ADDIS ABABA UNIVERSITY
ADDIS ABABA INSTITUTE OF TECHNOLOGY

SCHOOL OF MECHANICAL AND INDUSTRIAL ENGINEERING

GRADUATE PROGRAM IN RAILWAY ENGINEERING

ANALYSIS OF PASSENGER DEMAND FORECASTING MODELS IN THE CONTEXT OF AALRT

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And

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A Thesis submitted to the School of Graduate Studies of Addis Ababa University in partial fulfillment of the requirements for the Degree of Masters of Science in Mechanical Engineering **(Railway stream)**

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Declaration

I hereby declare that the work which is being presented in this thesis entitled "Analysis Passenger Demand forecasting Models in the Context of AALRT" is original work of my own, has not been presented for a degree in any other university; and that all the sources of the material used for the thesis have been duly acknowledged.

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ABSTRACT

High rate growth of population and economic activity of Addis Ababa increases the traffic flow of the city and results in high congestion of traffic and unbalance between the demand and mode of transport. To minimize this congestion of traffic and unbalance appropriate passenger demand forecasting model is needed. So, this study tries to fill this gap.

To select a suitable rail passenger demand forecasting model the two most common rail passenger demand forecasting models are compared based on their limitation and delimitation in the context of AALRT. According to this comparison the four stage passenger demand forecasting is found better than the elasticity passenger demand forecasting model for new rail service. Then, the analysis of estimating of passenger demand forecasting has been done by using the four stage passenger demand forecasting model.

The four stage model has trip generation, trip distribution, mode choice or modal split and trip assignment stages. The study analysed through the first three stages because AALRT has only one line to travel from origin to destination of the trip maker.

So, in this study the data analysis has been based on the data collected from different sources (like central statistics agency, city government of Addis Ababa education bureau, etc.). The data analysis result shows 11,666,568 trips are generated in Addis Ababa and 876072 total trips are generated in Kirkos sub city in the generation step; the generated trips in Kirkos has distributed into neighbor sub cities of Kirkos and in itself (Kirkos, Arada, Lideta, Bole Nifas Silk Lafto and Yeka is 662986.8, 6694, 66086, 33324, 24023 and 57766 respectively); choose the best transport mode to travel from origin zone to the destination zone.

As the finding of this thesis shows that the four stage rail passenger demand forecasting model is a better model in the context of AALRT. Finally the study recommended for ERC and other organizations to use four stage passenger demand forecasting model to estimate their demands.

Key words: AALRT, passenger demand forecasting, four stage model

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LIST OF ABBREVIATION

4SM	Four stage model
AALRT	Addis Ababa Light Rail Transit
CGAAEB	City Government of Addis Ababa Education Bureau
CSA	Central Statistics Agency
ERC	Ethiopian Railways Corporation
GDP	Gross Domestic Product
HB	Home-Based
LRT	Light Rail Transit
MOPs	Metropolitan Planning Organization
NHB	Non-Home-Based
O-D	Origin Destination

CHAPTER ONE

1. INTRODUCTION

Rail passenger demand forecasting is an activity of estimating the number of passengers selecting to travel by train and where they travel to and from. To address the activity of estimating the number of passengers different rail passenger demand forecasting models are used accordingly. So, the purpose of thesis work is assessing through the models to select the suitable one in the case of AALRT and analysing of the data by using the selected model.

The structure of this thesis is as follows. The first chapter describes about the introduction, background of the study, the statement of the problem, research questions, objectives, scope and limitation of the research. The second chapter covers literature review dealing with an overview of demand, passenger demand forecasting models and assessing on passenger demand forecasting models. The methodology and data collection and analysis is described in third chapter. The fourth chapter deals with the data analysis and interpretation of the study.

Finally the last chapter covers about the conclusion and recommendation of the study paper.

1.1. Background

The movement of people, freight and information, has always been an essential component of all human societies. Mobility can be provided by modes of transportation like walking, cycling, public transit, private vehicles or ridesharing, train and other modes. Access is the ultimate goal of any transportation mode. Accessibility indicates the ease of reaching any land use activity from a particular location, using a particular transport system.

As we know that the transport is the problem for many developing countries because of Economic problem this includes the problem of having a vehicle, fuel price, and the need of paying for a trip.

Infrastructure these include the kind of road we are using and also the distance of the trip we made i.e. the distance of where we live, where we work, where we learn, where we entertain and others. And also comes because of population growth (i.e. the rate at which the population grow, the need to go from one to another in some other reasons).

Since the need to work, learn and other journey of people has been increased therefore the need to predict future demand of transport and using different ways of mode has a significant role and will also enhance the people to choose an alternative of using transport (Hassan, 2007).

Urban transportation is one of the fundamental infrastructure for systematic growth of any urban settlement. With the growing business trade and urbanization all over the globe, there is a growth in demand for transportation. Individual mode of transportation causes problems due to this immense growing demand and the inadequacy of the supply of transport facilities. This imbalance between capacity or supply of transport facilities and the increasing demand from people causes an unmanageable condition. Traffic congestion, travel delays and dissatisfaction amongst the travelers are all the result of this imbalance.

Passenger transportation by railway historically plays an important part in the national economies; therefore the strategy of the railway transport development is always aimed at ensuring the high-quality population transportation. On the other hand, development of a transparent and efficient business - passenger transportation model - becomes the essential element of current reforms in the railway transport. The competitive ability of this branch mainly depends on dealing with problems of cross-financing and governmental subsiding of the railway transport complex. That’s why the problem of expenditure and income gained from the passenger transportation by railway and improvement of the control system aimed at efficiency of passenger transportation becomes of especial urgency (Hanibal, 2008).

The efficient management of any company requires planning, whether it is public or private, industrial, the retail sector, or services. In order to be effective, it is necessary to have expectations of the future conditions under which the company will operate and of as if they relate the elements this expectation. The manager of a railroad, in order to make the right decisions, must know the expectation of transport growth in order to put in place the necessary equipment and the man power, and also what the main factors are that affect this demand and the supply capacity of the arrival and departure terminals.

According to Tibletse Tefera’s study, Addis Ababa passengers are still serviced by public and private city bus and taxes. The rapid urbanization of the city coupled with socio-economic development has posed numerous Transportation challenges and this include insufficient public transport service, inadequate transport planning practice , lack of travel demand analysis and weak traffic management system (Tibletse, 2012).

1.2. Statement of the problem

Lack of travel demand analysis and in some cases the weaknesses of conducted analysis limit the effectiveness of transportation policies and actions in managing the excessively growing urban traffic in the developing world (Samiul).

As pointed out by (Pickrell, 1990) and (Richmond, 1998), estimates of the financial viability of projects are heavily dependent on the accuracy of traffic demand forecasts. Such forecasts are also the basis for socioeconomic and environmental appraisal of transportation infrastructure projects. According to the experiences gained with the accuracy of demand forecasting in the transportation sector, covering traffic volumes, spatial traffic distribution, and distribution between transportation modes, there is evidence that demand forecasting like cost forecasting, and despite all scientific progress in modeling is a major source of uncertainty and risk in the appraisal of transportation infrastructure projects.

Ethiopian Government has built a Light Rail Transit in Addis Ababa city, since the city is new to the Light Rail Transit (LRT) technology the traffic growth and transportation planning should be done and it is achieved by estimating the current and future possible number of passengers trips.

Even though, the estimation was done and the number of trains assign proportional to the passenger demand there is unbalance between passengers demanding for transport and transport mode that was already assigned by AALRT.

This unbalance may come due to the passenger demand forecasting model and considering criteria during forecasting.

Therefore, this paper tries to select a better passenger demand forecasting model to solve the above challenges.

1.3. Research questions

- Which passenger demand forecasting modeling is more suitable for AALRT case?
- What are the factors to be considered for carrying out passenger demand forecasting?

- How well the selected demand forecasting model works in the context of Addis Ababa light railway train?

1.4. Objective

General objective

The General objective is to select suitable passenger demand forecasting model for Addis Ababa light rail train for current and future possible trips made by passengers on Light Rail Transit (LRT) routes based on strengths and limitations (weaknesses) of passenger demand forecasting models in the case of AALRT.

Specific objective

- To asses different passenger demand forecasting models.
- To select better passenger demand forecasting model for AALRT.
- To estimate how many trip will be generated by using selected model.
- To compare train to other mode of transportation (like bus, taxi) by using selected model.

1.5. Scope and limitation of the study

Scope of the study

The scope of this paper is selecting better passenger demand forecasting model by comparing different models based on their limitation and delimitation and tries to contextualize in Addis Ababa Light Rail Train (AALRT). And also doing numerical analysis using the selected passenger demand forecasting model for AALRT.

Limitation of the study

- Numerical analysis does not include the migrants and tourists in the city because of absence of data.
- The trip distribution has made from Kirkos to neighbor sub cities.

CHAPTER TWO

2. LITERATURE REVIEW

2.1. Demand

(Ortuzar & Wilumsen, 2011) States that transport is a derived demand and not an end by itself. Supply of transport is service and not a good; it is not possible to stock it. Transport service need to be consumed as produced; otherwise, its benefits would be lost. For this reason, it is very important to estimate demand with accuracy as much as possible to optimize resources of transport supply. The demand for transport is highly differentiated and quantifiable; differentiated by time, purpose, type of cargo, speed and frequency and so on. Transport modelling is not transport planning; but it supports and sometimes plays an important role in transport planning (Ortuzar & Wilumsen, 2011).

According to (Gunduz, Ugur, & Ozturk, 2010) Public transportation and transit become one of the most important infrastructural investments. The most efficient solutions to public transportation are light rail train (LRT) and metro systems. Considerable gap in terms of the availability of the length of LRT or Metro line per citizen between developed and developing countries. Government make a huge investment in above mentioned public transportation system to compensate this gap. At this point, a precise early cost estimation of this system while taking investment decision become more critical for many parties including owner. The accuracy of estimation of construction cost as a critical factor for determining the success of project. So in this research study contrasts from other in literature by its introduction in to early cost estimation on track work.

(Puchalsky, 2005), has presented a paper on comparison of emissions from Light Rail Transit and Bus Rapid Transit system

Nowadays, the existing system of a transport service based on the transportation by roads cannot satisfy the increasingly growing needs of consumers' transportation. The railway transport is safer, much more environment-friendly, more efficient than car transport.

The demand for transport is derived, it is not an end in itself. With the possible exception of sightseeing, people travel in order to satisfy a need (work, leisure, health) undertaking an activity at particular locations.

In order to understand the demand for transport, we must understand the way in which these activities are distributed over space, in both urban and regional contexts. A good transport system widens the opportunities to satisfy these needs; a heavily congested or poorly connected system restricts options and limits economic and social development.

The demand for transport services is highly qualitative and differentiated. There is a whole range of specific demands for transport which are differentiated by time of day, day of week, journey purpose, type of cargo, importance of speed and frequency, and so on. A transport service without the attributes matching this differentiated demand may well be useless. This characteristic makes it more difficult to analyse and forecast the demand for transport services: tone and passenger kilometres are extremely coarse units of performance hiding an immense range of requirements and services (Ortuzar & Wilumsen, 2011).

2.2. Forecasting

Demand forecasting is the activity of estimating the quantity of a product or service that consumers will purchase in the future. For railways, this will usually be estimating the numbers of passengers opting or selecting to travel by train and where they travel to and from.

2.3. Forecasting Model

As concluded by (Furnish & Wignall, 2009) models are required in order to develop effective and lasting transport policies and strategies. These models will be most effective if a wide range of transport professionals have access to modelled outputs to inform and support policy and strategy development.

According to the view of Ortuzar and Willumsen a model can be defined as a simplified representation of a part of real world, the system of interest concentrate on certain elements considered important for its analysis from a particular point of view. Models are, therefore, problem and viewpoint specific. Such a broad definition allows us to incorporate both physical and abstract models (Ortuzar & Wilumsen, 2011).

Models are representation of reality that can be used to explore the sequence of particular policies or strategies. Models are deliberately simplified in order to keep them manageable and avoid extraneous detail while hopefully encapsulating the important (determining) features of the system interest. The reason for using models is to estimate the likely outcomes more quickly at lower cost and risk than would be through implementation and monitoring. A model will ideally produce an accurate forecast, at minimum cost in terms of data and computing resource (O'Flaherty & et.al, 2003).

The art of modelling consists of fundamentally of trading off accuracy requirements on one hand against resource on the other hand. Most models are based on the premise that, by observing the past or current behavior of system or individuals, one can infer rules which determine the behavior and then use those rules to predict unobserved behavior. The process of what rules to include in the model is Specification, and the process of reproducing what is being observed is Calibration, and to check for result against time and place is Validation (O'Flaherty & et.al, 2003).

With the increase in travel demand and traffic management problems, travel demand forecasting models are being employed increasingly to make informed decisions about the operational improvements to the existing transportation system and the design and performance of future transportation systems (Hanibal, 2008). According to Hannibal, the main advantage of using travel demand forecasting models for such purposes is that they are capable of capturing the interactive effects of different components of the system under study. For that, they provide a mechanism to predict the impact of various policies on travel. The modeling sophistication ranges from simple mathematical formulae to complex modeling software. In view of the developments in modeling approaches, several authors have been of the opinion that some of the approaches appear to be promising for application to cities in developing countries. However, it is also well known that none of the state of the art of modeling as well as state of the art of practice is free from some limitations (Hanibal, 2008).

According to (O'Flaherty & et.al, 2003),view the ongoing concerns of modelers to produce accurate model has resulted in continued attempt to develop models which accord with the insight revealed by behavioral research over the last decades. Such researches include individual activity schedule, the existence of non-compensatory decision making and the role of inertia habit in determining daily behavior.

Travel is one of many attributes of an activity. In conventional approaches, activity attributes such as the mode used and travel time consumed in accessing an activity are treated as travel attributes and are focus of descriptive and predictive models (with other activity attribute besides activity type being ignored). From this perspective conventional, trip-based, models are simply a special case of activity-based approaches. Though the activity approaches lack solid theoretical basis, with diverse theoretical, methodological, and empirical approaches used (McNally, 2000).

The activity base methods and approaches include theme of travel is derived from activity participation; sequence of behavior not individual trip relevant for analysis; house hold and other social structure influence travel and activity behavior; spatial, temporal, transportation and interpersonal interdependencies influence activity/travel behavior, and it reflects scheduling of time and space (McNally, 2000).

2.4. Decision Making

Before choosing a modelling framework one needs to identify the general decision-making approach adopted in the country, government or decision unit. It must be recognised that there are several decision-making styles in practice and that not all of them use modelling as a basic building block. In practice, no decision-making style fits any of these categories exactly. This time, we would just like to distinguish two different paradigms: 'substantive rationality' and 'muddling through', following the lines of the very important book by (Kay, 2010).

The *substantive rationality* view of the world assumes that we know what our objectives are and we can envisage all alternative ways of achieving them and, with some luck, quantify the costs and benefits associated to each approach. This would apply to important decisions like choosing a place to live.

The *muddling through* is a disciplined process but not one based on the substantive rational handling of defined objectives. The approach uses a combination of high-level (often unquantifiable) objectives, intermediate goals and immediate actions or experiments (Lindblom, 1959).

2.5. Methods of Choosing Modelling Approach

According the view of (Furnish & Wignall, 2009) it is important to follow an ordered process when considering model selection, to:

- Clearly establish the task purpose, objectives, issues and outcomes to be addressed.
- Identify data, analytical and assessment requirements.
- Review the potential for different types of model to support task requirements.

According to the point view of (Ortuzar & Wilumsen, 2011) the acceptability of modelling, or a particular modelling approach, within a decision style is very important. Models which end up being ignored by decision makers not only represent wasted resources and effort, but resulting frustrated analysts and planners. It is further proposed that there are several features of transport problems and models which must be taken into account when specifying an analytical approach:

a. **Precision and accuracy required**.

   Precision it shows that the level or units of measurement used to collect data and deliver model outputs.

   Accuracy which means degree to which a measurement or model result matches true or accepted values. Accuracy is an issue pertaining to the quality of data and model.

b. **The decision-making context**.

   This is the adoption of a particular perspective and a choice of a scope or coverage of the system j of interest. The choice of perspective defines the type of decisions that will be considered: strategic issues or schemes, tactical (transport management) schemes, or even specific operational problems. The decision-making context, therefore, will also help define requirements on the models to be used, the variables to be included in the model, or considered given or exogenous.

c. **Level of detail required**

   The level of resolution of a model system can be described along four main dimensions: geography, unit of analysis, behavioural responses and the handling of time.

d. **The availability of suitable data**

   Their stability and the difficulties involved in forecasting their future values. In some cases very little data may be available; in others, there may be reasons to

e. **The state of the art in modelling**

For a particular type of intervention in the transport system. This in turn can be subdivided into:

- behavioural richness;
- mathematical and computer tractability;
- availability of good solution algorithms

f. **Resources available for the study**

These include money, data, computer hardware and software, technical skills, and so on. Two types of resource are, however, worth highlighting here: time and level of communication with decision makers and the public.

g. **Data processing requirements**

This aspect used to be interpreting the data

h. **Levels of training and skills of the analysts**

i. **Modelling perspective and scope**

Formalize decision-making contexts using a two-dimensional framework: the level of analysis and the perspective.

2.6. Assessing of Forecasting Models

Based on the idea of transport analysis guidance there are two principal approaches to modeling of rail passenger demand. These are models have been developed explicitly to estimate the overall demand for travel and to consider the impact of potential intervention across the transport system as a whole (TAG, April 2009).

So, in this section the two passenger demand forecasting models (elasticity model and four stage model) that have been selected to assess based on the following reasons.

- They are most commonly used in the world
- Based on methods of choosing modeling approach

1. Elasticity Model

The definition of elasticity modelling is the ratio of percentage change in one variable to the percentage change in another variable. Rail forecasts have traditionally been prepared using an incremental elasticity-based modelling approach. In this modelling approach, historic evidence is used to determine a statistical relationship between the observed demand for travel (in this case rail services) and a range of variables representing those factors that affect rail passenger demand (TAG, April 2009).

Factors affecting rail passenger demand for elasticity modelling approach can be divided into

1. Exogenous (background) changes to rail demand that are caused by factors assumed to be outside the direct control of the rail industry
2. Endogenous (scheme or policy-related) initiatives which are assumed to be within the direct control of the rail industry.

   Exogenous and endogenous factors:

   Exogenous:

   - GDP or employment
   - Car ownership (e.g. maintenance fuel)
   - Population
   - Cost of travel by other modes (e.g. bus, taxi, rail)
   - Journey time by other modes
   - Availability of other modes

   Endogenous:

   - Rail fares
   - Rolling stock
   - Crowding
   - Punctuality/reliability of rail services
   - Rail journey time

   According to the (TAG, April 2009) report the following points considered when we using the elasticity modelling approach:

   - ✓ It is an approach used to consider the demand for travel on a mode-by-mode basis, that is to say, it has a very limited representation of other modes;
   - ✓ Models based on the elasticity approach are relatively simple to use as one does not require any data for factors which remain constant through time; and
   - ✓ Although most rail forecasts are commonly prepared using this method, use this incremental approach, a base demand figure (i.e. historical observed demand) is

required. Therefore, it is unlikely to be appropriate for forecasting demand for new stations and passenger services where there is no history of demand.

According to the view of (Preston, 1991) elasticity model is inapplicable to the case of new rail stations and services for at least two, closely related reasons. (1) Elasticity model is only applicable where changes are marginal. The introduction of a new rail service is clearly non-marginal. (2) Elasticity models is applied incrementally around the base level of demand. A problem here is that for local rail services, assuming a reasonably fine zoning system, zones with no nearby rail station can have zero base demand.

2. Four Stage Model

Many models in wide spread use can be traced back to the early day of transport modelling. A notable development in USA in the 1960s was the so called four stage model (4SM)/sequential travel demand model. But 4SM was criticized for its sequential structure and amount of data required running the complete suite (O'Flaherty et al, 2003).

The structure of the four-stage model has changed little since the 1960s, although within that framework there have been considerable advances in modelling techniques, not least as a result of significant increases in available computing power (Ortuzar & Wilumsen, 2011).

As the explanation of (John & Russels, 2010) the outset the transport system is simplified into a series of links (representing the various available networks) and zones (where trips begin and end).

The general definition and purpose of each step is as follows:

Trip generation: predicting the total number of trips generated by attraction and production in each zone of the study area.

Trip distribution: the trip ends are tied together, resulting in a trip or origin-destination (O-D) matrix.

Modal split: allocating of each trips to different transport mode such as train, bus or car.

Trip assignment: the trips are assigned to each network, resulting in a flow along each link.

Used Simultaneous/Direct Demand Model single step computation and calibration (generation, distribution, and modal split) instead of the conventional sequential 4SM, (generation, distribution, modal split, and assignment) for passenger intercity or inter-urban travel in Indonesia. The model considers: socio-economic, impedance (for modes interaction), and inter modal competition with dummy variables (non-quantified variables) (Umamil & Surgie, 2003).

This type of model can be used to forecast demand when considering a range of transport options in a particular transport corridor or geographic location. However, this method is seldom used to forecast demand for rail schemes (Guidance note on passenger demand forecasting).

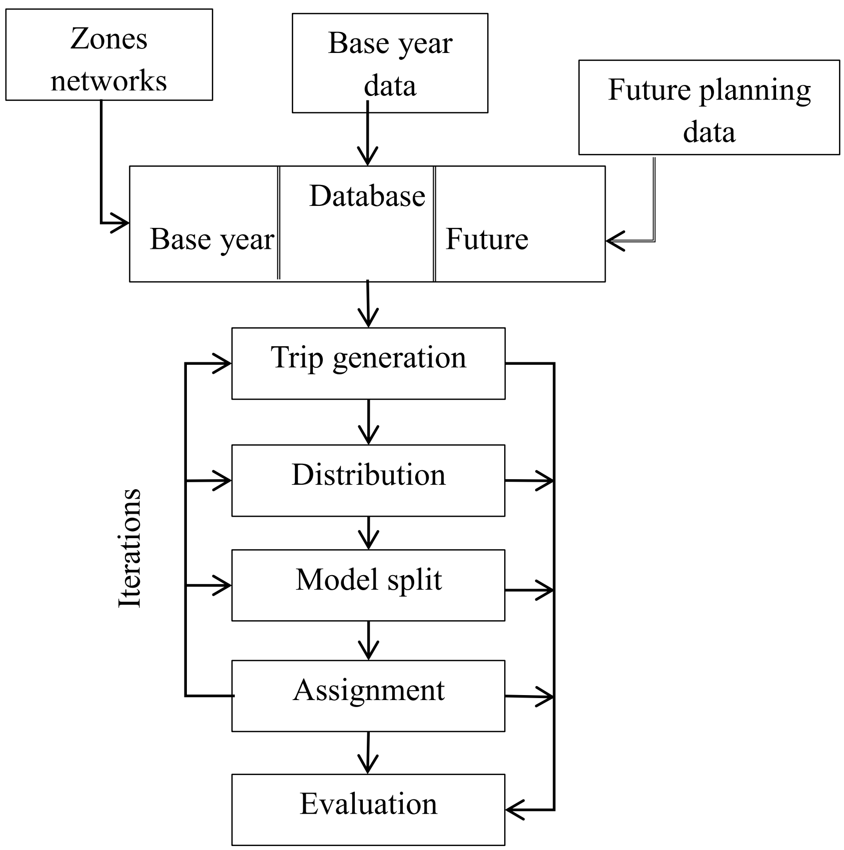

Figure 1 Four stage forecasting modeling process (Ortuzar and Willumsen 2011)

Trip generation

According to the explanation of (Ortuzar & Wilumsen, 2011) the aim of trip generation is to predict or estimate the number of trips that are generated by and attracted to each zone in a study area. In trip generation, methods are applied to predict productions and attractions or origins and destinations. The zones that contain the home end of home based trips or the origin end of non-home based trips are considered to have produced the trip while the destination zone where an out of home activity will be undertaken is considered to have attracted the trip. Trip making is highly varied reflecting the diverse activities pursued by people in their work and non-work activities. For the purposes of analysis, however, trips are typically grouped in terms of categories or purposes; while this may disguise the variety of activities pursued, it greatly simplifies model development. The number of purposes that should be used depends fundamentally on the analytic purpose at hand and the data available. In determining the trip purposes to model, all of the steps in the modeling process, not just trip production, need to be considered. However many purposes are utilized for modeling and it is sound practice to treat work trips as a separate from other forms of trip making. The journey to work is typically the most important trip to model correctly due to the large amount of travel accounted for by this purpose and the fact that work trips most commonly occur during the congested, peak travel periods.

Definition of words in trip generation

Words like trip or journey, home based trip, non-home based trip, trip attraction, trip production etc. are based on (Ortuzar & Wilumsen, 2011).

Trip or Journey it is a one-way movement from origin to a destination.

Home-based (HB) Trip this is either the origin or the destination of the journey is home of the trip maker.

Non-home-based (NHB) Trip is someone where neither end of the trip is the home of the traveler.

Trip production the definition of trip production is the home end of an HB trip or as the origin of an NHB trip.

Trip attraction this is the non-home end of an HB trip or the destination of an NHB trip.

Trip Generation is the total number of trips generated by households in a zone, be they HB or NHB. This is what most models would produce and the task then remains to allocate NHB trips to other zones as trip productions.

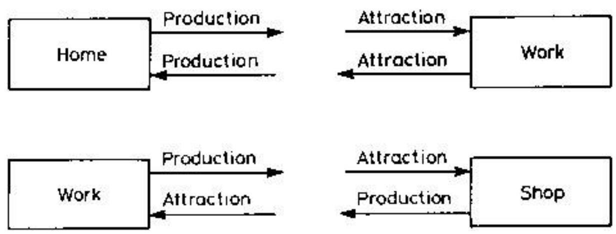

Figure 2 Trip production and attraction (Ortuzar and Willumsen 2011)

Sojourn is short period of stay in a particular location. It usually has a purpose associated with this stay: work, study, shopping, leisure, etc.

Activity An endeavor or interest often associated with a purpose as above but not necessarily linked to a fixed location. One could choose to go shopping or to the cinema in different locations.

Tour or Trip Chain it is set of linked sojourns and trips.

Factors affecting trip generation

According to (John & Russels, 2010) there are two factors that most commonly used to break down how trips are made:

1. Purpose
2. Person type

Trip by purpose: in this case trip generation model can be obtained if journey by different purposes. These are:

- Travel to work
- Education trip (travel to college or school)
- Travel to shop
- Social and recreational journey
- Others journeys (like escort trips)

Trip by person type: this type of trip is heavily dependent on socioeconomic attributes. Such as:

- ✓ Income (low, medium and high level of income)
- ✓ Household size and structure
- ✓ Car ownership (0, 1, 2, or more cars)

Analysis of trip generation

We know that trip generation is the first step in four step (four stage) forecasting model and it tells about how many trips are generated per a day. So these numbers of trips are calculated by the two common methods: growth rate factor and linear regression analysis.

Growth factor

According to the book of (Ortuzar & Wilumsen, 2011) considerations during analysis of growth factor.

- ❖ Trip type
- ❖ The minimum age to be include in the trip analysis (i.e. three and above)
- ❖ Households
- ❖ Income of the households

The basic equation for growth rate factor is

$$T_i = F_i t_i \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 1$$

Where T_i future trips in zone i

t_i current trips in zone i

F_i growth factor

To gate the growth factor (F_i) we should be relate population (P), income (I) and car ownership(C); so it becomes

$$F_i = \frac{f({P_i}^d {I_i}^d {C_i}^d)}{f({P_i}^c {I_i}^c {C_i}^c)} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 2$$

Where d designed year and

c current year

Linear regression

According to the view of (John & Russels, 2010) a model for forecasting trip numbers would include a number of explanatory variables: for example, the number of trips from a zone may be proportional to the zone population. Statistical techniques, in particular linear regression, are used in the development of such models. However, implicit in this approach is the assumption that forecasts are available for any explanatory variable. For example, if trip numbers today depend on today's population, it is necessary to know the future population in order to forecast future trips.

As pointed out by (Robert, 2006) metropolitan planning organization (MPOs) typically use regression equation or cross tabulated trip rates to estimate numbers of trips per household as a function of socioeconomic variables like household size, income, and car ownership.

The most commonly used analytical technique to develop the trip generation is multiple linear regression. In this technique, the dependent output variable is assumed to have a linear dependence on the independent input variables, which may or may not influence the trip generation.

The most common a linear regression function is,

$$T_i = a_o + a_1x_1 + a_2x_2 \dots + a_kx_k + e \dots\dots\dots\dots\dots\dots\dots\dots\dots 3$$

where, a_o $a_1 \dots a_k$ are coefficients of linear regression equation

T_i is dependent output variable

$x_1, x_2 \dots . x_k$ are independent input variables

e is the error in estimating the output variable

According to the view of (Khan, 2007) we have two types of linear regression techniques.

These are:

1. zonal-based
2. household-based

The main difference between the two techniques is

For zonal-based regression, T_i is generally taken as the number of trips generated for and attracted by each zone in the study area, while various independent variables can be considered and tested for estimation purposes. These variables are like,

- employment density of a zone (trips for work)
- school/ colleges/ university enrolment of zones (trips for education)
- shopping or marketing areas in the zone (trips for work, shopping)

For household-based regression tends to utilise various parameters associated with a household, in order to estimate. These parameters are,

- household size
- number of vehicles in a household
- number of adults in a household
- number of students and workers in a household

Generally we have the linear regression;

$$t_i = bx + a \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots 4$$

Where a and b are population parameters

x is household structure

Trip distribution

The purpose of trip distribution step is to estimate the number of trips performed from an origin zone to a destination zone generated trips in the trip generation step.

In the trip distribution stage of four-step model the person trip ends developed in the trip generation are linked geographically into complete trips, from an origin production zone to a destination or attraction zone. The trip generation step is essentially a destination choice model and generates a trip table, for each trip purpose utilised in the step as a function of activity-system attributes and network attributes. This trip table, also common known as Origin-Destination Matrix (O-D Matrix), provides a comprehensive illustration of the number of trips generated between different zones of the study area.

Analysis of trip distribution

To analyse the trip distribution we two known sets of trip ends are connected together to form a tip matrix between origins and destinations.

Generally there are two basic methods by which this connection can be achieved.

1. growth factor method
2. gravity method

Growth factor method

According to the (Ortuzar & Wilumsen, 2011) if the only information available is about a general growth rate τ for the whole of the study area, then we can only assume that it will apply to each cell in the matrix:

$$T_{ij} = \tau . t_{ij} \dots \dots \dots \dots \dots \dots \dots \dots 5$$

Where, T_{ij} is the future number of trips from zone i to zone j

t_{ij} is the present number of trips from zone i to zone j

τ is the constant factor derived by dividing the number of trip ends in the future by the base year.

According to the explanation of (Michael) the advantages of growth factor method are easy to apply, flexible, can be used to distribute trips by purpose, mode and time of day, by defining different growth factors for each zone. When applied to areas where conditions are stable over the study period, the result have been satisfactory. But, when applied to a study with significant changes in land use, such as proposal of new transportation facilities, and where travel costs change with time, this method gives unreliable estimates of future trips.

Gravity method

Distribution models of a different kind have been developed to assist in the forecasting future trip patterns when important changes in the network take place. These models make assumptions about group trip making behaviour and the way this is influenced by external factors such as total trip ends and distance travelled. The most widely used of these models is the gravity model. This model estimates trips for each cell in the matrix without directly using the observed trip pattern (Ortuzar & Wilumsen, 2011).

The gravity method has the following equation:

$$T_{ij} = \frac{\alpha P_i P_j}{d_{ij}^2} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots 6$$

Where, P_i = number population in the origin

P_j = number of population in the destination

d_{ij} = distance between origin (i) and destination (j)

α = proportional factor

This method was further generalised by assuming that the effect of distance could be modelled better by a decreasing function, to be specified of the distance or travel cost between the zones. This can be written as:

$$T_{ij} = \alpha O_i D_j f(c_{ij}) \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots 7$$

Where, $f(c_{ij})$ a generalised function of the travel costs with one or more parameters for calibration.

Comparison between growth factor and gravity method

Strength and weakness of growth factor method

It has similar strength and weakness as it indicated in the first step of four stage model trip generation step.

Strength and weakness of gravity method

From literatures (John & Russels, 2010), (Ortuzar & Wilumsen, 2011) the following strength and weakness of the gravity model is concluded.

Strength of gravity method

- it is synthesis method
- it works on population distance relation
- It works cost based

Weakness of gravity method

- Requires extensive calibration
- Long iterative process

In general based on the study of (John & Russels, 2010) intra-zonal trips are not well represented in the gravity model, not least because of the difficulty of measuring their cost function.

Modal choice

According to the explanation of (Khan, 2007) the issue of selecting the most appropriate travelling mode has always been a critical issue in travel behavioural modeling, since it tells an individual about the most efficient travelling mode available. Therefore, it is vital to develop and use models that are receptive to those attributes of travel that influence a certain individual's choice of mode.

So, the most important classic models in transport planning is choice of transport mode. Therefore modal split is a means of choosing different types of modes that should be helpful for distribution of trips. The modal split models can reflect a range of performance variables and trip-maker characteristics, but, they produce disaggregate results that must then be aggregated to the zonal level prior to traffic assignment.

There are factors that influencing choice of mode:

- characteristics of trip maker:
  Like; car availability or ownership, income, household structure
- characteristics of journey or trip:
  Like; trip purpose, time of the day
- characteristics of transport facility it has qualitative and quantitative factors
  Quantitative factor such as;
  Components of monetary cost (fuel, oil), components of travel time (waiting, walking, in-vehicle time),
  Qualitative factors such as;
  Safety, protection, security, the demands of the driving task, comfort and convenience,

Analysis of modal split

We know that modal split is the third step in four stage forecasting modeling. So, in this step we should be split into different modes what we have done in the previous steps by using different analyzing methods of modal split (like logit method).

Logit method

As explained by (Khan, 2007) the logit method is the most commonly used modal split method in the area of transportation planning, since they possess the ability to model complex travel behaviour of any population with simple mathematical technics.

The most commonly used discrete choice analysis method in travel forecasting. The basic idea underlying modern approaches to travel demand modeling is that travel is the result of choices made by individuals or collective decision-making units such as households.

This logit method may be binary logit (deals with two modes) or multinomial logit (deals with more than modes).

We have governed equation to get the generalized cost for each mode when the trip maker is goes from origin to the destination. That is;

$$\mathrm{Cij} = a_1 t_{ij}^{v} + a_2 t_{ij}^{w} + a_3 t_{ij}^{t} + a_4 f_{ij} + a_5 \phi_{ij} \ldots\ldots\ldots\ldots\ldots\ldots 8$$

Where: i and j are origins and destination

t_{ij}^{v} Vehicle travel time

t_{ij}^{w} Waking time

t_{ij}^{t} Waiting time

f_{ij} Monetary charge

ϕ_{ij} Parking cost

The probability of an individual i selecting a mode m, out of N number of total available modes, is given by,

$$p_{ij}^{mode} = \frac{e^{-\beta c_{ij}^{mode}}}{\sum e^{-\beta c_{ij}^{modes}}} \dots \dots \dots \dots \dots \dots \dots \dots \dots 9$$

Where; p_{ij}^{mode} Probability of using mode

c_{ij}^{mode} Generalized cost of mode

β Parameter for calibration

Probit method

The probit method is based on the random utility theory, representing the utility function as the sum of the systematic component and an error component. Which is,

$$U_i = V(x_i, s) + e_i \dots \dots \dots \dots \dots \dots \dots \dots \dots 10$$

Where, U_i the utility alternative i;

V the observed (systematic) component of the utility function;

x_i the vector of observed attributes of alternative i;

s the vectors observed characteristics of the individual of the study area

e the error component of the utility function.

As it indicates in the above equation the probit method has a complex estimation algorithms.

Trip assignment

Trip assignment is the last step of the four stage model and it is a process of the allocation of a given set of trip interchanges to a specific transportation network or system. The fundamental aim of the traffic assignment process is to reproduce congestion on the transportation system, the pattern of vehicular movements which would be observed when the travel demand represented by the trip matrix, or matrices, to be assigned is satisfied.

According to the analysis of (Ramos & Bazzab, 2015) traffic assignment represents an important step towards modeling and simulating transportation system. Specifically, the traffic assignment problem addresses how to efficiently connect the physical infrastructure (supply) and the vehicles that are going to use it.

According to the literatures (Marhew & Rao, 2006) the aims of traffic assignment procedures are:

- To estimate the volume of traffic on the links of the network and obtain aggregate network measures.
- To estimate inter zonal travel cost.
- To analyze the travel pattern of each origin to destination (O-D) pair.
- To identify congested links and to collect traffic data useful for the design of future junctions.

Trip assignment methods

In the trip assignment stage a set of rules and principles is used to load a fixed trip matrix onto the network and thus produce a set of links flows.

There are methods to assign or to choose the trips (like, rout choice, tree building)

Rout choice

It is the basic principle in assignment is the assumption of a rational traveler, i.e. one choosing the route which offers the least perceived (and anticipated) individual costs. There so many factors that affect/influence the choice of route when the trip maker makes a trip from origin to destination.

These are:

- ✓ journey time
- ✓ monetary cost (fuel)
- ✓ congestion and queue
- ✓ distance
- ✓ types of road etc.

These factors can be approximated in to two main factors of rout choice: time and monetary cost.

The fact that different trip makers often choose different routes when travelling between the same two points may be ascribed to three different types of reasons;

1. differences in individual perceptions of what constitutes the best route
2. The level of knowledge of alternative routes varies
3. Congestion effects affecting shorter routes

There are some methods to the route choice; like all-or-nothing assignment, user equilibrium assignment, etc.

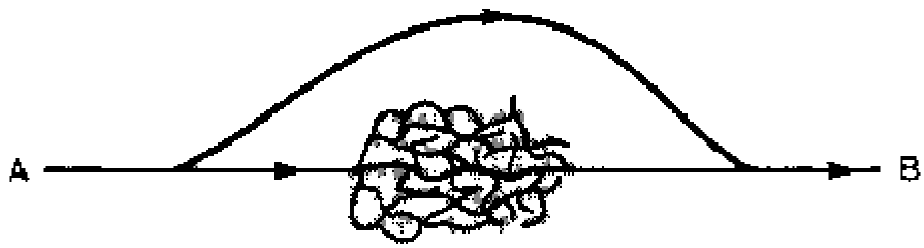

Figure 3 Town served by a bypass and a town center route (Ortuzar and Willumsen 2011)

All-or nothing assignment

In this method the trips from any origin place to any destination place are loaded onto a single, minimum cost, path between them. It assign without consideration of whether or not there is adequate capacity or heavy congestion; travel time is a fixed input and does not vary depending on the congestion on a link.

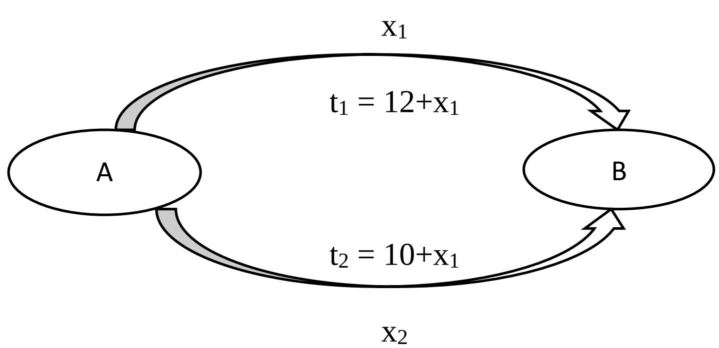

Figure 4 Two link problem with constant travel time function

System Optimum Assignment

The system optimum assignment is based on Wardrop's second principle, which states that drivers cooperate with one another in order to minimize total system travel time. This assignment can be thought of as a method in which congestion is minimized when drivers are told which routes to use. It can be useful to transport planners and engineers, trying to manage the traffic to minimize travel costs and therefore achieve an optimum social equilibrium.

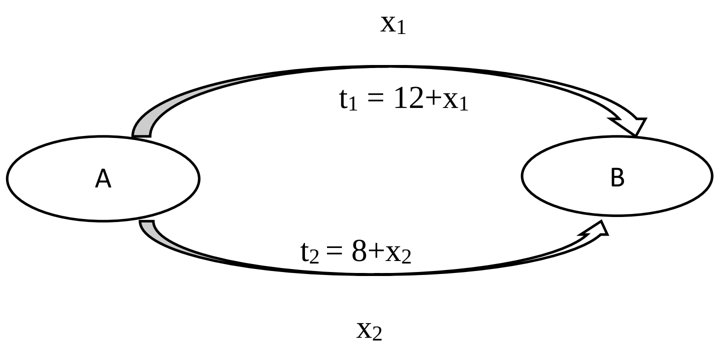

Figure 5 Two link problem with constant travel time function

$$minimize\ Z = \sum_a x_a t_a(x_a) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 11$$

$$subjected\ to \sum_k f_k^{ij} = q_{ij} : \forall i, j$$

$$f_k^{ij} \geq 0 : \forall k, i, j$$

$$x_a \geq 0 : a \in A$$

Comparison between all-or-nothing assignment and system optimum assignment

Weakness and strength of all-or-nothing assignment

Strength

- Assign to minimum cost
- Assign to a minimum distance
- It is good when congestion is absence
- It is must for one line

Weakness

- It assign without any consideration of congestion and queue
- Time does not vary in any condition (congested or free)

Strength and weakness of system optimum assignment

Strength

- It tries to manage the traffic to minimize the travel cost
- It uses for transport planners and engineers
- It minimize the congestion

Weakness

- It asks knowledge about the path

In general, due the reason addressed above the system optimum assignment is better for any traffic or trip assignment process if the train integrated with the other transport modes. But for only AALRT no chance to choose any assignment methods because the route is only one to travel from origin to destination.

Tree building

Tree building is an important stage in any assignment method for two related reasons. First, it is performed many times in most algorithms, at least once per iteration. Second, a good tree-building algorithm can save a great deal of computer time and costs.

CHAPTER THREE

3. METHODOLOGY AND DATA COLLECTION

3.1. Introduction

In this section, the suitable passenger demand forecasting model is designed in order to address the research objectives. To design the passenger demand forecasting model in this study a literature review was undertaken deeply on papers of national and international report review related to passenger demand forecasting and used models for forecasting of passenger demand. The outline of this chapter is the method design and data collection for data analysis based on the selected model for AALRT.

3.2. Method design

To design the suitable passenger demand forecasting model for AALRT different literatures, journal articles, and reports have been deeply seen in the literature review section. From these literatures the strength and weakness of the models assessed as follows:

Elasticity model

Strength

As it indicates in different literatures this model is applied to change the existing passenger services between known destinations where historical data on existing rail usage is available (passenger demand forecasting guidance) (Preston, 1991).

Limitation (weakness)

According to the literatures (Preston, 1991), (TAG, April 2009) the following weaknesses of the elasticity mode are listed.

- It is limited on representation of other modes
- It is not good for new rail because it needs the historical data
- It depends on GDP
- It use small variables than four stage model

Four stage model

According to the analysis of (Furnish & Wignall, 2009), passenger demand forecasting guidance and others literatures the four stage model has the following strengths and weaknesses.

Strength

- It is good for new rail service
- It uses house hold and zonal analysis
- It is good where there are heavy commuter flow
- Representing personal travel by private car modes
- Collating and organizing survey data.
- It has detail explanation with formula about each step

Limitation (Weakness)

- it takes time
- it require high cost during data collection
- not good at representing: non-car modes, especially non- motorised modes

Table 1 comparison between elasticity model and four stage model

Comparison parameters / factors	Models	
	Elasticity	Four stage
Data needed	Need historical data	No need historical data
Rail services	Good for change the existing rail service	Good for new rail service
Economic activity	Good for command economy	Good for free market economy
GDP	Dependent on GDP	Independent on GDP
Variables used	small	Large
Choice of transport mode	Doesn’t choose	Choose the better transport mode

According to strength and weakness of the elasticity and four stage passenger demand forecasting models the comparison is find out to select the better passenger forecasting model for AALRT in table 1.

As we know that, Ethiopia has follow the free market economy system and the AALRT is a new for the country or city. The historical data is not found in AALRT because the infrastructure is new.

As the comparison table 1 indicates the four stage rail passenger demand forecasting has been selected as more preferable than the elasticity rail passenger demand forecasting model in the context of AALRT.

In the four stage passenger demand forecasting modeling there are different approaches or methods that used to analysis each stage of the model.

Trip generation: in this step the two common approaches growth factor and linear regression analysis are used. To select the appropriate trip generation analysis method for AALRT the following merits and demerits of the methods are assessed based on the literatures.

Growth factor

It has some strength in the following area

According to the view of (Michael) the main advantage growth rate analysis is that the household categories may be estimated from census data using known relationships, such as distribution of income, car ownership, and family structure; large scale home interviews can be avoided in compared to regression analysis.

- Country which has the same or similar growth rate throughout the people
- Country which follows command economy

Weakness of growth factor

- It makes **over estimation** of trip generation (passenger demand forecasting guidance).
- Tends to underestimate the future trips between underdeveloped zones which could be extensively populated in the future

Strength of linear regression

- it considers all factors that affects trip
- it simple to understand
- it uses household structure

Weakness of linear regression

- as a method of forecasting it has simple error
- it need perfect or real data about the study area

Based on the literatures and the above merits and demerits of the growth factor and linear regression methods of trip generation the following table is developed to select the suit methods in case of AALRT.

Table 2 comparisons between the growth rate and linear regression of trip generation

	Trip generation methods	
	Growth factor	Linear regression
Economic policy	Good for command economy policy	Does not depend on the economic policy
Result of estimation	Make over estimation	More accurate
GDP	Dependent (Works for the country which have similar growth throughout)	Does not depend
Home interview	Small	Large

Because of the current situation of Ethiopia indicates, there is no same GDP distribution throughout the people and the country doesn't follow the command economy system. And also, taking large home or residence interview leads to more accurate value.

Due to these reasons the linear regression method is selected as a better trip generation method over the growth rate factor methods of trip generation.

Trip distribution: growth factor and gravity methods are commonly functional to analyse the trip distribution stage. But according to (John & Russels, 2010) it is better developing local distribution model. So this study try to use the author's method.

Modal split: the logit method and probit method are two most commonly methods to make the modal split or modal choice stage of the four stage models.

The comparison is done based on their strength and weakness by referring different literatures.

According to the study of (Khan, 2007) have the following strength and weakness:

Strength and weakness of the logit model

Strength

- it has simple model estimation
- it is highly applicable
- it has high accuracy

Weakness

- Model formulation and calibration becomes complex to small degree.

Strength and weakness of probit model

Strength

- can handle random taste variation,
- Applicable to panel data with temporally correlated errors
- Allow any pattern of substitution

Weakness

- Model formulation and calibration is highly complex
- It is low accuracy and limited applicable
- require normal distributions for all unobserved components of utility

Due to this complex estimation algorithms of the probit model, the transport planners generally prefers using logit models as they possess simple mathematical framework and can accurately model the behaviour of the study area (Khan, 2007). (Ghareid, 1996) Compared logit and probit methods by using them to estimate the travel behaviour different cities of Saudi Arabia and concluded that the logit method is superior to their probit counterpart in terms of their goodness-of-fit measure and tractable calibration. (Dow & Endersby, 2004) Later has supported his findings by concluding that the logit method should always be preferred over probit method.

Due to the literatures discussed above the following comparison table has organized to select the better method for the analysis of the modal choice step of the four stage rail passenger demand forecasting model.

Table 3 comparison between the logit and probit model

	Modal choice method	
	Logit method	Probit method
Method of estimation	Simple	Complex
Method formulation	Simple	Complex
Application	High	Low
Accuracy	High	Low

In general, table 3 shows the reason why the logit method is better than the probit method for this modal choice analysis.

Trip assignment: as the literature indicates, in this stage the traffic flow assigns in to the given routes to reduce the traffic congestion and to save time and money. In this study this stage is doesn't included because the AALRT have only one route to travel from origin to destination.

3.3. Study area

AALRT has two routes that has constructed in the first project phase of Ethiopian Railways Corporation. The first route is constructed from east to west starts from Ayat and ends at Torhailoch with a total length of 17.4km and 22 stations. And the second route is constructed from north to south starts from Minilik II Square and ends at Kality with a total length of 16.97km and 22 stations (China Railway Group Limited, 2009).

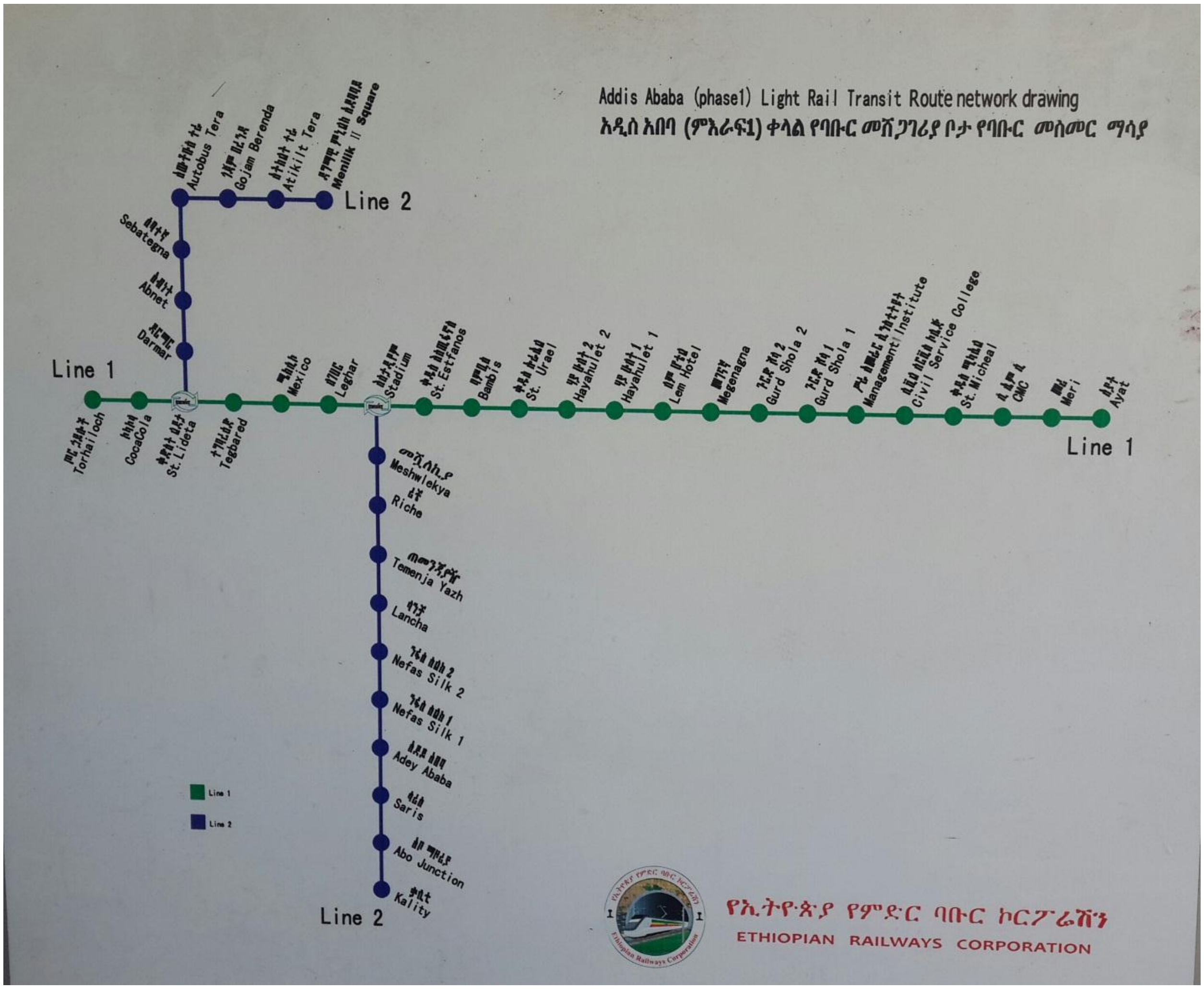

Figure 6 Addis Ababa Light Rail Transit from East to West (line 1) and North to South (line 2)

The study mainly focused on the AALRT's passenger demand forecasting analysis. Because of high increasing demand for every aspects of movement for economic and social activities in the city highly requires the every other alternative to meet. This is believed to be achieved by searching means of transportation the matters which addressing the affordability of the economic center of community and timely with the comfort of human need. So, AALRT should forecast the real passenger demand to satisfy the need of the community by increasing the number of trains if the demand becomes high.

The following figure shows the ten sub cities of Addis Ababa that used to divide into zones to do the forecasting analysis of the study. In this study the zoning system has divided based on the

AALRT line passes through the sub cities. The sub cities that AALRT line pass through are Kirkos, Bole, Yeka, Arada, Lideta and Nifas Silk Lafto.

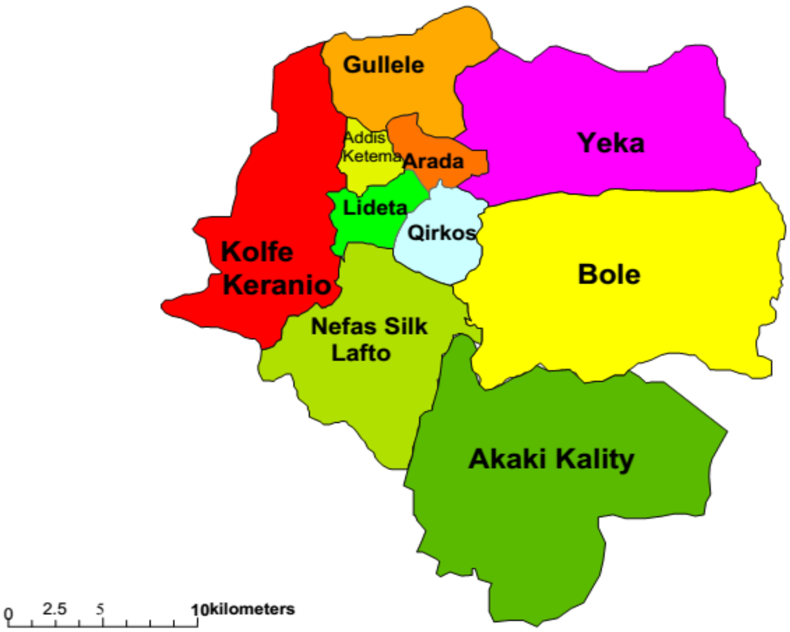

Figure 7 Sub Cities of Addis Ababa

3.4. Data collection

Data collection method

To describe the situation, the basic method for data collection is primary and secondary data. The data that obtained by direct observation and interviewing ten residences in Kirkos sub city and office managers of Addis Ababa sub cities particularly Yeka and Kirkos sub cites as primary data. The data that taken from the source of published or unpublished documents is secondary data. The source of this data like, Central Statistics Agency (CSA), Addis Ababa Transport Authority (AATA), Ethiopian Railway Corporation (ERC), City Government of Addis Ababa Education Bureau.

These data taken from Central Statistics Agency and City Government of Addis Ababa Education Bureau have been listed in the appendix of this study paper. But, the useful data for this study is listed out here in the suitable form for data analysis of this study paper.

Table 4 Estimated population of Addis Ababa sub cities grouped by age: 2013 *(CSA, may 2014)*

Sub cities	Age group		
	Total	0-4	5+
Akaki Kality	216846	18874	197972
Nifas Silk-lafto	384122	31418	352704
Kolfe Keraniyo	524759	49737	475022
Gulele	295342	21342	274000
Lideta	205909	12582	193327
Kirkos	232718	13700	219018
Arada	214783	11385	203398
Addis Ketema	275798	16895	258903
Yeka	415533	36193	379340
Bole	390246	27287	362959
Total	3156057	239415	2916642

Source: central statistics agency

Table 5 Population of Addis Ababa sub cities by number of household and average household size: 2013 (CSA, may 2014)

Sub Cities	Population size	Number of households	Average household size
Addis Ababa	3156057	808714	3.9
Akaki Kality	216846	60511	3.6
Nifas Silk-lafto	384122	98124	3.9
Kolfe Keraniyo	524759	124585	4.2
Gulele	295342	73945	4
Lideta	205909	52545	3.9
Kirkos	232718	64693	3.6
Arada	214783	53977	4
Addis Ketema	275798	65190	4.2
Yeka	415533	113702	3.7
Bole	390246	101441	3.8

Source: central statistics agency

Table 6 Number of students in each sub city of Addis Ababa: 2013/14 *(CGAAEB, 2014)*

S. No.	Sub city	Primary	Secondary	Total
1	Addis Ketema	56039	13525	69564
2	Akaki Kality	42265	11063	53328
3	Arada	39904	16921	56825
4	Bole	58229	16036	74265
5	Gulele	4729	16878	21607
6	Kirkos	29587	11091	40678
7	Kolfe keranio	107400	20795	128195
8	Lideta	28620	4842	33462
9	Nifas Silk Lafto	69091	23862	92953
10	Yeka	68089	16024	84113

Source city government of Addis Ababa education bureau

Table 7 Number of vecles in Addis Ababa

Type of vehicle	No. of vehicle
Minibus	5328
Bus (13-45 seat)	1058
Bus (>45 seat)	959

Source: Addis Ababa transport authority

Assumptions and considerations

During the data analysis the author has taken the following assumptions and considerations

- The data observed from day to day activity high population movement and high traffic congestion is occur around Mexico, Legehar and Stadium from other places which the Addis Ababa Light Rail Transient is pass through. Mexico, Legehar and Stadium are part of Kirkos sub city. Therefore, Kirkos sub city has been assumed as a transport hub from the other sub cities.

Figure 8 Traffic congestions at Legehar

- The population aged from 0 to 4 are not included in the analysis because they considered as a trip maker with their family.
- Most students are not be able to go abroad for leaning purpose (they should define themselves near home) and 5 to 10% students will go to the neighbor sub cities. But to get the real data the information of the student should be registered.
- Clinics are desired to be near village
- Location of industry zones, entertainment places, market places, offices, retain (shops), construction sites, and other places that seeks to invite many worker to go abroad.
- Most worker's home located around their working area and up to 10% workers will go to the neighbor sub cities. This to know the real data of the worker's personal information shall be registered by the responsible agencies or companies: like the company which employed the worker, central statistics agency.
- It doesn't include the traffic flow during the holydays

CHAPTER FOUR

4. DATA ANALYSIS AND INTERPRETATION

Data analysis using the selected forecasting model

In the previous two chapters the suitable rail passenger demand forecasting model for Addis Ababa light rail transit has been selected by assessing different literatures and comparison parameters and the input data to make the analysis also have been collected. These data have collected from different sources as an input of a primary and secondary data of the thesis. These collected data have analysed by using four stage rail passenger demand forecasting model. The three steps (trip generation, trip distribution and modal split) of the four stage model have analysed as follow:

Trip generation

It is the first step in four stage forecasting model to do the analysis of the gathered data and this analysis is done by using linear regression analysis to predict how many trips generate in the study area.

Linear regression

In order to calculate the regression analysis predict the number of trips per day, and first let's find average no of people in a single house.

$$\text{Average people in a single house} = \frac{\text{Total population}}{\text{number of house holds}} \ldots\ldots\ldots\ldots\ldots 12$$

$$= 3.6 \cong 4$$

The general form of a trip generation model is;

$$\mathrm{Ti} = \mathrm{f}\left(\mathrm{x}_{1,}\mathrm{x}_{2,}\mathrm{x}_{3,\ldots\ldots}\mathrm{x}_{\mathrm{i}\ldots\ldots}\mathrm{x}_{\mathrm{n}}\right) \ldots\ldots\ldots\ldots\ldots\ldots\ldots 13$$

Where, x_{i}'s are a prediction factor of explantory variable.

The most common a linear regression function is,

$$T_i = a_o + a_1x_1 + a_2x_2 \ldots + a_kx_k + e \ldots\ldots\ldots\ldots\ldots\ldots\ldots 14$$

where, a_o $a_1 \ldots a_k$ are coefficients of linear regression equation

T_i is dependent output variable

$x_1, x_2 \ldots . x_k$ are independent input variables

e is the error in estimating the output variable

Generally we have trip generation equationfor a single person;

$$t_i = bx + a$$

Where, t_i trips generated in zone i

x house hold number

a and b population parameters

The number of trip ends produced to the given study area is estimated using certain assumptions about the number of trips typicaly made by each type of household and to each type of destination in the region. And we used special factors to account for different rate of trip making that are characteristic of different parts of the region. Thus assumption and special factorss are include in the equations used to calculate the trip for study area.

Trip generation procedure, x_i's are taken to be ;

- ✓ Work trip (number of workers)
- ✓ Education trip
- ✓ Non-home based trip and
- ✓ Others

Non-home based trips are trips where origins or destinations of the trips are not home.

Other kinds of trips are designed to include visits like museums, entertainment places, churchs,mosques, migrants and peoples using for transitions.

So to do this analysis there are some considerations

There are about 7 sample households taken into account and different family sizes of these different house holds. Among the many regression analysis to be considered for large sampling regression method and private car owners will also be analysed. And the kids (0-4 years age) are not concidered as a trip maker.

Table 8 House hold size for Kirkos sub city

	House hold size (x)							
Trip Per Day(y)	No.	1	2	3	4	5	6	7
	Work trip	2	3	3	4	2	4	6
	Educational trip	0	2	0	0	3	5	3
	Non home based	2	2	3	7	3	6	8
	Others	2	2	4	4	2	5	3
	$\sum$ y	6	9	10	15	10	20	20

Therefore four trips are made by a single person and the total trip generated in Kirkos sub city is 876072

In this trip generation step the analysis shows four trips per day has been made by a single person in Kirkos sub city. The total estimated trip generated in Addis Ababa 11,666,568 and the total estimated trip in Kirkos sub city 876072 by using linear regression analysis of trip generation method. These trips has made by the people aged above 5 years the number of children aged below 5 years are not considered because they goes with their family. The trip generated in Addis Ababa is done to indicate how many trips are present in the city. But, the trips generated in Kirkos is ready to distribute in trip distribution stage.

When the trip generation procedure is completed, it estimate the number of person trip ends produced and attracted to each zone (neighbor of Kirkos). The next step, trip distribution will match up all of the trip ends, creating actual trips.

Trip distribution

The generated trips in the first step from each zone is then distributed to all other zones based on the choice of destination. This is called trip distribution which forms the second stage of travel demand modeling.

This step is the second stage of the four stage forecasting modeling and it analyse the person trip ends developed in the trip generation are linked geographically into complete trips, from an origin production zone to a destination or attraction zone.

In the methodology it describes the gravity trip distribution method is better than from growth rate factor method. But, due to the difficulty of cost function it is not recommended for intra-zonal trips. So it is better develop local distribution method.

To analyse the trip distribution stage of the four stage passenger demand forecasting model the personal information of the trip maker shall be registered in the following way.

- If the trip maker is employed worker place of work and place of resident
- If the trip maker is students where they learn and where they live

After it registered like this it is easy to make the trip distribution of the generated trip. The analysis in this study tries to show how many trips distributed to each zone.

So, to calculate the total trips that distribute into the neighbor sub city of Kirkos is as follows:

Trips per a day in a single person $\times$ ((% students that has going to neighbor sub city times number of students in Kirkos) $+$ (% workers that has going to neighbor sub city $\times$ number of workers in Kirkos) $+$ (% other trips))

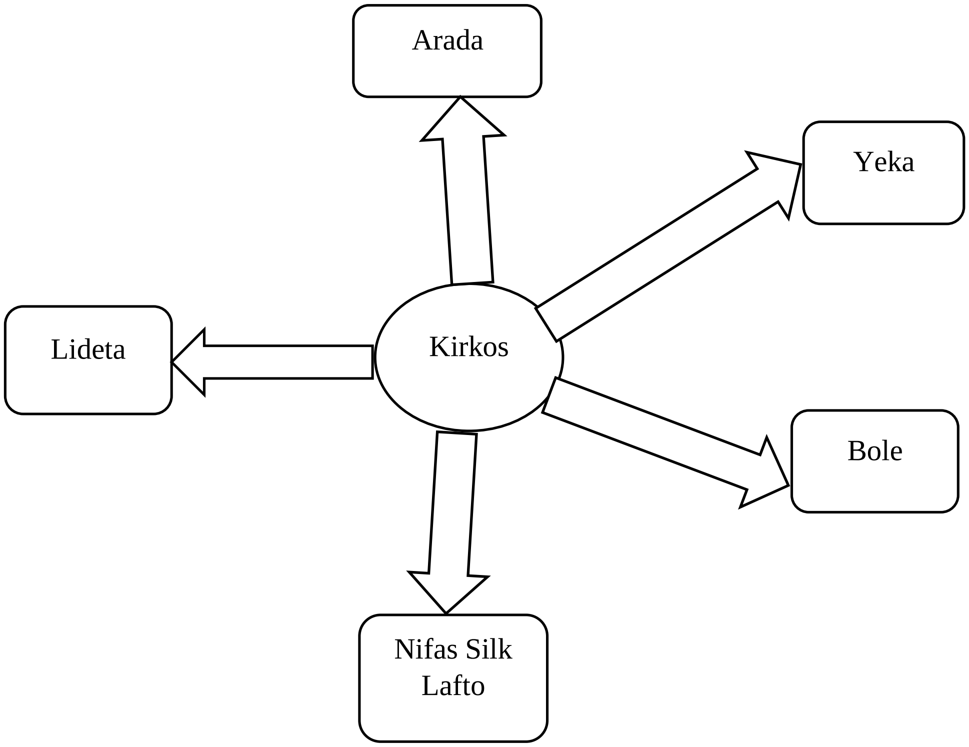

Figure 9 Trip distribution tree from origin zone to destination zones

By assuming the origin zone is Kirkos sub city and the generated trip is to be distributed to the neighbor sub cities or zones (Lideta, Nifas Silk Lafto, Bole, Yeka and Arada) and in to itself.

The result of the total trip that has been distributed from Kirkos to the neighbor sub cities is shown in the following table.

Table 9 Value of trip distribution origin destination

Origin	Destination					
1	T_{kk}	T_{kA}	T_{kB}	T_{kL}	T_{kNSL}	T_{kY}
	662987	17523	66086	33324	24023	57766

This step looked at how to calculate trip distribution and how many trips attracted from the origin zone to the destination zone that are generated in the first step of the four stage passenger demand forecasting model. These trips are generated in Kirkos sub city which has selected as a transport hub of Addis Ababa and distributed into its neighbor sub cities (Arada, Bole, Lideta, Nifas Silk Lafto and Yeka). As the result indicates in table 8 the trips distributed into Kirkos, Arada , Lideta, Bole Nifas Silk Lafto and Yeka is 662987, 6694, 66086, 33324, 24023 and 57766 respectively. Trip distributed Kirkos to Kirkos has taken more number because the most trip makers go the nearest of their home. Trips from Kirkos to Bole and Yeka takes the second and the third high trip flow next to trips from Kirkos to Kirkos because the most residence and working sites are found in Bole and Yeka sub cities. The other trips distributed from Kirkos to Lideta and Nifas Silk Lafto takes the average or half of the trip distributed into Bole and Yeka. And trip distributed in to Arada takes the least number and it indicates Arada has less residence and working sites when it compared to the other neighbor sub cities of Kirkos. This distributed trips need choose of transport mode to travel from their origin zone to the destination zone. So, this modal choice is analysed in the modal split step to select the better transport mode in time and money minimizing.

Modal split

Based on the literature, the methodology has select the logit method of modal split is the better method to analyse the third step of the four stage passenger demand forecasting model. So, using the logit method the choice of transport mode analysed as follow.

The generalised cost equation is

$$\mathrm{Cij} = a_1 t_{ij}^{v} + a_2 t_{ij}^{w} + a_3 t_{ij}^{t} + a_4 f_{ij}$$

Where: i and j are origins and destination

t_{ij}^{v} Vehicle travel time

t_{ij}^{w} Waking time

t_{ij}^{t} Waiting time

f_{ij} Monetary charge

The equation of probability of an individual i selecting a mode m, out of N number of total available modes is given by,

$$p_{ij}^{mode} = \frac{e^{-\beta c_{ij}^{mode}}}{\sum e^{-\beta c_{ij}^{modes}}}$$

Where; p_{ij}^{mode} Probability of using mode

c_{ij}^{mode} Generalized cost of mode

β Parameter for calibration

Table 10 Trips from Kirkos to neighbor sub cities by different mode of transport

		$(t_{ij})^v$	$(t_{ij})^w$	$(t_{ij})^t$	(F_{ij})
Trips from Kirkos to	Coefficient	0.03	0.04	0.06	0.1
Arada	Car	15	5	5	1.5
	Bus	20	5	5	1
	Train	25	5	10	4
Bole	Car	80	5	5	6
	Bus	90	5	10	2.5
	Train	40	5	15	4
Lideta	Car	30	5	10	4
	Bus	40	5	10	1.5
	Train	20	5	15	2
Nifas Silk Lafto	Car	40	5	5	3.5
	Bus	70	5	15	2
	Train	30	5	10	2
Yeka	Car	80	5	5	6
	Bus	90	5	10	2.5
	Train	40	5	15	4

As the result shows in table 10 travel from Kirkos to Arada car is best transport mode from other transportation modes; Kirkos to Bole train is best transport mode from other transportation modes; Kirkos to Lideta train is best transport mode from other transportation modes; Kirkos to

Nifas Silk Lafto train is best transport mode from other transportation modes; Kirkos to Yeka train is best transport mode from other transportation modes.

Table 11 probability of choosing transport mode from origin zone to destination zones

Mode	from Kirkos to Arada	Kirkos to Bole	Kirkos to Lideta	Kirkos to Nifas Silk Lafto	Kirkos to Yeka
Car	0.43	0.2498	0.5111	0.4129	0.2498
Bus	0.39	0.1944	0.2998	0.1072	0.1944
Train	0.18	6.16	0.385	0.4799	6.16

The analysis done from Kirkos (Legehar) to the end of each Addis Ababa Light Rail Transit routes. From this analysis the result of probability of choosing transport mode to travel from origin zone (Kirkos) to the destination zones (Arada, Bole, Lideta, Nifas Silk Lafto and Yeka) indicated in table 11. The transport mode which have high value of choosing probability indicates better transport mode for the travel. As the result shows traveling from Kirkos to Arada car is the best mode of transportation other than bus and train transport modes. However, traveling from Kirkos to Bole, Lideta, Nifas Silk Lafto and Yeka train is best transport mode from others transportation modes bus and car. So, train is better transportation mode for long travelling distance but it is not good for short distance when it compared to the bus and car transport mode.

CHAPTER FIVE

5. CONCLUSION AND RECOMMENDATION

5.1. CONCLUSION

The main objectives of this thesis are selecting better passenger demand forecasting model in the context of AALRT and develop analysing using the selected passenger demand forecasting model.

To address these objectives different literatures are revised about the elasticity passenger demand forecasting model and four stage passenger demand forecasting model by assessing the strength and weakness of the models. Different parameters are also used for the comparison of the rail passenger demand forecasting models. These parameters are: - data needed, GDP, rail service, economic activity, choice of transport mode. Based on these literatures the four stage passenger demand forecasting model has been adopted as a better model for AALRT. Because the four stage rail passenger demand forecasting modeling is fits with the current situation of the country that have been listed as a comparison parameters. This four stage passenger demand forecasting model also analysed by different methods (like linear regression in trip generation step, logit method in modal choice step). These methods also have deeply revised from the literatures to adopt method for the analysis.

So, the four stage rail passenger demand forecasting model is suitable for AALRT and the analysis have done by using four stage model.

Before the data analysis different assumptions and consideration are taken to do well analysis. These assumptions and considerations are like populations aged from 0 to 4 years are not considered as a trip maker, most students get their school around their village, most workers home located around their working place.

The data have been analysed using the four stage passenger demand forecasting and the following results are obtained.

At trip generation stage 4 trips per day are made by a single person in Kirkos sub city and the total estimated trips generated in the Kirkos sub city are 876072. This trip generation is done based on the household structure.

In the trip distribution stage the generated trip in trip generation stage have distributed into the neighbor sub cities of Kirkos in which the AALRT passes through. The result in this trip distribution stage indicates the trip distributed into Kirkos, Arada, Lideta, Bole Nifas Silk Lafto and Yeka is 662986.8, 6694, 66086, 33324, 24023 and 57766 respectively.

The modal split/modal choice stage of the model shows the best transport mode for the trip makers to travel from their origin to destination that used to minimize the travel cost (time and money). So, as it indicated in in modal split stage to travel from Kirkos to Arada car is best transport mode from other transportation modes (bus and train). Hence, train is not good to travel from Kirkos to Arada. But, for the other (Kirkos to Bole, Kirkos to Lideta, Kirkos to Nifas Silk Lafto and Kirkos to Yeka) train is the best transport mode from the other transportation mode (car and bus).

5.2. RECOMMENDATIONS

According to the scope and the method of the research analysis, the following recommendation is forwarded based on the result of the study.

- As an organization, I recommend that, ERC shall have its own passenger demand forecasting model for planning, making a policy and estimating passenger demand. The four stage passenger demand forecasting model is fit for AALRT because AALRT is new rail service, absence of historical data, unequal distribution of GDP and economic policy of the country. So, it is better to use the four stage model as passenger demand forecasting model of ERC.

5.3. FUTURE WORK

This thesis is limited on comparison of only two types of passenger demand forecasting models. The analysis is done on trip generation, trip distribution and modal split based on the total number of residence data Addis Ababa city. However, the migrants, visitors and others can be included in the data analysis. Therefore, the future studies can include other types of passenger demand forecasting models and migrants, visitors and other trip makers in the data analysis.

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Appendix 1 Estimated population of Addis Ababa Sub cities grouped by age and sex: 2013

Age Group	Total	Male	Female	Sex Ratio
ADDIS ABABA CITY ADMINISTRATION				
All Ages	3,156,057	1,464,887	1,691,170	86.6
0-4	239,415	122,353	117,062	104.5
5-9	215,905	108,977	106,928	101.9
10-14	267,531	116,519	151,011	77.2
15-19	373,517	142,474	231,043	61.7
20-24	403,852	171,031	232,820	73.5
25-29	429,171	204,243	224,928	90.8
30-34	296,758	151,597	145,160	104.4
35-39	247,914	125,136	122,778	101.9
40-44	144,545	77,048	67,496	114.2
45-49	122,585	55,056	67,529	81.5
50-54	102,714	43,678	59,036	74.0
55-59	90,737	39,843	50,895	78.3
60-64	78,034	37,116	40,918	90.7
65+	143,379	69,815	73,565	94.9
AKAKI KALITY-SUB CITY				
All Ages	216,846	105,636	111,210	95.0
0-4	18,874	9,322	9,551	97.6
5-9	14,688	8,394	6,294	133.4
10-14	18,904	8,684	10,220	85.0
15-19	25,518	10,125	15,393	65.8
20-24	29,841	14,327	15,514	92.4
25-29	29,587	13,942	15,645	89.1
30-34	18,750	10,589	8,161	129.8
35-39	17,736	9,471	8,264	114.6
40-44	9,122	4,637	4,485	103.4
45-49	8,656	3,613	5,043	71.7
50-54	5,761	1,882	3,879	48.5
55-59	6,467	2,899	3,568	81.3
60-64	5,305	3,556	1,749	203.3
65+	7,637	4,192	3,445	121.7
NEFAS SILK-LAFTO-SUB CITY				
All Ages	384,122	172,789	211,333	81.8
0-4	31,418	14,912	16,506	90.3
5-9	27,293	12,915	14,377	89.8
10-14	32,949	12,703	20,246	62.7
15-19	46,225	17,811	28,414	62.7
20-24	49,436	21,336	28,100	75.9
25-29	54,629	24,280	30,348	80.0
30-34	35,156	17,851	17,305	103.2
35-39	27,775	12,853	14,922	86.1
40-44	15,857	8,725	7,132	122.3
45-49	12,940	5,989	6,950	86.2
50-54	13,973	4,949	9,024	54.8
55-59	11,526	4,476	7,050	63.5
60-64	9,730	4,920	4,811	102.3
65+	15,214	9,066	6,148	147.5

Age Group	Total	Male	Female	Sex Ratio
		KOLFE KERANIYO-SUB CITY		
All Ages	524,759	260,280	264,480	98.4
0-4	49,737	27,726	22,012	126.0
5-9	43,723	24,440	19,283	126.7
10-14	51,936	24,220	27,716	87.4
15-19	63,401	23,619	39,782	59.4
20-24	67,474	30,233	37,241	81.2
25-29	66,054	31,778	34,276	92.7
30-34	49,632	27,539	22,093	124.6
35-39	41,466	21,579	19,887	108.5
40-44	21,652	12,981	8,671	149.7
45-49	21,215	10,103	11,112	90.9
50-54	14,321	7,601	6,720	113.1
55-59	10,148	5,702	4,446	128.3
60-64	7,505	3,935	3,570	110.2
65+	16,496	8,825	7,671	115.0
		GULELE-SUB CITY		
All Ages	295,342	137,599	157,744	87.2
0-4	21,342	11,065	10,277	107.7
5-9	18,608	8,593	10,015	85.8
10-14	22,198	10,087	12,111	83.3
15-19	34,710	13,730	20,980	65.4
20-24	40,058	17,276	22,783	75.8
25-29	41,230	19,601	21,629	90.6
30-34	27,840	13,619	14,221	95.8
35-39	25,221	14,293	10,929	130.8
40-44	13,473	5,911	7,562	78.2
45-49	11,250	4,969	6,281	79.1
50-54	9,381	4,708	4,673	100.8
55-59	9,272	3,229	6,042	53.4
60-64	6,651	3,301	3,350	98.5
65+	14,107	7,217	6,890	104.8
		LIDETA-SUB CITY		
All Ages	205,909	90,367	115,542	78.2
0-4	12,582	6,385	6,197	103.0
5-9	11,867	6,089	5,778	105.4
10-14	17,012	6,455	10,557	61.1
15-19	23,078	8,410	14,668	57.3
20-24	25,631	10,611	15,020	70.6
25-29	26,271	13,007	13,265	98.1
30-34	17,557	8,266	9,290	89.0
35-39	17,266	8,064	9,203	87.6
40-44	11,538	5,989	5,548	108.0
45-49	9,226	3,801	5,426	70.0
50-54	6,733	1,755	4,978	35.3
55-59	6,439	3,078	3,361	91.6
60-64	6,288	2,775	3,513	79.0
65+	14,420	5,682	8,738	65.0

Age Group	Total	Male	Female	Sex Ratio
		KIRKOS-SUB CITY		
All Ages	232,718	105,709	127,009	83.2
0-4	13,700	7,019	6,682	105.0
5-9	13,612	5,977	7,634	78.3
10-14	19,421	8,315	11,107	74.9
15-19	28,630	12,747	15,883	80.3
20-24	26,853	11,014	15,838	69.5
25-29	31,121	14,493	16,628	87.2
30-34	23,767	12,404	11,363	109.2
35-39	18,044	7,551	10,492	72.0
40-44	12,655	7,454	5,201	143.3
45-49	9,372	4,684	4,688	99.9
50-54	7,275	3,383	3,892	86.9
55-59	6,952	2,431	4,520	53.8
60-64	7,972	3,035	4,937	61.5
65+	13,345	5,201	8,144	63.9
		ARADA-SUB CITY		
All Ages	214,783	96,724	118,059	81.9
0-4	11,385	5,161	6,224	82.9
5-9	12,583	6,324	6,260	101.0
10-14	16,977	7,729	9,248	83.6
15-19	23,907	9,454	14,453	65.4
20-24	27,130	11,454	15,676	73.1
25-29	28,275	13,401	14,874	90.1
30-34	20,586	11,639	8,946	130.1
35-39	19,537	9,523	10,015	95.1
40-44	9,840	4,809	5,031	95.6
45-49	9,642	3,073	6,569	46.8
50-54	8,096	3,197	4,899	65.3
55-59	7,376	3,131	4,245	73.8
60-64	6,015	2,223	3,793	58.6
65+	13,432	5,607	7,825	71.7
		ADDIS KETEMA-SUB CITY		
All Ages	275,798	133,899	141,899	94.4
0-4	16,895	8,623	8,272	104.2
5-9	18,277	9,747	8,530	114.3
10-14	26,142	10,631	15,511	68.5
15-19	30,140	13,497	16,644	81.1
20-24	38,038	19,599	18,439	106.3
25-29	36,977	19,494	17,483	111.5
30-34	24,365	12,445	11,920	104.4
35-39	21,502	11,312	10,191	111.0
40-44	13,143	6,441	6,702	96.1
45-49	9,064	4,616	4,448	103.8
50-54	9,049	4,091	4,957	82.5
55-59	7,047	2,350	4,697	50.0
60-64	8,617	2,958	5,659	52.3
65+	16,542	8,096	8,446	95.8

Age Group	Total	Male	Female	Sex Ratio
		YEKA-SUB CITY		
All Ages	415,533	186,258	229,276	81.2
0-4	36,193	19,796	16,398	120.7
5-9	30,678	15,732	14,947	105.3
10-14	33,747	14,256	19,491	73.1
15-19	51,912	16,286	35,625	45.7
20-24	47,753	17,609	30,144	58.4
25-29	54,582	26,142	28,440	91.9
30-34	41,995	18,121	23,874	75.9
35-39	32,242	15,251	16,990	89.8
40-44	20,570	11,733	8,837	132.8
45-49	16,326	8,330	7,996	104.2
50-54	12,559	5,452	7,107	76.7
55-59	11,448	5,623	5,825	96.5
60-64	9,254	4,147	5,108	81.2
65+	16,273	7,779	8,494	91.6
		BOLE-SUB CITY		
All Ages	390,246	175,627	214,619	81.8
0-4	27,287	12,344	14,944	82.6
5-9	24,576	10,766	13,809	78.0
10-14	28,243	13,438	14,805	90.8
15-19	45,996	16,795	29,201	57.5
20-24	51,637	17,572	34,065	51.6
25-29	60,445	28,105	32,340	86.9
30-34	37,111	19,125	17,986	106.3
35-39	27,125	15,239	11,886	128.2
40-44	16,695	8,368	8,328	100.5
45-49	14,893	5,876	9,017	65.2
50-54	15,566	6,659	8,907	74.8
55-59	14,064	6,923	7,141	96.9
60-64	10,695	6,268	4,427	141.6
65+	15,913	8,149	7,764	105.0

Appendix 2 Economically active population of sub city of Addis Ababa aged ten years and above unemployed rate, age group and sex: 2013

Age Group	All Economically Active Population			Employed			Unemployed			Unemployment Rate		
	Total	Male	Female	Total	Male	Female	Total	Male	Female	Total	Male	Female
ADDIS ABABA CITY ADMINISTRATION												
All Ages	1,695,065	875,424	819,641	1,285,598	736,789	548,808	409,467	138,635	270,833	24.2	15.8	33.0
10-14	11,682	2,241	9,441	9,066	1,523	7,543	2,616	718	1,898	22.4	32.0	20.1
15-19	117,980	36,769	81,211	81,113	19,882	61,231	36,867	16,887	19,979	31.2	45.9	24.6
20-24	286,056	128,125	157,931	198,218	92,703	105,515	87,838	35,422	52,416	30.7	27.6	33.2
25-29	372,911	191,580	181,331	281,418	159,848	121,569	91,493	31,732	59,762	24.5	16.6	33.0
30-34	264,481	146,179	118,301	206,214	129,738	76,475	58,267	16,441	41,826	22.0	11.2	35.4
35-39	224,704	121,464	103,239	176,977	108,497	68,480	47,726	12,967	34,759	21.2	10.7	33.7
40-44	127,373	75,111	52,263	103,459	68,677	34,782	23,914	6,433	17,481	18.8	8.6	33.4
45-49	99,110	53,028	46,083	80,546	49,400	31,147	18,564	3,628	14,936	18.7	6.8	32.4
50-54	73,532	40,295	33,237	58,356	37,504	20,852	15,176	2,791	12,385	20.6	6.9	37.3
55-59	53,859	34,312	19,547	44,019	30,760	13,258	9,841	3,552	6,289	18.3	10.4	32.2
60-64	32,027	23,001	9,027	23,785	19,489	4,296	8,243	3,512	4,731	25.7	15.3	52.4
65+	31,350	23,319	8,032	22,427	18,767	3,661	8,923	4,552	4,371	28.5	19.5	54.4
AKAKI KALITY-SUB CITY												
All Ages	119,049	65,215	53,834	91,046	56,821	34,225	28,003	8,394	19,609	23.5	12.9	36.4
10-14	1,618	612	1,006	1,241	548	692	377	63	314	23.3	10.3	31.2
15-19	9,449	3,264	6,185	6,452	2,523	3,929	2,997	741	2,256	31.7	22.7	36.5
20-24	23,605	12,270	11,335	16,289	8,923	7,367	7,316	3,347	3,969	31.0	27.3	35.0
25-29	24,615	13,290	11,324	17,827	11,092	6,736	6,787	2,199	4,588	27.6	16.5	40.5
30-34	16,735	10,349	6,387	14,055	9,649	4,406	2,680	700	1,980	16.0	6.8	31.0
35-39	15,557	8,844	6,713	12,971	8,548	4,424	2,586	296	2,290	16.6	3.3	34.1
40-44	7,752	4,574	3,179	6,528	4,574	1,954	1,225	-	1,225	15.8	-	38.5
45-49	6,569	3,550	3,019	5,507	3,487	2,020	1,062	63	999	16.2	1.8	33.1
50-54	3,958	1,597	2,361	3,002	1,597	1,405	956	-	956	24.2	-	40.5
55-59	4,193	2,545	1,648	3,155	2,166	990	1,038	379	659	24.7	14.9	40.0
60-64	2,916	2,671	245	2,431	2,368	63	485	303	182	16.6	11.4	74.2
65+	2,080	1,649	431	1,586	1,346	240	494	303	191	23.7	18.4	44.2

Age Group	All Economically Active Population			Employed			Unemployed			Unemployment Rate		
	Total	Male	Female	Total	Male	Female	Total	Male	Female	Total	Male	Female
					NEFAS SILK-LAFTO-SUB CITY							
All Ages	203,880	102,348	101,532	152,342	85,787	66,555	51,538	16,561	34,976	25.3	16.2	34.4
10-14	1,449	257	1,192	1,345	257	1,088	104	-	104	7.2	-	8.7
15-19	12,782	4,171	8,611	9,034	2,116	6,918	3,748	2,055	1,693	29.3	49.3	19.7
20-24	36,191	16,585	19,605	25,671	12,819	12,852	10,520	3,766	6,754	29.1	22.7	34.4
25-29	47,373	22,830	24,542	35,368	19,348	16,020	12,005	3,483	8,522	25.3	15.3	34.7
30-34	31,515	17,273	14,243	23,645	14,555	9,090	7,871	2,718	5,153	25.0	15.7	36.2
35-39	24,671	12,631	12,040	18,248	10,766	7,481	6,423	1,864	4,559	26.0	14.8	37.9
40-44	14,448	8,392	6,056	11,930	7,923	4,007	2,518	469	2,049	17.4	5.6	33.8
45-49	9,936	5,694	4,242	8,028	5,381	2,647	1,908	313	1,595	19.2	5.5	37.6
50-54	10,073	4,636	5,436	7,327	4,284	3,043	2,746	353	2,393	27.3	7.6	44.0
55-59	6,928	4,129	2,799	5,344	3,443	1,901	1,585	686	899	22.9	16.6	32.1
60-64	4,677	2,997	1,679	3,460	2,438	1,022	1,217	559	657	26.0	18.7	39.1
65+	3,837	2,752	1,085	2,944	2,457	487	893	295	598	23.3	10.7	55.1
					KOLFE KERANIYO-SUB CITY							
All Ages	272,361	150,372	121,989	204,708	130,452	74,257	67,653	19,920	47,733	24.8	13.2	39.1
10-14	3,192	582	2,609	2,768	582	2,185	424	-	424	13.3	-	16.3
15-19	21,957	7,096	14,861	13,401	3,125	10,276	8,555	3,970	4,585	39.0	56.0	30.9
20-24	50,061	24,448	25,614	34,901	19,871	15,030	15,160	4,577	10,583	30.3	18.7	41.3
25-29	55,240	30,139	25,102	42,417	27,174	15,243	12,823	2,965	9,859	23.2	9.8	39.3
30-34	43,328	26,500	16,828	33,707	24,831	8,876	9,622	1,669	7,953	22.2	6.3	47.3
35-39	37,304	21,448	15,855	27,972	19,320	8,653	9,331	2,129	7,202	25.0	9.9	45.4
40-44	18,445	12,822	5,622	14,375	10,976	3,399	4,070	1,846	2,223	22.1	14.4	39.5
45-49	18,048	9,973	8,076	14,762	9,434	5,329	3,286	539	2,747	18.2	5.4	34.0
50-54	10,695	6,990	3,706	9,262	6,379	2,882	1,434	610	823	13.4	8.7	22.2
55-59	6,664	4,926	1,737	5,910	4,437	1,473	753	489	264	11.3	9.9	15.2
60-64	3,788	2,556	1,232	2,537	2,013	523	1,252	543	709	33.0	21.2	57.5
65+	3,639	2,892	747	2,696	2,309	387	942	582	360	25.9	20.1	48.1

Age Group	All Economically Active Population			Employed			Unemployed			Unemployment Rate		
	Total	Male	Female	Total		Total	Male	Female	Total		Total	Male
					GULELE-SUB CITY							
All Ages	157,877	82,617	75,260	124,698	71,239	53,459	33,179	11,378	21,801	21.0	13.8	29.0
10-14	838	135	703	652	135	517	186	-	186	22.2	-	26.5
15-19	9,258	2,990	6,268	6,681	1,875	4,806	2,577	1,116	1,462	27.8	37.3	23.3
20-24	26,824	12,475	14,349	18,560	8,851	9,710	8,264	3,624	4,640	30.8	29.1	32.3
25-29	35,783	18,210	17,573	27,482	15,574	11,908	8,302	2,636	5,665	23.2	14.5	32.2
30-34	24,644	13,100	11,544	19,272	11,320	7,952	5,371	1,780	3,591	21.8	13.6	31.1
35-39	23,210	13,560	9,650	20,715	12,620	8,096	2,494	941	1,554	10.7	6.9	16.1
40-44	11,605	5,817	5,788	10,033	5,447	4,586	1,572	370	1,202	13.5	6.4	20.8
45-49	8,486	4,781	3,705	6,891	4,395	2,496	1,594	386	1,208	18.8	8.1	32.6
50-54	6,672	4,281	2,391	5,776	4,281	1,495	896	-	896	13.4	-	37.5
55-59	5,022	2,936	2,086	4,121	2,787	1,334	901	149	752	17.9	5.1	36.1
60-64	2,512	1,759	752	2,040	1,665	374	472	94	378	18.8	5.3	50.2
65+	3,025	2,573	452	2,475	2,291	184	550	282	267	18.2	11.0	59.2
					LIDETA-SUB CITY							
All Ages	100,728	52,164	48,564	71,654	41,640	30,014	29,074	10,524	18,550	28.9	20.2	38.2
10-14	74	-	74	-	-	-	74	-	74	100.0	-	100.0
15-19	5,462	1,811	3,650	2,822	663	2,159	2,639	1,148	1,491	48.3	63.4	40.8
20-24	14,968	6,376	8,592	9,491	4,421	5,069	5,478	1,955	3,523	36.6	30.7	41.0
25-29	21,910	12,036	9,874	14,970	9,014	5,956	6,940	3,023	3,917	31.7	25.1	39.7
30-34	15,015	7,871	7,144	10,203	6,166	4,038	4,812	1,705	3,106	32.0	21.7	43.5
35-39	15,103	7,730	7,372	11,758	6,633	5,125	3,345	1,097	2,248	22.1	14.2	30.5
40-44	9,748	5,419	4,330	7,533	4,936	2,597	2,215	483	1,732	22.7	8.9	40.0
45-49	6,987	3,654	3,333	5,731	3,441	2,290	1,256	212	1,043	18.0	5.8	31.3
50-54	3,951	1,690	2,260	2,872	1,417	1,455	1,079	273	805	27.3	16.2	35.6
55-59	3,366	2,415	951	2,747	2,138	609	619	277	342	18.4	11.5	36.0
60-64	2,469	1,876	593	2,070	1,672	398	398	204	195	16.1	10.9	32.8
65+	1,677	1,286	391	1,456	1,139	317	221	147	74	13.2	11.4	18.8

Age Group	All Economically Active Population			Employed			Unemployed			Unemployment Rate		
	Total	Male	Female	Total		Total	Male	Female	Total		Total	Male
KIRKOS-SUB CITY												
All Ages	124,802	62,298	62,504	94,677	51,081	43,596	30,125	11,217	18,908	24.1	18.0	30.3
10-14	87	-	87	87	-	87	-	-	-	-	-	-
15-19	7,897	2,348	5,549	5,815	1,478	4,336	2,083	870	1,213	26.4	37.0	21.9
20-24	17,964	7,290	10,674	12,052	4,944	7,108	5,912	2,346	3,566	32.9	32.2	33.4
25-29	26,877	13,275	13,601	19,672	9,971	9,701	7,205	3,305	3,900	26.8	24.9	28.7
30-34	21,433	11,973	9,460	17,345	10,408	6,938	4,088	1,565	2,522	19.1	13.1	26.7
35-39	16,741	7,464	9,277	12,837	6,508	6,329	3,905	957	2,948	23.3	12.8	31.8
40-44	11,785	7,367	4,418	9,787	6,410	3,376	1,998	957	1,042	17.0	13.0	23.6
45-49	8,242	4,684	3,557	6,942	4,424	2,518	1,300	261	1,039	15.8	5.6	29.2
50-54	5,199	2,866	2,333	4,247	2,692	1,554	952	174	778	18.3	6.1	33.4
55-59	3,560	2,170	1,390	2,951	2,083	868	609	87	522	17.1	4.0	37.6
60-64	2,170	1,392	778	1,392	1,044	348	778	348	430	35.9	25.0	55.3
65+	2,848	1,467	1,381	1,552	1,120	433	1,296	348	948	45.5	23.7	68.6
ARADA-SUB CITY												
All Ages	115,467	58,940	56,528	84,004	46,227	37,777	31,464	12,712	18,751	27.2	21.6	33.2
10-14	364	76	288	221	-	221	143	76	67	39.3	100.0	23.3
15-19	6,577	2,927	3,650	3,713	1,387	2,325	2,865	1,540	1,325	43.6	52.6	36.3
20-24	17,580	7,718	9,862	11,789	4,613	7,175	5,791	3,104	2,687	32.9	40.2	27.2
25-29	23,776	12,138	11,638	17,759	9,770	7,989	6,017	2,368	3,649	25.3	19.5	31.4
30-34	18,772	11,083	7,689	13,497	8,951	4,545	5,276	2,132	3,144	28.1	19.2	40.9
35-39	17,770	9,379	8,390	13,969	7,986	5,983	3,801	1,393	2,407	21.4	14.9	28.7
40-44	8,563	4,742	3,821	6,892	4,230	2,662	1,671	513	1,159	19.5	10.8	30.3
45-49	7,863	2,769	5,095	5,386	2,186	3,200	2,478	583	1,895	31.5	21.1	37.2
50-54	5,544	2,973	2,571	4,244	2,618	1,626	1,300	355	945	23.4	11.9	36.7
55-59	4,325	2,456	1,869	3,300	2,166	1,134	1,026	290	735	23.7	11.8	39.3
60-64	2,025	1,227	798	1,225	939	286	800	288	511	39.5	23.5	64.1
65+	2,308	1,450	857	2,011	1,381	629	297	69	228	12.9	4.8	26.6

Age Group	All Economically Active Population			Employed			Unemployed			Unemployment Rate		
	Total	Male	Female	Total		Total	Male	Female	Total		Total	Male
ADDIS KETEMA-SUB CITY												
All Ages	142,681	78,618	64,063	98,807	60,760	38,047	43,874	17,858	26,016	30.7	22.7	40.6
10-14	1,307	177	1,130	695	-	695	611	177	435	46.8	100.0	38.5
15-19	10,110	4,355	5,755	5,485	1,912	3,573	4,625	2,443	2,182	45.7	56.1	37.9
20-24	24,461	13,422	11,039	14,531	8,359	6,171	9,930	5,062	4,868	40.6	37.7	44.1
25-29	32,280	17,669	14,612	22,108	12,972	9,136	10,173	4,697	5,476	31.5	26.6	37.5
30-34	21,062	11,575	9,486	14,965	9,660	5,305	6,096	1,915	4,181	28.9	16.5	44.1
35-39	18,808	10,703	8,105	14,021	9,573	4,448	4,787	1,130	3,657	25.5	10.6	45.1
40-44	11,144	6,093	5,050	8,099	5,398	2,701	3,045	695	2,350	27.3	11.4	46.5
45-49	7,232	4,268	2,964	5,668	3,660	2,008	1,565	608	956	21.6	14.3	32.3
50-54	6,006	3,570	2,437	5,050	3,309	1,741	956	261	695	15.9	7.3	28.5
55-59	3,917	2,002	1,915	2,874	1,741	1,133	1,043	261	782	26.6	13.0	40.8
60-64	2,698	1,738	959	2,089	1,478	611	608	261	348	22.6	15.0	36.2
65+	3,657	3,045	611	3,222	2,698	525	435	348	87	11.9	11.4	14.2
YEKA-SUB CITY												
All Ages	231,434	112,735	118,699	176,631	94,661	81,970	54,803	18,074	36,729	23.7	16.0	30.9
10-14	1,658	295	1,363	1,175	-	1,175	483	295	188	29.1	100.0	13.8
15-19	17,318	4,357	12,961	13,391	2,341	11,050	3,927	2,016	1,911	22.7	46.3	14.7
20-24	36,024	13,964	22,061	24,829	8,930	15,898	11,196	5,033	6,162	31.1	36.0	27.9
25-29	50,159	25,147	25,012	40,338	21,772	18,566	9,821	3,374	6,446	19.6	13.4	25.8
30-34	36,605	17,627	18,977	28,650	16,360	12,289	7,955	1,267	6,688	21.7	7.2	35.2
35-39	30,291	15,008	15,283	23,567	13,530	10,037	6,724	1,477	5,246	22.2	9.8	34.3
40-44	19,210	11,733	7,477	15,436	10,740	4,696	3,775	994	2,781	19.6	8.5	37.2
45-49	14,420	8,068	6,352	11,544	7,583	3,961	2,876	485	2,391	19.9	6.0	37.6
50-54	10,521	5,452	5,070	6,972	4,841	2,131	3,549	611	2,938	33.7	11.2	58.0
55-59	6,962	4,915	2,047	5,887	4,087	1,800	1,074	827	247	15.4	16.8	12.1
60-64	4,390	3,407	982	3,170	3,049	121	1,219	358	861	27.8	10.5	87.7
65+	3,877	2,763	1,114	1,673	1,427	245	2,204	1,335	869	56.9	48.3	78.0

Age Group	All Economically Active Population			Employed			Unemployed			Unemployment Rate		
	Total	Male	Female	Total		Total	Male	Female	Total		Total	Male
					BOLE-SUB CITY							
All Ages	226,786	110,118	116,668	187,030	98,122	88,908	39,756	11,996	27,760	17.5	10.9	23.8
10-14	1,096	107	990	883	-	883	213	107	107	19.4	100.0	10.8
15-19	17,169	3,449	13,720	14,319	2,461	11,859	2,850	988	1,861	16.6	28.7	13.6
20-24	38,378	13,578	24,800	30,106	10,972	19,134	8,272	2,606	5,666	21.6	19.2	22.8
25-29	54,898	26,845	28,053	43,477	23,163	20,314	11,421	3,682	7,739	20.8	13.7	27.6
30-34	35,371	18,827	16,544	30,874	17,838	13,036	4,497	990	3,508	12.7	5.3	21.2
35-39	25,250	14,697	10,554	20,919	13,013	7,905	4,332	1,683	2,649	17.2	11.5	25.1
40-44	14,673	8,151	6,521	12,848	8,045	4,803	1,825	107	1,719	12.4	1.3	26.4
45-49	11,327	5,588	5,739	10,087	5,410	4,678	1,240	178	1,062	10.9	3.2	18.5
50-54	10,913	6,240	4,673	9,605	6,087	3,518	1,308	154	1,154	12.0	2.5	24.7
55-59	8,922	5,819	3,103	7,729	5,712	2,017	1,193	107	1,086	13.4	1.8	35.0
60-64	4,384	3,377	1,007	3,371	2,823	548	1,013	554	460	23.1	16.4	45.6
65+	4,404	3,441	963	2,812	2,599	213	1,592	841	750	36.1	24.5	77.9

Appendix 3 City Government of Addis Ababa Education Bureau

Detail Table By Sub-city

Sector	Primary Education
Ownership	All
Program Mode	All

Sub-city	Grade 1		Grade 2		Grade 3		Grade 4		Grade 5		Grade 6		Grade 7		Grade 8		TOTAL		TOTAL
	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	
Addis Ketema	1581	1924	1438	2437	1537	4085	1616	4321	1711	8655	1858	5354	2069	6537	5396	5520	17206	38833	56039
Akaki-Kaliti	2580	2980	2268	2713	2000	2434	2380	2342	2335	3641	2142	3501	2435	3890	2077	2547	18217	24048	42265
Arada	1817	1999	1602	1841	1849	6602	1898	2200	1700	2836	1951	2866	2146	3243	2141	3213	15104	24800	39904
Bole	3792	4850	3351	4147	3172	3630	3083	3627	3194	4299	2885	3935	3177	4050	3073	3964	25727	32502	58229
Gullelie	2714	8116	2349	2634	1934	5273	2104	2534	2157	2536	2024	2422	2287	2717	2382	3107	17951	29339	47290
Kirkos	1748	2259	1580	1798	1586	1726	1729	2002	1604	2071	1621	2031	1872	2281	1550	2129	13290	16297	29587
Kolfe-Keranio	7140	12729	5339	6183	5176	5823	5191	5748	13882	8343	4575	5885	5347	6412	4276	5351	50926	56474	107400
Lideta	1200	1395	1107	1240	1045	1303	1209	1232	4799	5307	2530	1304	1159	1323	1033	1434	14082	14538	28620
Nefas Silk-Lafto	4575	5428	3832	4685	10325	4300	3409	4177	3385	3997	2997	3612	3286	3925	3164	3994	34973	34118	69091
Yeka	4274	5234	3641	4773	3383	5268	3415	3986	4362	4828	4595	5264	3415	4313	3078	4260	30163	37926	68089
Total	31421	46914	26507	32451	32007	40444	26034	32169	39129	46513	27178	36174	27193	38691	28170	35519	237639	308875	546514

Sector	Primary Education
Ownership	All
Program Mode	Regular Class

Sub-city	Grade 1		Grade 2		Grade 3		Grade 4		Grade 5		Grade 6		Grade 7		Grade 8		TOTAL		TOTAL
	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	
Addis Ketema	1413	1645	1268	2184	1286	3854	1398	4021	1514	8482	1608	5184	1808	6403	5040	5332	15335	37105	52440
Akaki-Kaliti	2228	2498	2113	2456	1851	2198	2237	2150	2169	3477	2018	3344	2250	3710	1883	2354	16749	22187	38936
Arada	1808	1973	1561	1759	1757	6379	1813	1968	1572	2585	1770	2584	1987	2951	1830	2708	14098	22907	37005
Bole	3303	3630	2877	3223	2755	2940	2745	2944	2746	3538	2417	3319	2707	3343	2457	3029	22007	25966	47973
Gullelie	2546	7719	2249	2400	1859	5079	2005	2303	1976	2232	1815	2080	2029	2355	1923	2430	16402	26598	43000
Kirkos	1680	2030	1509	1619	1506	1522	1632	1720	1494	1828	1505	1771	1744	1968	1317	1733	12387	14191	26578
Kolfe-Keranio	6602	11191	4943	5248	4827	5093	4799	4980	13498	7672	4152	5243	4900	5714	3693	4586	47414	49727	97141
Lideta	1128	1322	1081	1200	981	1214	1192	1191	4713	5191	2460	1231	1085	1247	947	1347	13587	13943	27530
Nefas Silk-Lafto	4215	4671	3560	4126	10054	3799	3267	3880	3223	3639	2870	3303	3129	3646	2846	3470	33164	30534	63698
Yeka	3966	4391	3413	4249	3157	4871	3206	3528	4113	4373	4319	4797	3141	3774	2748	3706	28063	33689	61752
Total	28889	41070	24574	28464	30033	36949	24294	28685	37018	43017	24934	32856	24780	35111	24684	30695	219206	276847	496053

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Sector	Primary Education
Ownership	All
Program Mode	All

Sub-city	Grade 1		Grade 2		Grade 3		Grade 4		Grade 5		Grade 6		Grade 7		Grade 8		TOTAL		TOTAL
	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	
Addis Ketema	1581	1924	1438	2437	1537	4085	1616	4321	1711	8655	1858	5354	2069	6537	5396	5520	17206	38833	56039
Akaki-Kaliti	2580	2980	2268	2713	2000	2434	2380	2342	2335	3641	2142	3501	2435	3890	2077	2547	18217	24048	42265
Arada	1817	1999	1602	1841	1849	6602	1898	2200	1700	2836	1951	2866	2146	3243	2141	3213	15104	24800	39904
Bole	3792	4850	3351	4147	3172	3630	3083	3627	3194	4299	2885	3935	3177	4050	3073	3964	25727	32502	58229
Gullelie	2714	8116	2349	2634	1934	5273	2104	2534	2157	2536	2024	2422	2287	2717	2382	3107	17951	29339	47290
Kirkos	1748	2259	1580	1798	1586	1726	1729	2002	1604	2071	1621	2031	1872	2281	1550	2129	13290	16297	29587
Kolfe-Keranio	7140	12729	5339	6183	5176	5823	5191	5748	13882	8343	4575	5885	5347	6412	4276	5351	50926	56474	107400
Lideta	1200	1395	1107	1240	1045	1303	1209	1232	4799	5307	2530	1304	1159	1323	1033	1434	14082	14538	28620
Nefas Silk-Lafto	4575	5428	3832	4685	10325	4300	3409	4177	3385	3997	2997	3612	3286	3925	3164	3994	34973	34118	69091
Yeka	4274	5234	3641	4773	3383	5268	3415	3986	4362	4828	4595	5264	3415	4313	3078	4260	30163	37926	68089
Total	31421	46914	26507	32451	32007	40444	26034	32169	39129	46513	27178	36174	27193	38691	28170	35519	237639	308875	546514

Sector	Primary Education
Ownership	All
Program Mode	Regular Class

Sub-city	Grade 1		Grade 2		Grade 3		Grade 4		Grade 5		Grade 6		Grade 7		Grade 8		TOTAL		TOTAL
	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	
Addis Ketema	1413	1645	1268	2184	1286	3854	1398	4021	1514	8482	1608	5184	1808	6403	5040	5332	15335	37105	52440
Akaki-Kaliti	2228	2498	2113	2456	1851	2198	2237	2150	2169	3477	2018	3344	2250	3710	1883	2354	16749	22187	38936
Arada	1808	1973	1561	1759	1757	6379	1813	1968	1572	2585	1770	2584	1987	2951	1830	2708	14098	22907	37005
Bole	3303	3630	2877	3223	2755	2940	2745	2944	2746	3538	2417	3319	2707	3343	2457	3029	22007	25966	47973
Gullelie	2546	7719	2249	2400	1859	5079	2005	2303	1976	2232	1815	2080	2029	2355	1923	2430	16402	26598	43000
Kirkos	1680	2030	1509	1619	1506	1522	1632	1720	1494	1828	1505	1771	1744	1968	1317	1733	12387	14191	26578
Kolfe-Keranio	6602	11191	4943	5248	4827	5093	4799	4980	13498	7672	4152	5243	4900	5714	3693	4586	47414	49727	97141
Lideta	1128	1322	1081	1200	981	1214	1192	1191	4713	5191	2460	1231	1085	1247	947	1347	13587	13943	27530
Nefas Silk-Lafto	4215	4671	3560	4126	10054	3799	3267	3880	3223	3639	2870	3303	3129	3646	2846	3470	33164	30534	63698
Yeka	3966	4391	3413	4249	3157	4871	3206	3528	4113	4373	4319	4797	3141	3774	2748	3706	28063	33689	61752
Total	28889	41070	24574	28464	30033	36949	24294	28685	37018	43017	24934	32856	24780	35111	24684	30695	219206	276847	496053

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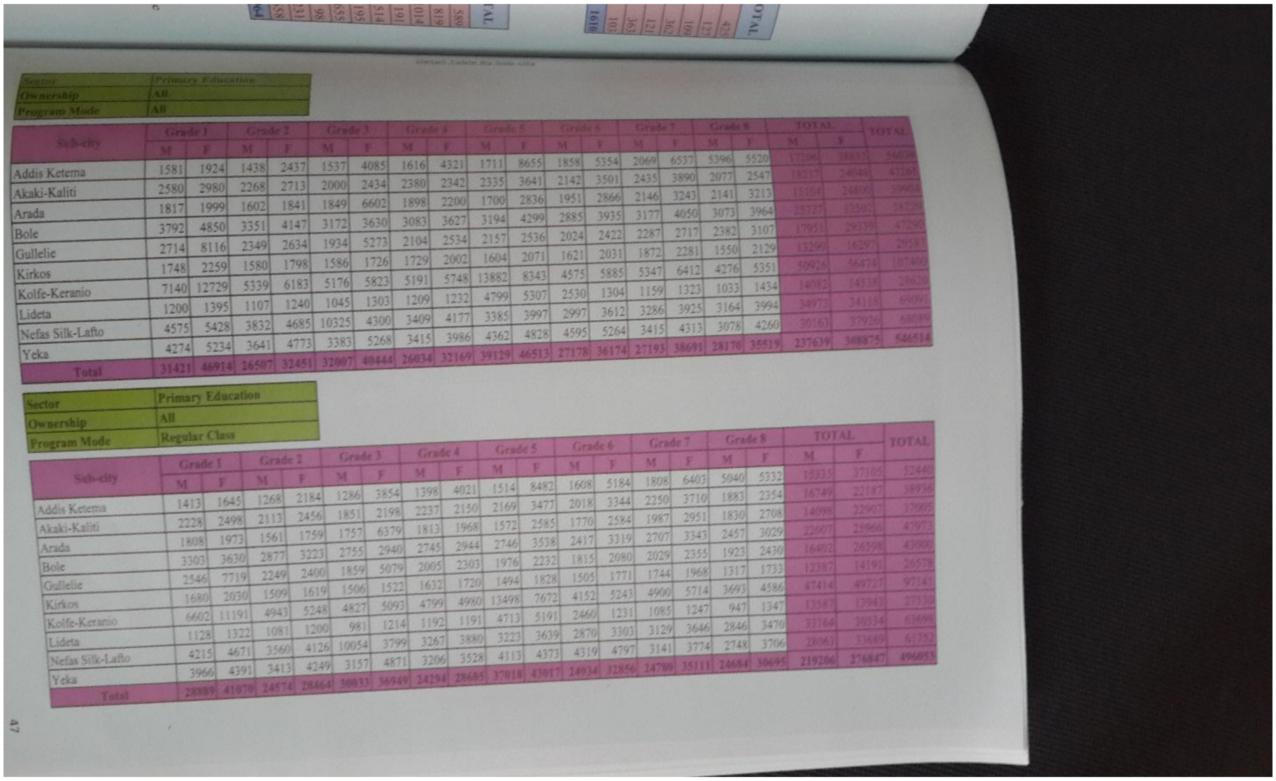

Sector	Primary Education
Ownership	All
Program Mode	All

Sub-city	Grade 1 M	Grade 1 F	Grade 2 M	Grade 2 F	Grade 3 M	Grade 3 F	Grade 4 M	Grade 4 F	Grade 5 M	Grade 5 F	Grade 6 M	Grade 6 F	Grade 7 M	Grade 7 F	Grade 8 M	Grade 8 F	TOTAL M	TOTAL F	TOTAL
Addis Ketema	1581	1924	1438	2437	1537	4085	1616	4321	1711	8655	1858	5354	2069	6537	5396	5520	17206	38833	56039
Akaki-Kaliti	2580	2980	2268	2713	2000	2434	2380	2342	2335	3641	2142	3501	2435	3890	2077	2547	18217	24048	42265
Arada	1817	1999	1602	1841	1849	6602	1898	2200	1700	2836	1951	2866	2146	3243	2141	3213	15104	24890	39994
Bole	3792	4850	3351	4147	3172	3630	3083	3627	3194	4299	2885	3935	3177	4050	3073	3964	25727	32502	58229
Gullelie	2714	8116	2349	2634	1934	5273	2104	2534	2157	2536	2024	2422	2287	2717	2382	3107	17951	29339	47290
Kirkos	1748	2259	1580	1798	1586	1726	1729	2002	1604	2071	1621	2031	1872	2281	1550	2129	13290	16297	29587
Kolfe-Keranio	7140	12729	5339	6183	5176	5823	5191	5748	13882	8343	4575	5885	5347	6412	4276	5351	50926	56474	107400
Lideta	1200	1395	1107	1240	1045	1303	1209	1232	4799	5307	2530	1304	1159	1323	1033	1434	14082	14538	28620
Nefas Silk-Lafto	4575	5428	3832	4685	10325	4300	3409	4177	3385	3997	2997	3612	3286	3925	3164	3994	34973	34118	69091
Yeka	4274	5234	3641	4773	3383	5268	3415	3986	4362	4828	4595	5264	3415	4313	3078	4260	30163	37926	68089
Total	31421	46914	26507	32451	32007	40444	26034	32169	39129	46513	27178	36174	27193	38691	28170	35519	237639	308875	546514

Sector	Primary Education
Ownership	All
Program Mode	Regular Class

Sub-city	Grade 1 M	Grade 1 F	Grade 2 M	Grade 2 F	Grade 3 M	Grade 3 F	Grade 4 M	Grade 4 F	Grade 5 M	Grade 5 F	Grade 6 M	Grade 6 F	Grade 7 M	Grade 7 F	Grade 8 M	Grade 8 F	TOTAL M	TOTAL F	TOTAL
Addis Ketema	1413	1645	1268	2184	1286	3854	1398	4021	1514	8482	1608	5184	1808	6403	5040	5332	15335	37105	52440
Akaki-Kaliti	2228	2498	2113	2456	1851	2198	2237	2150	2169	3477	2018	3344	2250	3710	1883	2354	16749	22187	38936
Arada	1808	1973	1561	1759	1757	6379	1813	1968	1572	2585	1770	2584	1987	2951	1830	2708	14098	22907	37005
Bole	3303	3630	2877	3223	2755	2940	2745	2944	2746	3538	2417	3319	2707	3343	2457	3029	22007	25966	47973
Gullelie	2546	7719	2249	2400	1859	5079	2005	2303	1976	2232	1815	2080	2029	2355	1923	2430	16402	26598	43000
Kirkos	1680	2030	1509	1619	1506	1522	1632	1720	1494	1828	1505	1771	1744	1968	1317	1733	12387	14191	26578
Kolfe-Keranio	6602	11191	4943	5248	4827	5093	4799	4980	13498	7672	4152	5243	4900	5714	3693	4586	47414	49727	97141
Lideta	1128	1322	1081	1200	981	1214	1192	1191	4713	5191	2460	1231	1085	1247	947	1347	13587	13943	27530
Nefas Silk-Lafto	4215	4671	3560	4126	10054	3799	3267	3880	3223	3639	2870	3303	3129	3646	2846	3470	33164	30534	63698
Yeka	3966	4391	3413	4249	3157	4871	3206	3528	4113	4373	4319	4797	3141	3774	2748	3706	28063	33689	61752
Total	28889	41070	24574	28464	30033	36949	24294	28685	37018	43017	24934	32856	24780	35111	24684	30695	219206	276847	496053

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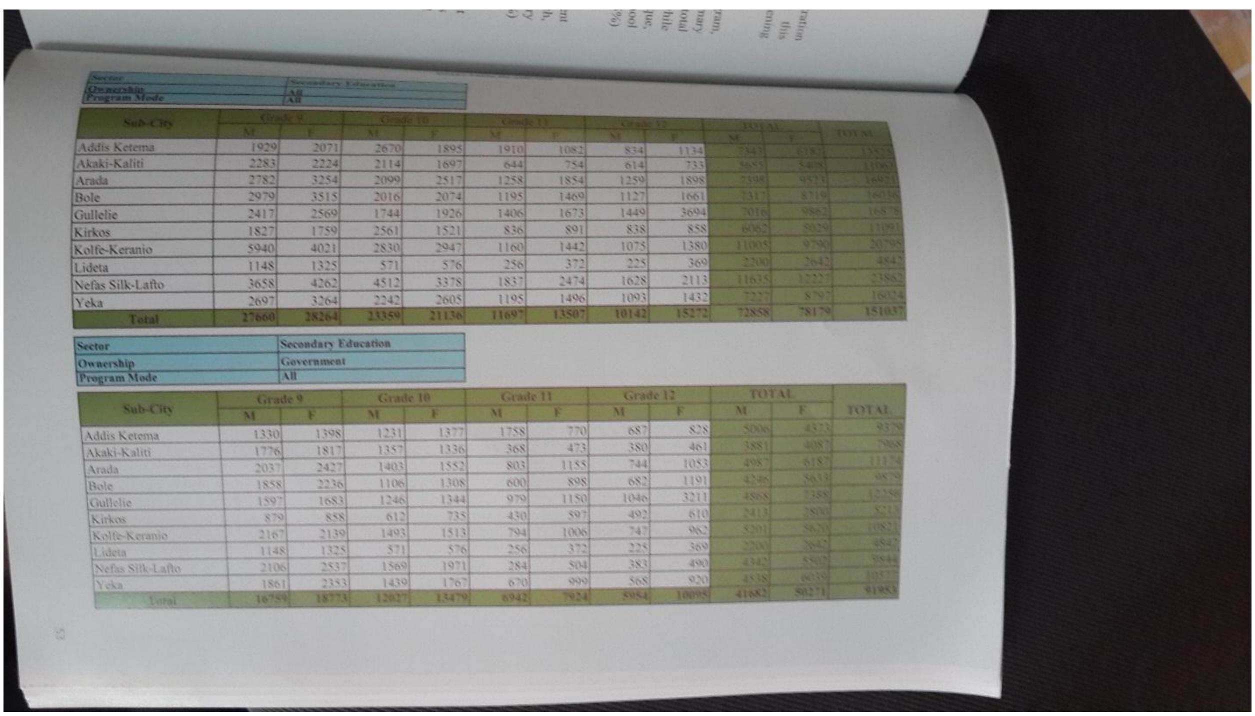

Sector	Secondary Education
Ownership	All
Program Mode	All

Sub-City	Grade 9 M	Grade 9 F	Grade 10 M	Grade 10 F	Grade 11 M	Grade 11 F	Grade 12 M	Grade 12 F	TOTAL M	TOTAL F	TOTAL
Addis Ketema	1929	2071	2670	1895	1910	1082	834	1134	7343	6182	13525
Akaki-Kaliti	2283	2224	2114	1697	644	754	614	733	5655	5408	11063
Arada	2782	3254	2099	2517	1258	1854	1259	1898	7398	9523	16921
Bole	2979	3515	2016	2074	1195	1469	1127	1661	7317	8719	16036
Gullelie	2417	2569	1744	1926	1406	1673	1449	3694	7016	9862	16878
Kirkos	1827	1759	2561	1521	836	891	838	858	6062	5029	11091
Kolfe-Keranio	5940	4021	2830	2947	1160	1442	1075	1380	11005	9790	20795
Lideta	1148	1325	571	576	256	372	225	369	2200	2642	4842
Nefas Silk-Lafto	3658	4262	4512	3378	1837	2474	1628	2113	11635	12227	23862
Yeka	2697	3264	2242	2605	1195	1496	1093	1432	7227	8797	16024
Total	27660	28264	23359	21136	11697	13507	10142	15272	72858	78179	151037

Sector	Secondary Education
Ownership	Government
Program Mode	All

Sub-City	Grade 9 M	Grade 9 F	Grade 10 M	Grade 10 F	Grade 11 M	Grade 11 F	Grade 12 M	Grade 12 F	TOTAL M	TOTAL F	TOTAL
Addis Ketema	1330	1398	1231	1377	1758	770	687	828	5006	4373	9379
Akaki-Kaliti	1776	1817	1357	1336	368	473	380	461	3881	4087	7968
Arada	2037	2427	1403	1552	803	1155	744	1053	4987	6187	11174
Bole	1858	2236	1106	1308	600	898	682	1191	4246	5633	9879
Gullelie	1597	1683	1246	1344	979	1150	1046	3211	4868	7388	12256
Kirkos	879	858	612	735	430	597	492	610	2413	2800	5213
Kolfe-Keranio	2167	2139	1493	1513	794	1006	747	962	5201	5620	10821
Lideta	1148	1325	571	576	256	372	225	369	2200	2642	4842
Nefas Silk-Lafto	2106	2537	1569	1971	284	504	383	490	4342	5502	9844
Yeka	1861	2353	1439	1767	670	999	568	920	4538	6039	10577
Total	16759	18773	12027	13479	6942	7924	5954	10095	41682	50271	91953

Sector	Secondary Education
Ownership	All
Program Mode	All

Sub-City	Grade 9		Grade 10		Grade 11		Grade 12		TOTAL		TOTAL
	M	F	M	F	M	F	M	F	M	F	
Addis Ketema	1929	2071	2670	1895	1910	1082	834	1134	7343	6182	13525
Akaki-Kaliti	2283	2224	2114	1697	644	754	614	733	5655	5408	11063
Arada	2782	3254	2099	2517	1258	1854	1259	1898	7398	9523	16921
Bole	2979	3515	2016	2074	1195	1469	1127	1661	7317	8719	16036
Gullelie	2417	2569	1744	1926	1406	1673	1449	3694	7016	9862	16878
Kirkos	1827	1759	2561	1521	836	891	838	858	6062	5029	11091
Kolfe-Keranio	5940	4021	2830	2947	1160	1442	1075	1380	11005	9790	20795
Lideta	1148	1325	571	576	256	372	225	369	2200	2642	4842
Nefas Silk-Lafto	3658	4262	4512	3378	1837	2474	1628	2113	11635	12227	23862
Yeka	2697	3264	2242	2605	1195	1496	1093	1432	7227	8797	16024
Total	27660	28264	23359	21136	11697	13507	10142	15272	72858	78179	151037

Sector	Secondary Education
Ownership	Government
Program Mode	All

Sub-City	Grade 9		Grade 10		Grade 11		Grade 12		TOTAL		TOTAL
	M	F	M	F	M	F	M	F	M	F	
Addis Ketema	1330	1398	1231	1377	1758	770	687	828	5006	4373	9379
Akaki-Kaliti	1776	1817	1357	1336	368	473	380	461	3881	4087	7968
Arada	2037	2427	1403	1552	803	1155	744	1053	4987	6187	11174
Bole	1858	2236	1106	1308	600	898	682	1191	4246	5633	9879
Gullelie	1597	1683	1246	1344	979	1150	1046	3211	4868	7388	12256
Kirkos	879	858	612	735	430	597	492	610	2413	2800	5213
Kolfe-Keranio	2167	2139	1493	1513	794	1006	747	962	5201	5620	10821
Lideta	1148	1325	571	576	256	372	225	369	2200	2642	4842
Nefas Silk-Lafto	2106	2537	1569	1971	284	504	383	490	4342	5502	9844
Yeka	1861	2353	1439	1767	670	999	568	920	4538	6039	10577
Total	16759	18773	12027	13479	6942	7924	5954	10095	41682	50271	91953