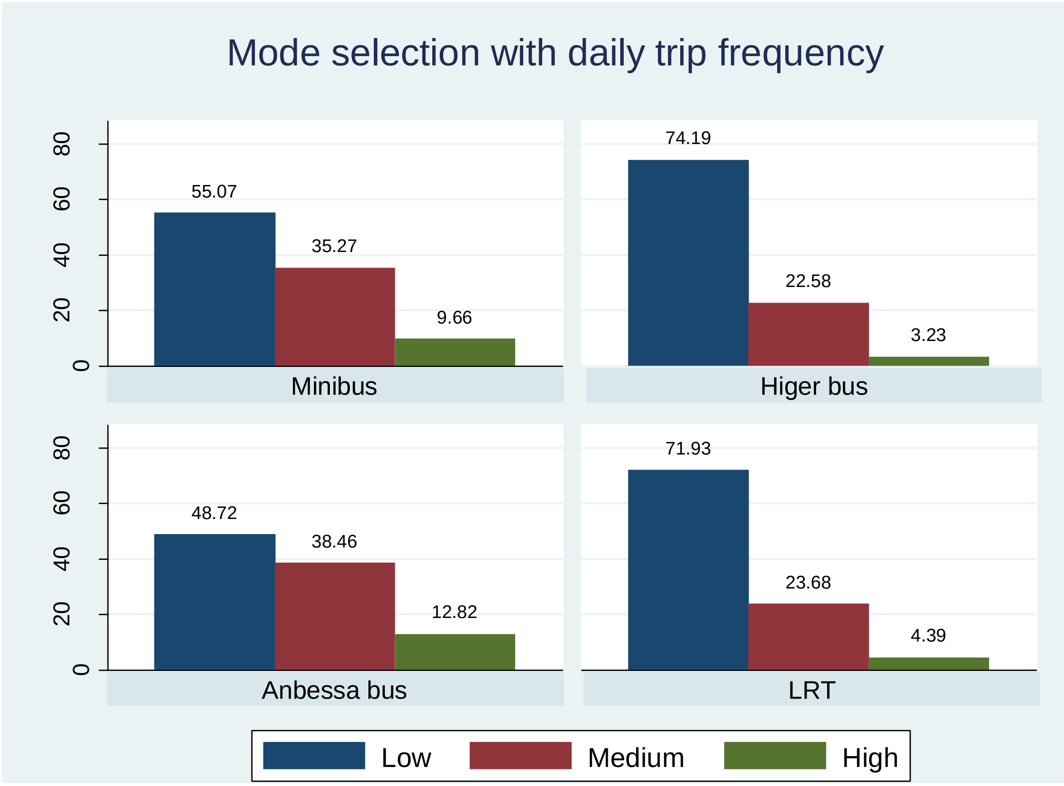

Figure 16: Mode selection with trip frequency

Peak hour mode selection: most of the peak hour trips are taken by Minibus. All modes, with exception of LRT, show to contain more peak hour trips than non-peak hour trips. LRT has less peak hour travelers than non-peak hour travelers unlike the rest of the modes.

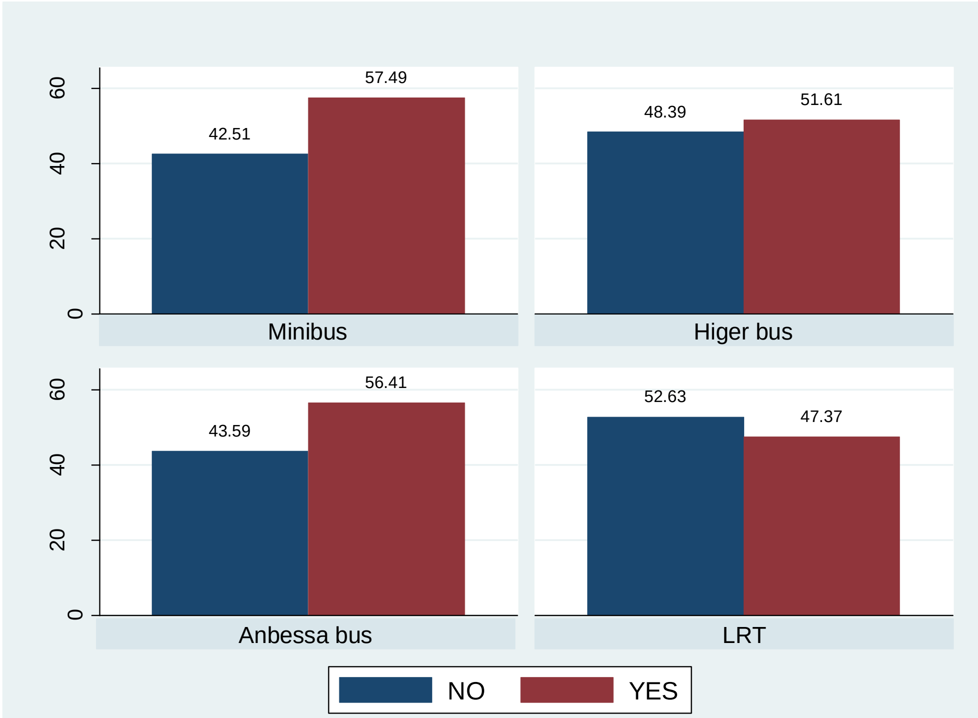

Figure 17: Mode selection with peak hour

4.3 Overview and Comparison of Operational Characteristics of Travel Modes

The alternative modes of public transport are evaluated and compared with respect to some parameters including; cost per km, waiting time, access time, speed, comfort, safety and accessibility. Cost by distance indicates the fare each mode charge divided by its corresponding distance. Waiting time describes the frequency of arrival of each mode at station points. Access time shows the distance people have to travel to reach to the point where they can find the required public transport. Speed is an indication of the time required to traverse a given distance, measured in km/hr. Comfort, safety and accessibility are the quality measures of public transport which are rated by respondents. The rating ranges from very poor to very good indicating passenger' perception of the public transports. The results from this section will give a better understanding of people's preference and model of mode choice.

Cost by distance: Minibus has a cost of 0.59 birr/km which has the highest fare from the four alternatives. LRT takes the second-place costing 0.47 birr/km. The next fare level is Higer bus and the cost is 0.46 birr/km which is very close to that of LRT. The least expensive mode of transport among the alternatives is Anbessa bus with a value of 0.3 Birr/km.

Waiting time: for the modes of transport which have a fixed schedule (Anbessa bus and LRT for the case of this study) the waiting time can be found directly from operating companies. And accordingly waiting time for Anbessa bus and LRT are 31min and 15 min respectively. For the case of Minibus and Higer bus which doesn't have any fixed schedule waiting time is taken as the average of waiting time of respondents who actually use these modes as a means of transport. From the results found Anbessa bus has the highest waiting time which is 31min. The next highest waiting time is 30min for Higer bus. Minibus has 19 min average waiting time and LRT has the least waiting time that is 15 min.

Access time: the time required for public transport users to reach stations where they can get the service to their home is taken as access time. And this value is taken directly from respondent and the average value is taken. Minibus and LRT have a similar access time of 10min. The access time for Higer bus is 15min while it's 16min for Anbessa bus.

Speed: in order to find speed for modes without a schedule, distance is found from origin and destination of the respondent and time that is required to traverse this distance is also taken from the respondents. Dividing these two parameters (distance/time) speed can be calculated. For the case of scheduled mode speed is found from the corresponding operating companies. These speeds range from the slowest modes Anbessa bus and Higer that have a speed of 13.2km/hr to the fastest LRT with a speed of 19km/hr. In the middle, there is a Minibus with a speed of 16.3km/hr.

Comfort: it's observed from the Figure 19 below LRT gets the highest rate for very good (14.29%) followed by Anbessa bus (10%) and Minibus (7.77%) while there is 0% very good rating for Higer bus. The highest rate for Minibus, Higer bus and LRT are moderate while this is poor for Anbessa bus. The highest rate of poor is given for Anbessa bus which is followed by Higer bus.

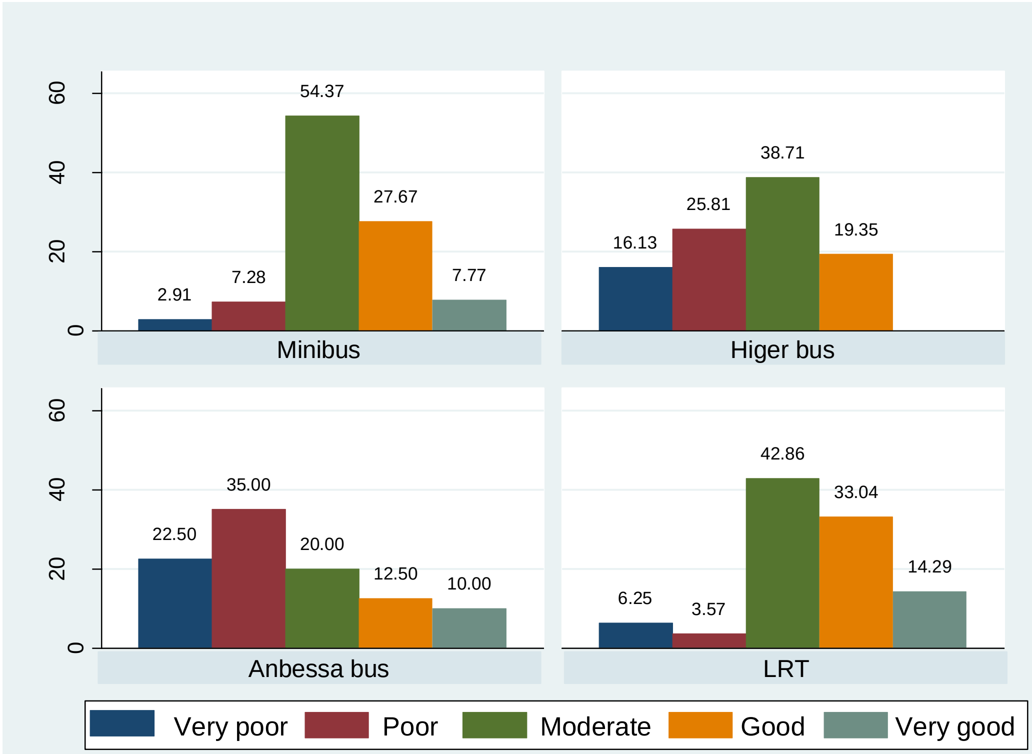

Figure 18: comfort rating result

Safety: safety signifies the risk of an accident that might occur using the transports. The highest rate for Minibus and Anbessa bus is moderate and for Higer bus both moderate and good have equal proportions as shown in Figure 20. LRT got the highest rate of good followed by Anbessa bus. In general, the result shows that people believe LRT to be the safest mode. Then Anbessa bus is the next safest mode, perceived by people.

Figure 19: Safety rating result

Accessibility: the highest rate for Higer bus and LRT is good. Minibus gets the highest rank of moderate while it's poor for Anbessa bus. Anbessa bus is perceived to be the least accessible mode which could be because of high distance between stations and limited coverage of Anbessa bus mode. Overall LRT is perceived to have better accessibility than the rest of the modes in passengers' perception. This is shown in Figure 21 below.

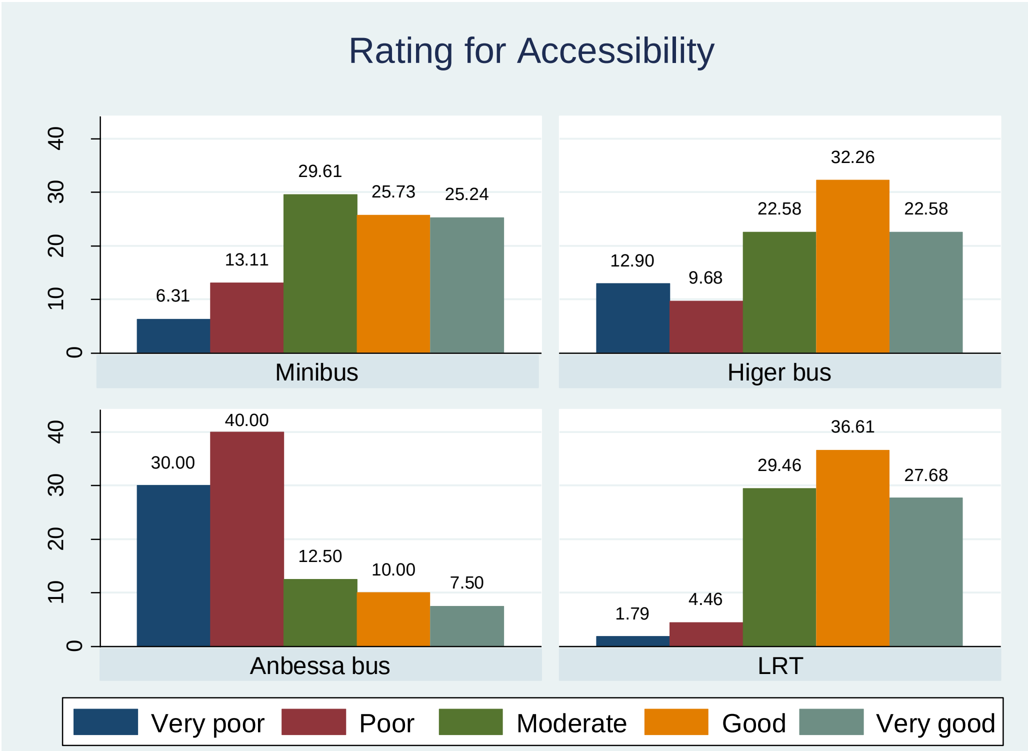

Figure 20: Accessibility rating result

4.4 Mode choice model

In order to study the preference of each mode and to make forecasts, the mode choice model has been developed in the study. The independent variables used in the model and the labels used in the equations are listed in the table below.

Table 11: Label for independent variables

Variable	Label	Unit
Sex	SEX	
Age	AGE	Years
Family size	FS	
Monthly individual income	MII	Birr
Daily trip frequency	DTF	
Peak hour	PH	
Distance	D	Km
Travel time	TT	Minute
Waiting time	WT	Minute
Access time	AT	Km/hr
Cost by distance	CBD	Birr/km

In order to analyze any inter-relation among the proposed independent variables a correlation test has been made and the result is shown in table 12 below. The independent variables are not cross related as the results indicate.

Table 12: Inter-correlation among independent variables

	Sex	Age	Family size	Monthly individual income	Distance	Peak hour	Travel time	Waiting time	Access time	Cost by distance	Daily trip frequency
Sex	1										
Age	-0.172	1									
Family size	-0.016	0.047	1								
Monthly individual income	-0.088	0.326	-0.087	1							
Distance	-0.091	0.038	0.074	0.029	1						
Peak hour	0.047	-0.095	0.074	-0.055	0.047	1					
Travel time	-0.006	0.067	0.086	0.063	0.796	0.118	1				
Waiting time	0.041	0.004	0.025	0.101	0.192	0.030	0.291	1			
Access time	0.024	0.006	-0.041	0.020	-0.054	0.130	0.040	0.131	1		
Cost by distance	0.027	-0.048	-0.131	0.139	-0.41	-0.026	-0.387	-0.184	-0.067	1	
Daily trip frequency	-0.163	0.018	0.059	0.059	0.095	0.023	0.060	0.094	0.0291	0.034	1

Three models are proposed considering different independent parameters. For the first model, only the demographic parameters of the individuals are considered that includes; Gender, Age, Family size and Monthly individual income. In the second model trip characteristics like daily trip frequency, peak hour and distance considered. While in the final model the characteristics of mode are added to that of model-2. The mode characteristics considered are speed, waiting time, access time and cost by distance. The coefficients together with significant levels are shown in table 12 below.

Table 13: Results for mode choice models

Variables	**Higer bus**			**Anbessa bus**			**LRT**		
	Model-1 (β)	Model-2 (β)	Model-3 (β)	Model-1 (β)	Model-2 (β)	Model-3 (β)	Model-1 (β)	Model-2 (β)	Model-3 (β)
Sex	0.129	0.0198	0.0366	-0.619	-0.609	-0.739	-0.489*	-0.560**	-0.769**
	(0.33)	(0.05)	(0.08)	(-1.52)	(-1.49)	(-1.64)	(-1.91)	(-2.10)	(-2.44)
Age	0.366	0.184	1.113*	0.99	0.981	0.656	-0.116	-0.284	-0.241
	(0.61)	(0.3)	(1.78)	(1.64)	(1.56)	(1.05)	(-0.26)	(-0.65)	(-0.45)
Family	0.155	0.19	0.253	0.742**	0.727**	0.685**	0.317	0.346	0.286
size	(1.1)	(1.29)	(1.17)	(2.25)	(2.24)	(2.03)	(0.87)	(0.88)	(0.58)
Monthly	-	-	-	-0.0451	-0.0449	-	-	-	-
income	0.0847***	0.0805***	0.104***	(-1.32)	(-1.31)	0.0705**	0.0531**	0.0525**	0.0760**
	(-2.90)	(-2.74)	(-3.46)			(-2.07)	(-2.01)	(-1.97)	(-2.39)
Daily trip		-1.049**	-		-0.14	-0.421		-	-
frequency		(-2.20)	1.401***		(-0.30)	(-0.89)		0.940***	1.251***
			(-3.05)					(-3.08)	(-3.02)
Peak hour		-0.278	-0.205		-0.0437	-0.0374		-0.488**	-0.282
		(-0.71)	(-0.52)		(-0.12)	(-0.10)		(-2.00)	(-0.97)
Distance		0.103	0.146		0.335	0.186		0.505**	0.455
		(0.28)	(0.43)		(0.86)	(0.44)		(2.02)	(1.46)
Constant	-2.902	-1.452	-4.442*	-	-	-4.675*	-0.104	0.512	1.615
	(-1.50)	(-0.62)	(-1.77)	5.491***	5.967***	(-1.76)	(-0.07)	(0.32)	(0.76)
				(-2.59)	(-2.60)				
The reference category is Minibus									
				For the four Alternative public transports (β)					
Travel time					3.281*** (4.43)				
Access time					-1.030*** (-4.36)				
Waiting time					-1.521*** (-6.36)				
Cost/ distance					-3.060*** (-3.96)				
Pseudo r^2	0.0361	0.0579	0.412	0.0361	0.0579	0.412	0.0361	0.0579	0.412
AIC	879.5	878.2	646.4	879.5	878.2	646.4	879.5	878.2	646.4
chi^2	25.58	48.34	153.6	25.58	48.34	153.6	25.58	48.34	153.6

*t statistics in parentheses *p<0.10, **p<0.05, ***p<0.01*

4.5 The goodness of fit measures

In order to take out the best model among the three models described above some goodness of fit, measures are required. The measures used in the study are Pseudo R-square, loglikelihood, asymptotic t-test. These values for each model are discussed in the paragraphs below.

4.5.1 Pseudo R-square

For ordinary least squares regression, the true R-square is used to show how much the variables in the model explain the dependent variable. Total variability explained by the model is indicated by this model. The more variability explained the better the model. The MNL models are estimates the maximum likelihood estimates arrived at through iterative process. They are not calculated to minimize variance so the ordinary least square approach to goodness of fit doesn't apply. Pseudo R-square has been developed to evaluate the goodness of fit for these models. The similarity of scale 0 – 1 makes them look like R-square. There are some ways of calculating this pseudo-R-square. In this study three of them are presented and listed in Table 13.

Mc Fadden's: the ratio of log likelihood of the full model to intercept model decreases as the model gets better. As shown in the equation below the pseudo-R-square is calculated as one minus ratio of log likelihood and this value increases as the model get better.

$$R^2 = 1 - \frac{ln\hat{L}(M_{full})}{ln\hat{L}(M_{Intercept})} \tag{4.1}$$

Where, $M_{full} = model\ with\ predictor$

$M_{Intercept} = model\ without\ interceptor$

Nagelkerke / Cragg & Uhler's: this value indicates how the model gets improved with predictors. As it can be found from the formula below when the model predicts the probability perfectly the likelihood will be one and so will R-square.

$$R^2 = \frac{1-\left\{\frac{L(M_{Intercept})}{L(M_{full})}\right\}^{2/N}}{1-L(M_{Intercept})^{2/N}} \tag{4.2}$$

Count: this approach transforms the continuous probability variable into a binary variable of zero or one. If the probability calculated is greater than 0.5 its considered as having an output of one and zero otherwise. Then, the predicted values having one that matches the actual one and predicted zero that match actual zero are tallied. This is the number of records correctly predicted, given this cutoff point of 0.5. The R-square is this correct count divided by the total count.

$$R^2 = \frac{\#correct}{Total\ count} \tag{4.3}$$

From the above three models, the third model has the highest R-squares

Table 14: R-square values for models

R-square	Model-1	Model-2	Model-3
Mc Fadden's	0.002	0.003	0.412
Nagelkerke / Cragg & Uhler's	0.087	0.137	0.726
Adj. Count	0.011	0.092	0.688
AIC	879.463	878.230	646.437

4.5.2 Log-likelihood ratio test

The goodness of fit of two statistical models can be compared using log-likelihood ratio test based on likelihood ratio. The likelihood is the probability the data given the parameter estimates. Removing predictors from a model will almost always make the model less fit resulting lower log likelihood. But this change should be statically significant. In order to test this log likelihood ratio can be used.

The null hypothesis for this test is that the unrestricted model (the one with more variables) will not improve the model fit with significant level. The formula for log likelihood ratio is:

$$\begin{aligned} LR &= -2\ ln(L(m1)/L(m2)) \\ &= 2(ll(m2) - ll(m1)) \end{aligned} \tag{4.4}$$

Where, L(m1) and L(m2) is the likelihood for model one (restrictive model) and model two (less restrictive) respectively.

ll(m) is the log likelihood for the respective models.

The LR has a chi distribution with a degree of freedom being the number of variables that are restricted. In Table 14 below the LR for each model with respect to zero model is shown. While the next Tables shows the ratio for model-2 (Table 15) with respect to model-1 and model-3 (Table 16) with respect to model-2.

Table 15: Likelihood ratio test for alternative hypothesis that the models are better than zero coefficient model

Tests	Model-1	Model-2	Model-3
Log likelihood	-424.732	-415.115	-287.219
Likelihood ratio	31.80	51.04	306.83
Significance	0.0015	0.0003	0.0000

Table 16: Likelihood ratio test for alternative hypothesis the model-2 is better than model-1

Variables	Test for hypothesis model-2 is better compared to model-1
Log likelihood of restricted model	-424.732
Log likelihood of unrestricted model	-415.115
LR	19.23
No. of restrictions	4
Significance	0.0233

Table 17: Likelihood ratio test for alternative hypothesis the model-3 is better than model-2

Variables	Test for hypothesis model-3 is better compared to model-2
Log likelihood of the restricted model	-415.115
Log likelihood of the unrestricted model	-287.219
LR	255.79
No. of restrictions	4
Significance	0.0000

The above two tables confirm that the model has fit the data better with the added variables with a good significance level.

4.5.3 The Asymptotic t-Test

These are values seen in the bracket from the table of the model results. From t statistics value we can reject or accept a null hypothesis that the individual variable has no effect on the outcome with a certain level of significance. If the t-statics calculated is higher than the value shown in the table below then null hypothesis can be rejected with the corresponding confidence level shown.

Table 18: Critical t-values for selected confidence interval

Confidence level	Critical t-value
90%	1.645
95%	1.96
99%	2.576
99.5%	2.810
99.9%	3.290

The value of t-statistics has improved from model-1 to model-2 and then model-3. The additional variable also has high t-statics that can allow rejecting the null hypothesis that additional explanatory from model-2 and model-3 don't affect the outcome.

Taking the above model fit measures and the low ACI value observed, model-3 is taken as the optimal model for the study. And it is shown in Table 18 below.

Table 19: The selected model

Variables	**Higer bus**	**rrr (exp β)**	**Anbessa bus**	**rrr (exp β)**	**LRT**	**rrr (exp β)**
Sex	0.0366 (0.08)	1.04	-0.739* (-1.64)	0.48	-0.769** (-2.44)	0.46
Age	1.113* (1.78)	3.04	0.656 (1.05)	1.93	-0.241 (-0.45)	0.79
Family size	0.253 (1.17)	1.29	0.685** (2.03)	1.98	0.286 (0.58)	1.33
Monthly individual income	-0.104*** (-3.46)	0.90	-0.0705** (-2.07)	0.93	-0.0760** (-2.39)	0.93
Daily trip frequency	-1.401*** (-3.05)	0.25	-0.421 (-0.89)	0.66	-1.251*** (-3.02)	0.29
Peak hour	-0.205 (-0.52)	0.81	-0.0374 (-0.10)	0.96	-0.282 (-0.97)	0.75
Distance	0.146 (0.43)	1.16	0.186 (0.44)	1.20	0.455 (1.46)	1.58
Constant	-4.442* (-1.77)		-4.675* (-1.76)		1.615 (0.76)	
The reference category is Minibus						

For the four Alternative public transports

	β	**rrr (exp β)**
Travel time	3.281*** (4.43)	26.60
Access time	-1.030*** (-4.36)	0.36
Waiting time	-1.521*** (-6.36)	0.22
Cost by distance	-3.060*** (-3.96)	0.05

*t statistics in parentheses *p<0.10, **p<0.05, ***p<0.01*

Demonstration on the optimal model

To see how much the model is usable and the possibility of using it to other samples this section is committed to testing the model ability in determining mode choice of individuals within the sample. This is a self-explanatory procedure and it will be more powerful if it was used with the different sample but this is out of the scope of this study. In Table 20 random samples are taken and the choice probability found from the developed model is cross-checked with the actual choice made by individuals. From the result, it can be concluded that the model is powerful in determining mode choice as probability calculated is highest for selected modes and it may be applied to other samples in the study corridor.

Table 20: Model validation

Model validation			
Mode choice probability (from the model)	Trip maker	Modes	Choice (actually made by individuals)
.1211078	1	Anbessa bus	0
.0430167	1	Higer bus	0
.1539504	1	LTR	0
.6819251	1	Minibus	1
.7355638	2	Anbessa bus	1
.0185034	2	Higer bus	0
.1207159	2	LTR	0
.1252171	2	Minibus	0
.0014924	3	Anbessa bus	0
.0014642	3	Higer bus	0
.0043818	3	LTR	0
.9926616	3	Minibus	1
.0269935	4	Anbessa bus	0
.0256576	4	Higer bus	0
.6271089	4	LTR	1
.32024	4	Minibus	0
.0299043	5	Anbessa bus	0
.5676455	5	Higer bus	1
.104643	5	LTR	0
.2978071	5	Minibus	0
.1039263	6	Anbessa bus	0
.127428	6	Higer bus	0
.4093655	6	LTR	1
.3592802	6	Minibus	0

4.6 Model interpretations and policy implications

Although a thorough interpretation cannot be made using the coefficients of MNL models they still can be used to draw out some conclusions. From the signs of these coefficients the relationship, whether positive or negative, the independent variable has with dependent can be explained. The signs should align with theory and judgment. The numerical effects regressors have on outcome variable can be addressed more with log odd (exp β), which is also known as a relative risk ratio. This is a risk of outcome relative to the base outcome. The interpretation of case-specific variable coefficients for the MNL model is made by taking one dependent variable as a reference. The reference mode selected in the analysis is Minibus. Therefore, all the interpretations are made in reference to Minibus. The interpretation is discussed below for each variable.

Gender

The variable Gender has been coded 0 for male and 1 for female. The estimated probabilities for gender have a negative sign for Anbessa bus and LRT while its positive for Higer bus in Table 17 with respect to the reference mode i.e., Minbus. Meanwhile, the probabilities for Anbessa bus and LRT are statistically significant at 10% and 5% level, respectively. This indicates that being a female traveler will reduce the probability of using Anbessa bus and LRT by 0.48 and 0.46 respectively, compared to using a Minibus.

Female travelers prefer the expensive transport mode (minibus) despite the existence of relatively cheaper ones. This could be associated with the inconvenience of easily accessing modes at the station compared to males.

Age and Family size

The estimates for age is not statistically significant Anbessa bus and LRT while it has 10 percent significant for Higer bus. It shows a negative value for LRT while positive for Anbessa. Increase in age of individual will increase the probability of choosing Higer bus by 3.04 than a minibus. Similarly, family size has statistically insignificant and positive estimates for Higer bus and LRT while Anbessa has a positive estimate with 5% significance level. The increase in family size will increase the probability of choosing Anbessa bus by 1.98 than Minibus.

Monthly individual income

The estimated coefficient for traveler's income is negative in each of the three modes having a statically significant estimate 1% for Higer bus and 5% for Anbessa bus and LRT. This indicates that an increase in monthly income by one birr per month will reduce the probability of using Higer bus, Anbessa and LRT by 0.90, 0.93 and 0.93, respectively compared to using Minibus. Notably, the compared estimates for Higer bus could suggest that there will be a higher tendency of preferring Minibus than Higer bus when compared with the rest two modes because of the similarity of fare between the two modes.

The overall estimates indicate that whenever travelers' income increases the choice for a mode which is convenient in terms of access, comfort, speed and waiting time is preferred. Given the negative externalities associated with a larger number of minibusses (such as environmental pollution, traffic congestion), the public sector should improve accessibility, speed and minimize waiting time for Higer and Anbessa buses so that a rise in income will not shifts travelers' mode choice towards minibus.

Daily trip frequency

The coefficients for daily trip frequency are negative for all three modes with a statistical significance of 1% level for Higer bus and LRT. The estimates indicate that if a daily trip frequency is increased by a unit the probability of choosing Higer bus and LRT will be reduced by 0.25and 0.29respectively.

For travelers that afford using modes for high-income group using minibus is the 1st option for increased daily trip frequency. If the daily trip frequency is associated with the income generating activity, then those travelers using Higer bus (medium income group) will decline compared to Minibus.

Peak hour and Distance

The estimated coefficients for peak hour showed negative estimates for all modes with no statistical significance. Accordingly, when the trip is made during the peak hours then the probability of using Higer bus, Anbessa and LRT when compared with Minibus.

Since there is a higher demand for all modes during the peak hour in addition to the high value of time in this hours, most travelers prefer to use relatively easily accessible but the expensive mode, i.e., minibus.

Coefficients for distance are positive for all modes showing an increase in the probability of choosing Higer bus, Anbessa bus and LRT with respect to Minibus. However, these estimates have no significant level.

Travel time

The estimated coefficient for travel time is positive for Anbessa bus and Higer bus and LRT with 1% significance level having an odd ratio of 26.6.

Access time

The estimated coefficient for access time indicates negative relation of access time with probability of mode choice. 1% significant level and an odd ratio of 0.36 is reported in the result.

Waiting time

The estimated coefficient for waiting time is negative having a 1% significance level. An increase in waiting time will decrease the probability of mode choice by 0.22.

Cost by distance

The sign for the coefficient of cost by distance indicates a negative relation of cost with mode choice. The estimated coefficient has 1% significance level and an odd ratio of 0.05.

5 Conclusions

This study examined currently competing public transports on the road corridor from Megenagna to Ayat. Using 391 survey samples data required to fit logit model for mode choice have been collected. Comfort, safety and accessibility of the transport modes were rated by public transport users. Case-specific variables (i.e. sex, income, family size, age, daily trip frequency and peak hour) and alternative specific variables (i.e. travel time, waiting time, access time and cost by distance) were used to study the preference of people in choosing public transport modes.

The highest share of respondents (52.7%) use minibus as the primary mode of public transport. On the other hand, Anbessa bus has the highest percentage (39%) of people who don't want to use it as a means of transport. The major reasons not to use Anbessa bus are comfort (30%), low speed (28%) and low safety (24%). And 93% of respondents expressed their willingness to use the mode if the above-mentioned problems are solved. The result from logit model showed that sex, age, family size, monthly income, daily trip frequency, travel time, access time, waiting time and cost by distance affect mode choice significantly. Females tend to use minibus than Anbessa bus and LRT. Increasing income will affect the choice of Higer bus, Anbessa bus and LRT negatively with a high significant level. The mode attributes (i.e. access time, waiting time and cost by distance) also have a significant negative effect on mode choice.

Female travelers prefer the expensive transport mode (Minibus) despite the existence of relatively cheaper ones like Anbessa bus and LRT. This could be the inconvenience these modes create to access and use them. By improving the comfort and quality of these transport modes a considerable increase of Anbessa bus and LRT users can be attained. While the extra money females pay for transportation will reduce at the same time.

The overall estimates indicate that whenever travelers' income increases the choice for a mode which is convenient in terms of comfort, access and waiting time is preferred (i.e. Minibus). Given the negative externalities associated with a larger number of minibusses (such as environmental pollution, traffic congestion), the public sector should improve accessibility, speed and minimize waiting time for Higer and Anbessa buses so that a rise in income will not shifts travelers' mode choice towards minibus.

Waiting time, access time and cost by distance have a high significant negative effect on mode choice. And among the alternatives, Anbessa bus has the highest waiting time. Tremendous increase of Anbessa bus users can be achieved if more buses are provided to reduce waiting time. The same applies with accessibility, by increasing the special cover of Anbessa bus more users can be achieved. However, comfort should be the major concern that Anbessa bus operators should address since the majority of respondents reported that they don't use Anbessa bus because of its low comfort. And this can also be the cause that increasing income is demotivating people to select this mode.

6 Recommendations

Incentives like subsidizing public transport sector to increase the proportion of large public transports users should be considered by the government as mode choice is highly affected by the cost of the transport. The government should also work on the quality of large public transports more in order to gain more users.

The environmental benefits and congestion minimization effect of using large buses instead of Minibus should be investigated in more detail.

Public transport modes as a whole will benefit if modal shift can be achieved from private cars while benefiting the environment as well. This study focused only on public transport and more studies shall be conducted to address the mode choice behavior of private cars and mode shifting from private cars to public transport.

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Appendices A: Questionnaire

Dear Participants፡-

The purpose of this research is to collect necessary data that will be used to improve the public transport and satisfy its customers. The research will also be used for a paper work of master's degree in Addis Ababa Institute of Technology. All the information you will provided will only be used for the purposes mentioned and is secured. Thank you in advance for your cooperation.

Note: Please put the "√" sign on the space provided
Part one: General information on the transport user

1. Gender ☐ male ☐ female
2. Age________________________
3. Family size________________________
4. Monthly income____________________

Part two: Information on transport facilities

5. Do you use public transport? Yes No ☐ ☐
6. Which public transport do you use frequently? (choose just one)
   - ☐ Minibus ☐ Higer bus
   - ☐ Anbessa Bus ☐ LRT
7. Which public transport do you avoid using mostly (you can choose more than one)
   - ☐ Minibus
   - ☐ Anbessa Bus
   - ☐ Higer bus
   - ☐ LRT

8. What is the reason behind avoiding the transport means you selected above (you can choose more than one)

Minibus	Anbessa Bus	Higer bus	LRT
☐ Low speed	☐ Low speed	☐ Low speed	☐ Low speed
☐ Long waiting time	☐ Long waiting time	☐ Long waiting time	☐ Long waiting time
☐ Low comfort	☐ Low comfort	☐ Low comfort	☐ Low comfort
☐ Not Safe	☐ Not Safe	☐ Not Safe	☐ Not Safe
☐ High fare	☐ High fare	☐ High fare	☐ High fare
☐ No reason	☐ No reason	☐ No reason	☐ No reason
Other______	Other ______	Other ______	Other ______

9. Will you choose to use the transport mode if the above-mentioned problems are solved?

   ☐ yes

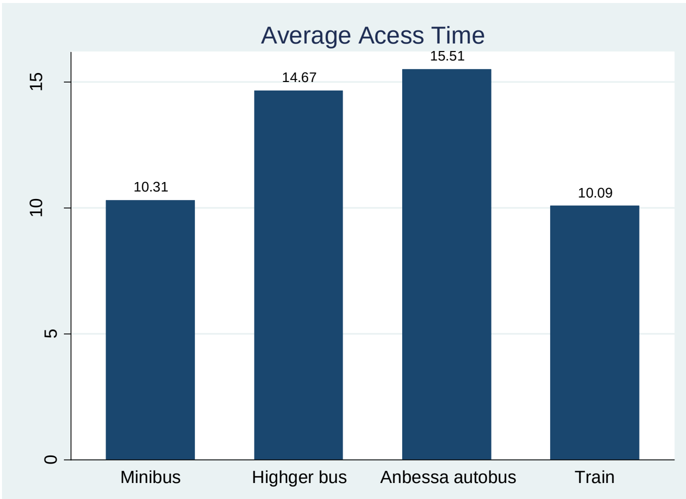
   ☐ No

10. Origin and destination of your trip_____________________________________
11. How many minutes do you travel from origin to destination using the mode you choose? ________
12. On average how many minutes do you wait the transport mode? ____________
13. how long does it take you, in minute, to get the transport service from your house? _________
14. how much do you pay per day on average to use the transport mode you choose? _________
15. On average, how many times do you use the transport per day?_______
16. The time you use the public transport mostly
    - ____ O'clock am to ____ O'clock am
    - ____ O'clock am to ____ O'clock pm
    - ____ O'clock pm to ____ O'clock pm

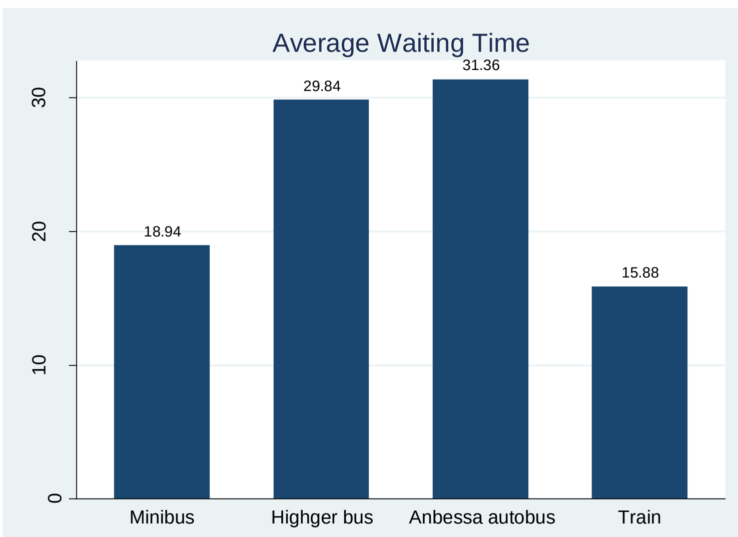
17. Please circle the answers that best describe the mode's characteristic for you

Modes	Parameter	Very poor	Poor	Moderate	Good	Very good
Minibus	Comfort	1	2	3	4	5
	Safety	1	2	3	4	5
	Accessibility	1	2	3	4	5
Anbessa Bus	Comfort	1	2	3	4	5
	Safety	1	2	3	4	5
	Accessibility	1	2	3	4	5
Higer Bus	Comfort	1	2	3	4	5
	Safety	1	2	3	4	5
	Accessibility	1	2	3	4	5
LRT	Comfort	1	2	3	4	5
	Safety	1	2	3	4	5
	Accessibility	1	2	3	4	5

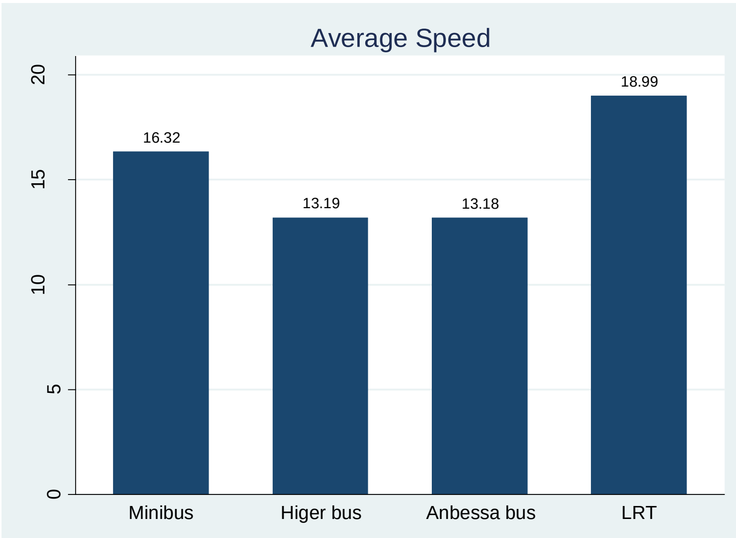
Appendix B: mean access time of each mode



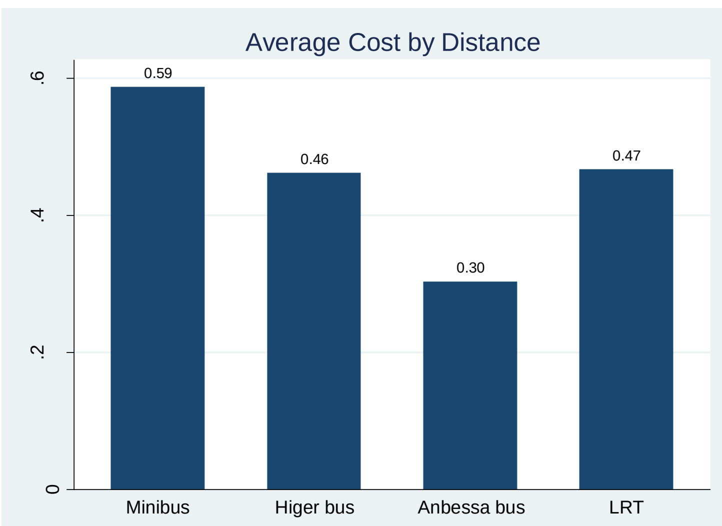
Appendix C: mean waiting time of each mode



Appendix D: mean speed of each mode



Appendix E: mean cost by distance of each mode



Appendix F: Sample daily report from ERC

AALRT - Operation Daily Report East-West line		Page 1
	Date	`15/09/2017
	PART1	
General Data		Unit
Number of services(trains/trips) to be operated (Time Table) in peak hours	94	N°
Number of services (trains/trips) to be operated (Time Table) in flat hours	30	N°
Number of services (trains/trips) operated (actual) in peak hours	90	N°
Number of services (trains/trips) operated (actual) In flat hours	30	N°
Train Km (AALRT definition)	3793	Trkm
Number of Cancellations	4	N°
Planned interval between trains during peak hours (time table)	15	min
Planned interval between trains during flat hours (time table)	20	min
Number of coupled train-sets on duty during peak hours (actual)	7	N°
Number of single train-sets on duty during peak hours (actual)	1	N°
Number of coupled train-sets on duty during flat hours (actual)	5	N°
Number of single train-sets on duty during flat hours (actual)	1	N°

Appendix G: Sample daily report from AATMA

የተሸከርካሪው አይነት																									
ተ.ቁ	ክፍለ ከተማ	ኮድ 1 ሚኒባስ			ኮድ 3 ሚኒባስ			ሃይገር			ቅጥቅጥ			ጧትና ማታ በድጋፍ ሰጪነት የሚሰጡ						አሊያንስ			አንበሳ መደበኛ		
														ፌዴራል ትራን.			ልዩ አንበሳ								
		እቅድ	ክንውን	%	እቅድ	ክንውን	%	እቅድ	ክንውን	%	እቅድ	ክንውን	%	እቅድ	ክንውን	%	እቅድ	ክንውን	%	እቅድ	ክንው	%	እቅድ	ክንው	%
1	ልደታ	211	107	51%	568	184	32%	13	8	62%	29	5	17%	9	0	0%				25	4	16%	723	137	19%
2	ኮልፌ	478	373	78%	554	481	87%	109	35	32%	30	27	90%	6	3	50%	1	0	0%						
3	አ/ከተማ	372	221	59%	500	403	81%	22	16	73%	27	19	70%				3	3	100%						
4	ጉለሌ	790	532	67%	430	405	94%				5	2	40%				3		0%						
5	አራዳ	348	355	102%	425	155	36%	33	35	106%	30	6	20%	10	0	0%	10	10	100%						
6	ቂርቆስ	853	373	44%	539	183	34%	52	24	46%	47	2	4%	23	2	9%	4		0%						
7	ቦሌ	855	707	83%	926	674	73%				7	1	14%	13	0	0%	1	0	0%						
8	የካ	1150	349	30%	920	198	22%	173	16	9%	24	11	46%	32	0	0%									
9	አ/ቃሊቲ	512	295	58%	422	376	89%	162	103	64%	95	102	107%	4	5	125%	6	2	33%						
10	ን/ላፍቶ	669	486	73%	568	379	67%							4	3	75%									