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ADDIS ABABA LIGHT RAIL TRANSIT INTERNAL TRIP PRODUCTION FORECASTING

By

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POSTGRADUATE PROGRAM IN RAILWAY ENGINEERING ADDIS ABABA UNIVERSITY

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Approved by Board of Examiners

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DECLARATION

I hereby declare that the work which is being presented in this thesis entitled “Light Rail Transit Internal Trip production forecasting” is original work of my own, has not been presented for a degree of any other university and all the resource of materials used for this thesis have been duly acknowledged.

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Digafe Tadesse Date

This is to certify that the above declaration made by the candidate is correct to the best of my knowledge.

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ABBREVIATIONS, KEY TERMS AND DEFINITIONS

Abbreviations

AA: Addis Ababa

AACI: Addis Ababa City Plan Institute

AALRT: Addis Ababa Light Rail Transit

ATA: Addis Ababa transport authority

CSA: Central Statistics Authority

ERC: Ethiopian Railways Corporation

G.C: Gregorian's Calendar

ITE: Institute of Transportation Engineers

KM: Kilo Meter

LRT: Light Rail Transit

LRTs: Light Rail Transit Systems

NRNE: National Railway Network of Ethiopia Organization

PTS: Public Transport System

TAZ: Transportation Analysis Zone

USD: United States dollar

Key Terms

Kebele - The smallest local administration unit (average size of Kebeles is 2000 households)

Woreda - Local administration unit above Kebeles (the number of Kebeles in each Woreda ranges from 4- 18)

Light rail transit: Electrically propelled rail vehicles operate singly or in trains.

Trip: the out way and return journey.

Trip production: the trips produced by residents.

Trip generation: the trips generated i.e. (produced and attracted) by residents

Internal trip: the trips produced by residents of specific area only.

Transport - a means of conveying people or goods from one place to another.

Urban transport - all types of means of transportation used in urban areas

Route: the specific way followed by vehicles.

ABSTRACT

This study mainly focuses on the Addis Ababa Light Rail Transit (AALRT) estimation of residential based person internal trips which unless analyzed can affects the project justification during the early stage of project installation, transportation planning during operation stages, identification of markets, service planning, facility assessments and revenue estimations.

To estimate the trips the required primary and secondary data are collected, the primary data on locations closest to LRT routes are collected with a direct observation and interviewing of government officials and the secondary data on socio-economic data, census data and land use data are collected from various sources such as Central Statistics Authority, Addis Ababa Transport Authority and Addis Ababa City Plan Institute. The data gathered are analyzed using the Land Activity Rate or Land Use Method of trip based model for the base year trip production calculation and Growth Factor Methods for future trip projection calculations.

the land activity rate is used to determine the total land areas covered by the LRT routes and the Institute for Transportation Engineers (ITE) standard is used to determine the trips per hectare produced and finally the growth factor method is used to project the trips for future times.

Based on these models the numbers of trips are calculated both on North-South and East-West LRT routes as a minimum and a maximum values in interval for the consecutive five years. The North–South route forecasting shows a minimum of 603,159 person trips per day and a maximum of 2,031,691 person trips per day whereas the East-West route forecasting shows a minimum of 1,124,988 person trips per day and a maximum of 3,789,434 person trips per day generated after five years in 2019G.C.Thus from the forecasted result of residential based internal trip production of the coming five years, the Ethiopian Railways Corporation (ERC) will be able to carry out the supply side facility estimation and future revenue projections so as to make the company responsive for the changes made on the travel needs.

CHAPTER ONE:-INTRODUCTION

1.1 Background of the study

Ethiopia has introduced the first Addis Ababa- Djibouti diesel Rail vehicle a century ago, which is now phased out because of several reasons. And its capital city 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 (Tibleste Tefera, 2012). These are discussed below in detail.

i) Insufficient Public Transport Service

Addis Ababa city transport is road based; the public transport service of the city is composed of Mini Bus Taxis with 11 seat capacity, Anbassa city Bus with 100 seats and the Higer Midum Bus with 37 seats (Tibleste Tefera, 2012). The limited capacity of the sector could not satisfy the mobility needs of the city. There is a wide gap between demand and supply. 80% trips are served by minibus Taxis and because of this the road is congested and polluted. Because of congestion average speed is about 10km/h in peak hour (Tibleste Tefera, 2012).

ii) Inadequate Transport Planning Practice

Transport planning is crucial in the provision of equitable, efficient and effective transport service in a city. However, transport planning has not been in place and this limitation is attributed to Lack of consistent trip generation identification, analysis and traffic assignment (Tibleste Tefera, 2012).

iii) Lack of Travel Demand Analysis

Developing countries such as Ethiopia are characterized by Lack of proactive planning based on city development plan and neglect of non – motorized transport despite its dominance (Tibleste Tefera, 2012).

iv) Weak Traffic Management System

Effective traffic management is crucial for effective utilization of existing infrastructure but prevailing traffic management practice in our city is at a lower level (Tibleste Tefera, 2012).according to Tibleste, The situation is influenced by the following factors such as increase on street parking, illegal on street vending, weak traffic regulation enforcement, lack of intelligent transport systems application, absence of traffic management center and lack of traffic management Process.

To effectively solve such urban transportation problems especially that of the Downtown area, the government of Ethiopia started to build a Light Rail Transit in the city of Addis Ababa which is more energy-efficient and environment-friendly means of transport (Commission of the European Communities, 2006). Ethiopian Railways Corporation (ERC) has the mandate to carry out the project; the project has planned two lines, the East-West line and the North-South line. About 3 km is the shared section, which has the greatest passenger flow.

During the feasibility study the Ethiopian Railways Corporation carried out the assessment and also performed the passengers flow forecast based on the number of existing transportation facilities in both routes as follows. Based on the passenger transport survey the passenger flow of Line North-South and East-West in Addis Ababa LRT is forecasted as 536,935 and *734,393* persons/day respectively. This is discussed in the following tables in detail.

Table 1: The ERC Passenger Flow Survey about N-S Route

Type of Transportation	Number of Vehicles	Stations for Short Distance	Daily passengers(persons/day)
Minibus	1,160	26	299,920
Medium bus	72	8	69,264
Large bus	-	30	62,503
Auxiliary medium bus	39	11	28,080
Auxiliary Large Bus	91	26	77,168
Total	**1,362**	**101**	**536,935**

And similarly for the east to west route ERC has estimated as follows.

Table 2: The ERC Passenger Flow Survey about E-W Route

Type of Transportation	Number of Vehicles	Stations for Short Distance	Daily Passengers (persons/day
Minibus	1160	17	216,640
Medium Bus	267	27	256,854
Large Bus	—	31	34,803
Auxiliary Medium Bus	188	32	135,360
Auxiliary Large Bus	107	28	90,736
Total	**1,722**	**135**	**734,393**

From the result observed in the tables 1 and 2 above the methods used does not consider the basic determinant factors such as zonal population, average household income, average vehicle ownership per household and the land use characteristics of the study zone which affects the number of on foot passenger trips which covers the largest share and which is not addressed with ERC study.

Besides, this passenger flow forecast is not predictive i.e. only the existing trips are assessed against available transportation systems. But it is the demand prediction that is used to manage the transportation supply sides. Therefore, for the gabs identified and discussed above, this research works is required.

1.2 Statement of the Problem

Although travel demand analysis is an important component of any urban transportation planning exercise, it seems to have been neglected in transportation planning activities in the cities of the developing world (Samiul). As per Samiul, Limited attempts have been made to analyze the relationships between various forms of land use and behaviors of travelers to guide planning of major transport developments. Lack of travel demand analysis and in some cases the weaknesses of conducted analyses limit the effectiveness of transportation policies and actions in managing the excessively growing urban traffic in the developing world (Samiul).

Recently the Ethiopian Government started to build 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 customers or passenger trips.

To do so, the Ethiopians Railways Corporation (ERC) has performed the estimation considering the current number of transportation vehicles on the LRT routes from North to South and East to West (China Railway Group Limited, 2009). But the estimation fails to address the major potential trips made on foot which has the largest share in the city (Tibleste Tefera, 2012) and also fail to predict the future possible trips .therefore to fill this gap this research is needed which incorporates the present and future socio-economic characteristics of the residents.

1.3 Research Questions

This study tries to answer the following trip demand research questions. These are;

- What is the contribution of trip production forecasting for traffic growth?
- What is the contribution of trip production forecasting for transportation planning?
- What relation exists between trip production forecasting and land use planning?
- How trip production forecasting influences the Railway markets?
- What is the appropriate trip production analysis for the new Railway stations of developing countries?

1.4 Objective of the Study

1.4.1 General Objective

The General objective of this research is to estimate the current and future possible trips made by passengers on Addis-Ababa Light Rail Transit (AALRT) routes.

1.4.2 Specific Objective

In achieving the general objective stated above there will be the following specific objectives as well. These are;

1. To estimate the base year person trip productions
2. To forecast the passenger trip production for the design year.
3. Identifying the major parameters for trip production analysis
4. To identify the residential areas (kebeles) closest to the LRT routes.
5. To explore the appropriate modeling technique for railway station of developing countries.

1.5 Significance of the Study

Now a day, about four million people are living in Addis-Ababa and most of them are relying heavily on public transport to meet their mobility needs. Thus, efficient and effective public transport operations have become critical to sustainable economic and social development. The efficiency and effectiveness of public transport can only be achieved by performing trip demand prediction of passengers which makes the transportation service planning better. Besides this, the amount of Railway facilities required, the future revenue and expenditure projections can also be estimated.

Hence, the findings of the study could serve as an important base for transport planners, transportation professionals and policy makers to make decision on policy and investment in the Railway transport industry.

1.6 Limitations

- Only the basic parameters that influence trips are analyzed other minor factors are not incorporated which may affect the accuracy of the result.
- There are no, or limited data on non-residential land uses i.e. for industrial, commercial school or office space areas which can affect the analysis.
- The modeling technique is used in developing countries as alternative method in which there is insufficient and unreliable data and this can also affect the analysis.

1.7 Organization of the Study

The thesis is organized in to six chapters including the introduction part which shows the existing necessity and problem formulation of the Addis Ababa Light Rail Transit (AALRT) trip production estimation. Different literatures related to trip production forecasting is discussed in chapter two; chapter three deals with the research methodology in which the methods and procedures followed to accomplish the research findings are discussed. Chapter four deals with data collection required to accomplish the thesis. The fifth chapter is about the research result and discussion that deals with the presentation of the research finding and the last chapter deals with conclusion and recommendation which presents conclusion, contribution of the thesis and puts forward recommendations.

CHAPTER TWO:-LITERATURE REVIEW

In this chapter different issues related to the trip demand analysis such as urban transport and its characteristics, the historical relationship between transport and development, the transport demand forecasting and its advantages ,transport demand and supply, demand forecasting in developing countries in particular, the past studies related to the Ethiopia demand analysis and the demand modeling techniques are discussed below.

2.1 Transport and Development

In recent years, with half the world's population living in towns and cities and most of them relying heavily on public transport to meet their mobility needs, efficient and effective public transport operations have become critical to sustainable economic and social development (Chandra).

Since the beginning of civilization, the viability and economic success of communities have been, to a major extent, determined by the efficiency of the transportation infrastructure (Chandra).Therefore, to ensure efficient and reliable urban mobility, Light Rail Transit Systems (LRTSs) are considered to be the most promising technological approach (Fabio, 2006) it is playing an increasingly major role for urban public transport and urban environment in both developed and developing countries to relief the urban traffic congestion Occurred by automobiles. However, although Light Rail Transit Technology is considered to be efficient means of transport, the urban traffic congestion can occur unless the estimation of the passenger demand is performed. The expanding urban traffic growth in developing countries has become a major concern to city planners, transportation professionals and policy makers.

2.2 Transport Demand and Supply

The concept of demand and supply are fundamental to the economic theory and is widely applied in the field of transport economics (Jean Paul, 2013). In the area of travel demand and the associated supply of transport infrastructure, the notion of demand and supply could be applied (Jean Paul, 2013). As per Jean, Transport demand is Transport needs, which can be expressed in terms of number of people, volume, or tons per unit of time and space and Transport supply is the capacity of transportation infrastructures and modes, generally over a geographically defined transport system and for a specific period of time. Supply is expressed in terms of infrastructures or capacity, services or frequency and networks or coverage. The transport demand and supply are interrelated by the principle of equilibrium, the concept of equilibrium is central to the supply- demand analysis; it is when the transportation demand and the transportation facility provisions or supply are in equilibrium (Jean Paul, 2013).The Relationships between transport supply and demand continually change, but they are mutually interrelated, from a conventional economic perspective, interact until equilibrium is reached between the quantity of transportation the market is willing to use at a given price and the quantity being supplied for that price level (Jean Paul, 2013).

2.3 Transport Demand Forecasting

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 (Hannibal Bwire, 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 (Hannibal Bwire, 2008).

In fact a model that is appropriate to a particular application may be inappropriate in a different application context. Therefore before proceeding to use models one needs to select a model that meets the specific and unique analysis requirements and constraints of the project at hand or of a Particular planning department (Hannibal Bwire, 2008).

Although there is very little literature about model assessment and selection procedure, none has identified and incorporated criteria for assessment of methods for data provision. Consequently, most past studies do not provide a suitable procedure that can support systematic evaluation of a pool of potential models versus quality of obtainable data versus efforts for data provision. Such deficiencies support the need for further guidance on model selection procedure to developing countries (Hannibal Bwire, 2008).

2.4 Demand Forecasting in Developing Countries

Although Travel Demand Analysis is an important component of any urban Transportation Planning exercise, it seems to have been neglected in transportation planning activities in the cities of the developing countries (Hasan, 2007)**.**Limited attempts have been made to analyze the relationships between various forms of land use and behaviors of Travelers to guide planning of major Transport developments. According to Hasan, Lack of travel demand analysis and in some cases the weaknesses of conducted analyses; limit the effectiveness of transportation policies and actions in managing the excessively growing urban traffic in the developing countries.

Thus Travel Demand Forecasting is used for this purpose; to predict travel characteristics and usage of Transport services under different socio-economic scenarios, and for different transport service and land-use configurations. Making use of the models, the Travel Demand forecasting attempts to quantify the existing and future interaction between the supply and the demand for the transportation systems, the prediction for transportation facilities and services is done for future by extrapolating present travel behavior, growth characteristics and changing socio-economic conditions (Meyer, 1990).

2.5 Past Studies Related to Ethiopia

Because, Ethiopia recently plans to improve urban transport in Addis Ababa city by introducing urban Electric Rail Transit, a demand analysis is required to balance the required supply. In its feasibility study, the Ethiopian Railways Corporation (ERC) has studied the possible amount of passenger flow forecast in terms of person's trip/day on the Railway Lines from North to South and East to West routes based on the carrying capacity of the existing transportation systems like Minibus, Medium bus, Large bus, Auxiliary Medium bus and Auxiliary Large buses (China Railway Group Limited, 2009). However, there are a large number of passenger trips on foot which covers the largest share of the trips in the city accounted as 70% (Tibleste Tefera, 2012), which, are not addressed with the feasibility study i.e. the number of existing transportation systems cannot reveal on foot trips. And also no travel demand prediction is made only the existing trips are assessed against available transportation systems. To estimate the number of passenger trips, the available number of transportation systems cannot be determinant factor, Rather factors such as zonal population, average household vehicle ownership and the land use characteristics of the study zone should be considered.

2.6 Trip Demand Modeling

Travel demand forecasting and the models used vary from place to place. The top most used models to forecast the demand for the new rail way companies are the **Activity based** and the **Trip based** forecasting methods (Goran Jovicic, 2001).

i) The Activity Based and Trip based Approaches

The activity-based approach to travel demand analysis views travel as a derived demand; derived from the need to pursue activities distributed in space (Jones, 1990) whereas The trip based (the sequential modeling process approach) uses individual trips as the unit of analysis. The sequential modeling process can be considered as the most practical modeling approach **(**Ho.Ep, 1999) particularly for the developing countries, where the availability of reliable data and professionals with advanced modeling knowledge is relatively limited.

ii) The Trip Based Approach

The trip based approach consists of four steps of travel demand modeling. These are Trip generation, trip distribution, modal split and the trip assignment.

But in this research due to data unavailability, the analysis will be done only for trip generation sub model, the rest three sub models will not be discussed here.

1).Trip Generation

Trip generation is the first stage of the classical four step aggregate demand models .it is these stage in transportation analysis that relates land use activities and socio economic characteristics to the number of trips that start or end at a specific location.

These trip ends are frequently used as an input to other steps of a transportation forecasting models such as trip distribution model, modal split model and traffic assignment model. For the most part urban travel demand or trip generation is a derived demand, *i.e.,* it is not valued for its own sake, but rather as a means to accomplishing an end (Steven, 1992)**.**We travel to work, to school, to shopping to social recreational and so forth. Travel itself has a disutility attached to it: it takes time and usually costs money.

Therefore, people do not usually travel unnecessarily, but rather in response to a set of needs they wish to fulfill, and a set of disabilities or costs associated with it. Therefore, for a specific trip purpose the trip generation aims at predicting the total number of trips produced and attracted to each zone of the study area. This is accomplished by establishing a functional relationship between travel and land use and socio economic characteristics of the study zones to and from which the travel is made. In other words this stage answers the questions to how many trips originate from and attracted to each zone (Federal High way Administration, 1975).Trips as defined in these trip generation models include non-motorized trips (bicycle, walk) as well as motorized modes (auto, transit).

Trip generation can be classified in to trip production and trip attraction sub models.

a) **Trip production sub model**

The trip production is the trips generated by a residential land use in a zone, where these trips may be trip origins and destinations. Production models are based on trips made by households, workers or students at the Home end of home-based trips. The home-based work and home-based school trip generation (production) models are applied to persons who are eligible to take either work or school trips, namely, workers or Students. Factors like vehicle ownership, income, and household structure, and family size, value of land, residential density and accessibility are the determinant criterion that controls the amount of trips produced at house hold and zonal levels.

b).Trip Attraction sub model

The trip attraction is the trip end connected to a non-residential land use in a zone, such as employment, retail service, and so on. Attraction models are based on trips made at the non-home end of home-based trips for the same reason mentioned above the analysis for trip attraction sub model will not be discussed in this research.

Modeling Trip Generation

There are **four** basic trip generation analysis techniques. These are; **Cross classification**, **multiple linear regression, Land activity rate**, and **growth factor models**. The two most convenient and widely used trip generation modeling are the **land activity rate** and the **growth factors** (Tom V, 2006).

a).Cross classification

Cross-classification model, sometimes referred to as category analysis model, is based on the assumption that the number of trips generated by similar households or households belonging to the same category is the same (Arun).According to Arun Chatterjee The model predicts the trips produced by a zone by simply aggregating the total trips produced by the all the households in that zone. However, two basic questions need to be answered here: (i) how does one define similar households, or alternatively how does one define categories of households, and (ii) how does one determine the rate of trip generation for a given category of household. The answer to both these questions is: through empirical observations and analysis. What is done is that, first, data on demographic characteristics and trip making behavior of large number of households are collected. This data is then analyzed to see what characteristics of the households are important in defining a homogeneous group -- households which produce approximately the same number of trips.

This method of analysis although simple in its structure, has few difficulties. The foremost is the problem with defining categories correctly at best it is very difficult. There are other problems like handling additional data on trip generation behavior (Arun).

b).Multiple Linear Regressions:

Multiple linear regression process consists of developing equations in which trips or a trip rate (i.e. trips /house hold) is related to independent variables which explain the variation in the dependent variable (trips or trip rates).

The equations are usually developed by trip purpose and generally are based on the data aggregated to zonal level as observations.

The important statistics used in evaluating the equations developed include: (a) the multiple correlation coefficient which indicates the degree of association between the independent and dependent variables in the equation and (b) the standard error of estimate which indicates the degree of variation on the data about the regression line .established regression analysis has been an important tool in trip generation analysis.

Regression analysis is a statistical tool for the investigation of causal or functional relationships between variables (S.Chattfuee, 2006) or rather; regression is the study of dependence (S.Weisberg, 2005) usually, the researcher seeks to ascertain the causal effect of one variable upon other ones.

In trip generation modeling, the frequently used method is multiple linear regressions. The implementation of this method in transportation demand analysis was first occurred in 1950s (J.D, 2011) Having found the relationship between dependent and independent variables by regression, transportation experts are able to predict trips generated by each traffic zone. The relationship between variables can be expressed by the following equation (A. A, 2012).

$$Y=\beta_0+ \beta_1X_1+ \beta_2X_2+\ldots+ \beta_nX_n+\varepsilon \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(1).}$$

Where Y is the dependent variable, which in a transportation demand study is the number of produced or attracted trips.

X_1; X_2... and X_n are independent variables effective on trip production or attraction, and β_0, β_1, β_2... and β_n called the regression parameters or coefficients which are unknown constants to be determined from the data. ε is assumed to be a random error representing the discrepancy in the approximation. It accounts for the failure of the model to fit the data exactly. In order to construct and calibrate the model, independent variables affecting each trip purpose are chosen, and then for each traffic zone, the most recent data on the variables' values are collected. These data are generally gathered from origin-destination surveys, as well as other sources such as organizations and governmental agencies those are responsible for providing socio-economic information.

c).Land Activity Rate

The Land Activity Rate approach is based up on the development of rates in which trips are related to land use characteristics reflecting the character, location and intensity of land use (Tom V, 2006). This analysis is a combination of several models that are developed by determining the average trip production rates associated with the important trip generators within the study zone. An example of these trip generators is the residential land use phenomenon. The best model that fits the case of new Railway station for developing countries with no data is the Land Activity Rate technique along with the Growth Factor model (Tom V, 2006).

d).Growth Factor model

Growth factor model tries to predict the number of trips produced or attracted by a household or zone as a linear function of explanatory variables.

As per (Tom V, 2006) the model has the following basic equation.

$$T_i = f_i t_i \quad \ldots\ldots(2)$$

Where: T_i is the number of future trips in the zone and t_i is the number of current trips in that zone and f_i is a Growth factor. The growth factor f_i depends on the explanatory variable such as population (P) of the zone, average house hold income (I) and average vehicle ownership (V).

The simplest form of f_i is represented as follows (Tom V, 2006).

$$f_i = \frac{P_{id} V_{id} I_{id}}{P_{ic} V_{ic} I_{ic}} \quad \ldots\ldots(3)$$

Where; the subscript "d" denotes the design year and the subscript "c" denotes the current year.

As we can see from the previous literatures discussed above, the land activity rate (for trip production) and the growth factor methods (for future projection) can better describe the situations.

2.7 Summary of Literature Review

The Ethiopian Railways Corporation (ERC) has estimated the amount of passenger flow forecast in terms of person's trips/day on both Railway routes of North-South and East - West, based on the carrying capacity of the existing transportation systems without considering the basic determinant factors such as zonal population, average household income, number vehicle ownership and the land use characteristics of the study zone which affects the number of on foot passenger trips which covers the largest share in the city (Tibleste Tefera, 2012) and which is not addressed in ERC feasibility study.

Among the commonly used trip production analysis methods such as Activity based and the Trip based analysis the Trip based method best models the developing countries situations where the availability of reliable data is relatively limited (Goran Jovicic, 2001). This Trip based technique uses the Land Activity Rate method for trip production modeling and the Growth Factor Methods for future projection modeling. The main advantage of this model is that it considers the current and future socio economic conditions of passengers which are very crucial in trip estimations (Goran Jovicic, 2001).

CHAPTER THREE:-RESEARCH METHODOLOGY

The previous chapters have identified the problems related to the transport network challenges and the demand and supply analysis problems in Addis Ababa, the methods that can be used to evaluate and identify these challenges and a brief description of the possible solutions. The nature of finding solutions to the problems specified requires close scrutiny of factors that Affect, limit and determine the overall development of the Railway Company. Such investigation requires a range of methodology to enable arrived at some reasonable conclusions.

The sections below focus on the data and the methods required in analyzing the problems to achieve the stated objective.

The Study Area

The study area for this research work is the residential kebeles closest to the Addis-Ababa Light Rail Transit Routes. Residential areas both at left and right of the LRT routes up to an average of half a kilo Meter or 500 meter are considered.

Study Design

Observational research study with descriptive type of research techniques is used.

Data Collection

To describe the situation, the attempt is made in identifying and collecting extensive primary and secondary data from various sources**.**

The primary data is obtained by direct observation and interviewing of the officials in selected districts of Addis Ababa to obtain data on the residential kebeles closest to the LRT routes. And the secondary data was mostly obtained from such Sources as published and unpublished documents collected from pertinent institutions such as Central Statistics Authority (CSA), Addis Ababa Transport Authority (ATA) and Addis Ababa City Plan Institute (ACI).

Data Analysis

The data gathered is organized and analyzed using the selected modeling techniques such as the Land Activity Rate and Growth Factor Methods.

3.1 Model Selection

Among the existing different types of demand forecasting techniques, the Trip based forecasting technique is used to model the demand; this approach consists of four steps of travel demand modeling. These are Trip generation, Trip distribution, Modal split and the Trip assignment. But in this research due to data unavailability, the analysis will be done only for Trip generation sub model, to model the Trip generation analysis the Land Activity Rate Technique is used and to model the future Trip projections the Growth Factor Method is used.

The Land Activity Rate or the Land Use trip production modeling is widely used in relating the amount of trips produced to the land use characteristics, because travel is an activity generated by land uses (Steven, 1992).as per Steven, travel occurs because land uses or activities are separated, journey is made between land uses. Therefore, travel forecasting is directly related to land use planning. it is very important to assure that the forecasting procedure reflects and accounts for community's land use planning .if the forecast does not take in to account the current and future land use planning activities, the transportation plan will not support the community's vision of its future.

The categories for describing Land Use are varied and many in number. Each general Land Use category can have more sub categories.

A general Land Use category breakdown for travel forecasting could include the following uses as Office, Commercial, Residential (single/multi -family), Institutional, Industrial and special land uses. Land Use modeling estimates the number of trips the site of a given category generates which is expressed as trips per 1000ft or hectare of land use activities.

3.2. Materials and Methods

There are some important data inputs and modeling techniques used as a basic material to accomplish this research work, these are;

- The current and projected Number of car ownership in Addis Ababa.
- The current and projected population of Addis Ababa.
- The 2007 population and housing census are also important resources to examine the amount of residents in each kebele of LRT routes.
- Among the existing Trip generation modeling techniques such as Regression Analysis, Cross Classification and Land Activity Rate methods the best that fits this work is the Land Activity Rate (Land Use) trip generation or production technique with regard to unavailability of data for new Railway stations in developing countries.
- The Residential locations so called kebeles in each sub city, which are accessible and closest to the AALRT routes, are identified along with their quantity in numbers and sizes in hectares as an input materials. This includes the North to South and East to West locations.
- The North to South Railway routes starts at the Menlik II square from the North direction and Kality at South direction, passing through Menlik II square-Merkato-Lideta –Legare-Gothera and Kality.and The East-West route starts at Torhailoch from the Western Direction and Ayat at the Eastern diection. The line includes Torhailoch~Lideta~Lagare~Adwa Square~CMC and Ayat.
- To forecast the number of passengers (internal trips) on the Railway lines using land use forecasting method, residential areas located near the routes are considered.
- The North to South route consists of six sub cities and the closest kebeles of each sub cities are identified and listed below.

Arada sub-city: in Arada sub city four kebeles such as 01/02, 03/09, 13/14 and 10 are closest and have access to the LRT route.

Addis-ketema: in Addis-ketema sub-city six kebeles such as 01/02/03, 10/11/12, 04/05, 06/07, 16/17 and14/21 are identified.

Lideta sub city: in this sub city three kebeles such as kebele15/16/17, 05/08, and 07/14 are identified

Qirkos subcity: in this sub city six kebeles such as kebele 01/19, 20/21, 13/14, 11/12, 15/16 and 05/06/07 are identified.

Nefas silk lafto sub city: in this sub city five kebeles such as kebele 10/18, 12/13, 16/17, 9/14 and 16/17 are identified.

Akaki- kality sub city: since it ends at the beginning of kality in the first phase, only two kebeles 10/11 and 12/13 are identified. Therefore, from all six sub cities a total of twenty six (26) kebeles are considered.

- The West-East LRT route consists of five sub cities and the closest kebeles of each sub cities are identified and listed below.

Kolfe- Keranyo sub city: in kolfe keranyo sub city because this West to East line starts from Torhiloch in the first phase, only a single kebele is closer to it and that is kebele 13.

Lideta sub city: in this sub city seven kebeles such as kebele 01,02/03,35,05/38, ,16,17 and 07/14 are identified.

Qirkos sub city: in Qirkos sub city five kebeles are identified and these are; kebele 01,15,13,14 and kebele 30.

Bole sub city: in bole sub city ten kebeles are identified and these are kebele 12, 13,14,15,16, 18, 21, 28,35and 36.

Yeka sub city: in yeka sub city four kebeles such as kebele 13, 14, 20 and 21 are identified.

Similarly, from all five sub cities a total of twenty seven (27) kebeles are considered.

3.3 Procedures

After collection of the necessary research data the analysis of the data and its interpretation will then follow. Therefore the analyses of the collected information from the different sources are organized and the Land Activity Rate of trip production modeling and the Growth Factor Modeling are used to come up with results.

For the existing two LRT routes North to South and East to West, the Sub cites and kebeles in each sub city through which the line passes or which are closest and accessible to it are identified with their features such as their magnitudes in number and sizes in hectares are computed. The areas of each kebeles staring from the origin to the destination point of the routes will be summed up to yield total area of land in hectares.

Then from Institute Transportation Engineers (ITE) the minimum and maximum trips per hectare are available as a standard as 38 and 128 trips per day per hectare. Therefore both the maximum and minimum value of trips is taken and is used to calculate the total trips produced by residents of the specified kebeles on the routes.

3.3.1 North –South Route Residential Area Estimation

To estimate the residential land use area closer to the LRT North to South route, the Area of single kebeles in each sub city should be known based on the data listed in table 5.

Assumptions

The Area of each kebeles in their respective sub city is assumed to have the same size.

Arada sub city

Area of single kebele in Arada sub city (A_{sk}) =Area of Arada sub city/ number of kebeles in Arada sub city i.e. A_{sk} $=11.56km^2/10=1.16km^2$

Since there are four kebeles in this sub city near the route, the total residential land use area in the sub city will be $A_t=1.16\ km^2x4=4.64km^2$.

Addis ketema sub city

Area of single kebele in Addis Ketema sub city (A_{sk}) =Area of Addis Ketema sub city/ number of kebeles in Addis Ketema sub city i.e. (A_{sk})=9.98km^2/9=1.11km^2

And since there are six kebeles in this sub city near the route the total land use area will be A_t=1.11km^{2}x6=6.66km^2

Lideta sub city

Area of single kebele in Lideta sub city (A_{sk}) =Area of Lideta sub city/ number of kebeles in Lideta sub city i.e. (A_{sk}) =12.40km^2/9=1.38km^2 And since there are three kebeles in this sub city near the route the total land use area will be A_t=3x1.38km^2=4.14km^2.

kirkos sub city

Area of single kebele in kirkos sub city (A_{sk}) =Area of kirkos sub city/ number of kebeles in kirkos sub city i.e. (A_{sk})=16.26 km^2/11=1.48 km^2 And since there are six kebeles in this sub city near the route the total land use area will be A_t=6x1.48 km^2=8.88 km^2..

Nefas Silk Lafto sub city

Area of single kebele in Nefas Silk Lafto sub city (A_{sk}) =Area of Nefas Silk Lafto sub city/ number of kebeles in Nefas Silk Lafto sub city i.e. (A_{sk}) =63.59 km^2/10=6.36 km^2 And since there are five kebeles in this sub city near the route the total land use area will be A_t=5x6.36 km^2=31.8 km^2

Akaki- kality sub city

Area of single kebele in Akaki- kality sub city (A_{sk}) =Area of Akaki- kality sub city/ number of kebeles in Akaki- kality sub city i.e. (A_{sk}) =126.13 km^2/8=15.77km^2 And since there are two kebeles in this sub city near the route the total land use area will be A_t=2x15.77km^2=31.54 km^2.

Therefore on the line from North to South the area of residential kebeles in all six sub cities will be A_T=4.64km^2+6.66km^2+4.14km^2+8.88 km^2+31.8 km^2+31.54 km^2=87.66 km^2=8766 hectares.

3.3.2 The North –South Route Trip Calculation

According to the Institute of Transportation Engineers (ITE) standard, the total trips per hectare of residential land use is given in the interval from 38 -128 trips per hectare per day as a minimum and maximum for low to high population densities. Considering both the minimum and maximum values we will have two cases in trip calculation.

The Minimum total trips produced on the North to South route =38 trips per day per hectare×8,766 hectares=333,108 trips per day and

The Maximum total trips produced on the North to South route=128 trips per day per hectare×8766 hectares= 1,122,048 trips per day.

In Addis Ababa, among the total trips produced the share of private cars is only 4.7% (Addis Ababa Transport Authority, 2000). Therefore reducing this we will have the net total minimum and maximum on foot trips produced per day.

For minimum case we have Vehicle trips=0.047×333,108trips per day=15,656vehicle trips per day will be produced. The remaining 333,108 trips per day-15656=317,452 trips per day will be person on foot trips, and for maximum case we have Vehicle trips= 0.047×1,122,048 = 52,736 vehicle trips per day will be produced. The remaining 1,069,311 trips per day will be person on foot trips.

Therefore on foot person trip is in the range of 317,452-1,069,311 trips per day.

3.3.3 The West- East Route Residential Area estimation

To estimate the residential land use area closer to the LRT West to East route, the area of single kebeles in each sub city should be known based on the data listed in table 5 in a similar way.

Assumptions

The Area of each kebeles in their respective sub city is assumed to have the same magnitude.

Kolfe Keranyo sub city

Area of single kebele in Kolfe Keranyo sub city (A_{sk}) =Area of Kolfe Keranyo sub city/ number of kebeles in Kolfe Keranyo sub city i.e. (A_{sk}) =65.10km^2/10=6.51km^2 and since there is only one kebele in this sub city near the route the total land use area will be A_t=1x6.51=6.51 km^2.

Lideta sub city

Area of single kebele in Lideta sub city (A_{sk}) =Area of Lideta sub city/ number of kebeles in Lideta sub city i.e. (A_{sk}) =12.40km^2/9=1.38km^2 and since there are seven kebeles in Lideta sub city the total land use area will be A_t=7x1.38km^2=9.66km^2

kirkos sub city

Area of single kebele in kirkos sub city (A_{sk}) =Area of kirkos sub city / number of kebeles in kirkos i.e. (A_{sk}) =16.26 km^2/11=1.48 km^2 and since there are five kebeles in this sub city the total land use area will be A_t= 5x1.48 km^2=7.4 km^2

Bole Sub city

Area of single kebele in Bole sub city (A_{sk}) =Area of Bole sub city / number of kebeles in Bole i.e. (A_{sk}) = 120.93/11=10.99 km^2 and since there are ten kebeles in this sub city near the LRT route, the total land use area will be A_t=10x10.99 km^2=110 km^2

Yeka Sub city:

Area of single kebele in Yeka sub city (A_{sk}) =Area of Yeka sub city / number of kebeles in Yeka i.e. (A_{sk}) = 82.30/11=7.48 km^2 and since there are four kebeles in this sub city near the LRT route, the total land use area will be A_t=4x7.48 km^2=29.92 km^2.

Therefore on the line from West to East the area of residential kebeles in all five sub cities will be A_T= 6.51km^2+9.66km^2+7.4km^2+110 km^2+29.92 km^2 =163.5 km^2 =16,350 hectares.

3.3.4 The West–East Route Trip calculation

Using the ITE standard of trips which is in the range of 38 -128 trips per hectare per day as a minimum and maximum, considering both values we will have two cases in trip calculation.

The Minimum total trips produced on the West-East route =38 trips per day per hectare×16,350 hectares=621,300 trips per day and

The Maximum total trips produced on this route is=128 trips per day per hectare×16,350hectares= 2,092,800 trips per day.

In Addis Ababa, among the total trips produced the share of private cars is only 4.7% (Addis Ababa Transport Authority, 2000).Therefore reducing this we will have the net total minimum and maximum on foot trips produced per day.

For minimum case we have Vehicle trips=0.047×621,300trips per day=29,201vehicle trips per day will be produced. The remaining 621,300 trips per day-29,201=592,099 trips per day will be person on foot trips,

For maximum case we have Vehicle trips= 0.047×2,092,800 = 98,361 vehicle trips per day will be produced. The remaining 2,092,800 -98,361 =1,994,439 trips per day will be person on foot trips. Therefore on foot person trip is in the range of 592,099 - 1,994,439 trips per day.

CHAPTER FOUR:-DATA COLLECTION

In order to sufficiently explore the LRT internal trip production by residents, in Addis Ababa, the attempt is made in identifying and collecting extensive primary and secondary data from various sources**.**

The secondary data was mostly obtained from such Sources as published and unpublished documents collected from pertinent institutions such as Central Statistics Authority (CSA), Addis Ababa Transport Authority (ATA) and Addis Ababa City Plan Institute (ACI), and the primary data is obtained by direct observation and interviewing of the officials to obtain data on the residential kebeles near the LRT routes.

Data acquisition

Before acquiring the data use in this research the data that are useful, the type of data and the availability of data are evaluated before the field work did commence. The type of data used in this research comprises of two types, i.e. primary data and secondary data. The data identified is given in the tables 3 and 4 below.

Table 3: The Research Data Identified

Data on Travel Demand	Available Information
Socio-economic Data	Car ownership, income projection
Census Data	Population density, structure distribution, etc.
Land use Data	Residential areas

Primary data

The primary data are collected by interviewing concerned governmental officers in some districts and kebeles of Addis Ababa to obtain information on the number and list of residential kebeles accessible to the LRT routes.

Secondary data

Table 4: The Source and Format of Secondary Data

Data	**Source**	**Format**	**Remark**
Land use Data	City plan Institute	word	Aggregate at city level
Census Data	Central statistics Authority	excel	Aggregate at kebele level
Vehicle Ownership	Transport Authority	word	Aggregate at city level

4.1 The LRT Transport Network System

4.1.1 The North –South Route

The Line North-South goes along the important North South transportation corridors in Addis Ababa which covers 16.9 km. This line goes through city center, and is one of the most important contacting lines between city center and city Southern and Northern parts as well as suburbs. The central part of this line goes through highly populated areas and the busiest commercial areas with large traffic flow; the Southern part of the line goes through industrial zone of the city and Kality Town.This line passes through six sub cities going through Menelik II Square～Merkato～Lideta～Lagare～Gotera～Kallti～Akaki and also shares with the East West line in the road section from Lideta to Lagare.

4.1.2 The East-West Route

The Line East-West goes along the important East -West transportation corridor in Addis Ababa which covers 17.35 km. The two lines (North-South and East-West lines) use common track of about 2.7 km. This line goes through city center, and is one of the most important contacting lines between city center and city Western parts.

The Eastern and central parts of this line go through highly populated areas, the busiest commercial areas and Ayat residential area with large traffic flow; the Western part of the line goes through western city and line includes Torhailoch～Lideta～Lagare～Adwa Square ～CMC ～Ayat.and the details for both routes are shown in figure 1 below.

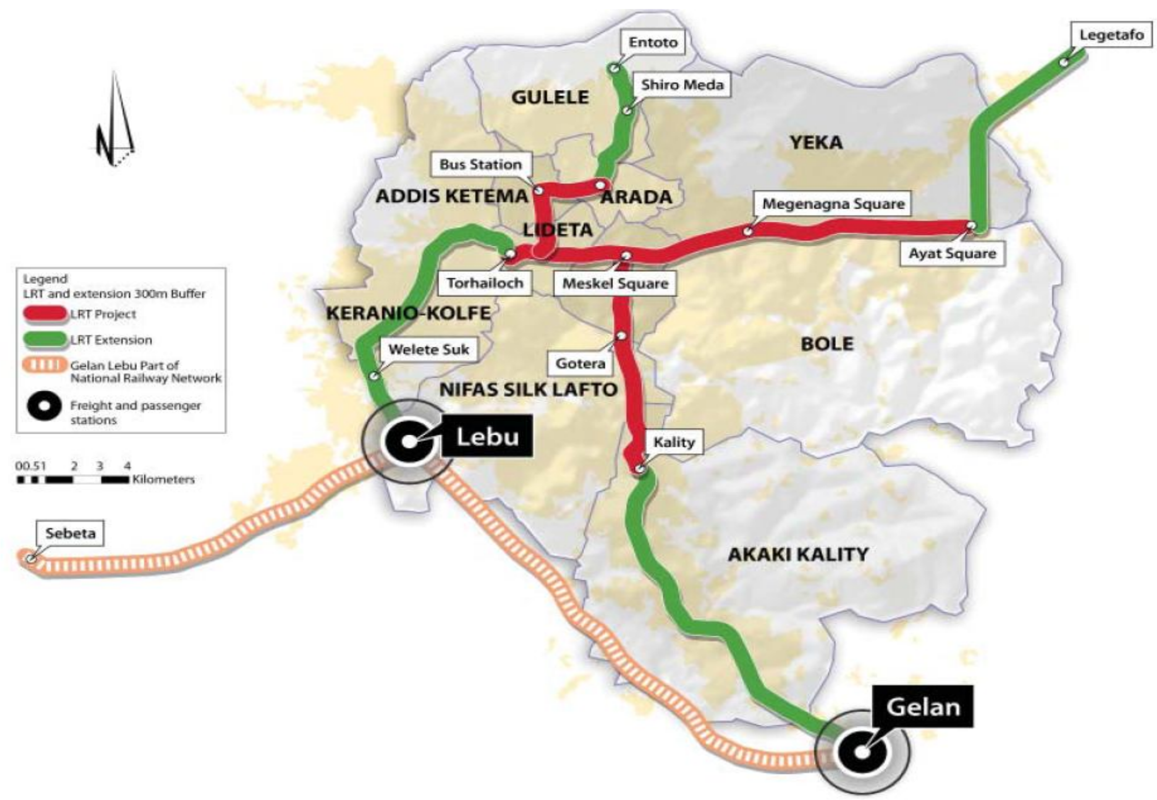

Figure 1: The Addis-Ababa LRT Transport Routes Profile

Source: Ethiopian Railways Corporation

4.2 Addis Ababa Residential Land use characteristics

4.2.1 Population Distributions

The Addis Ababa City is divided into Ten Sub-cities and again the sub cities are further divided in to Ninety-Nine Kebeles. Based on the 2007 Population and Housing Census Report, There is a difference in sub-city population distribution which shows uneven distribution. The whole Populations are urban dwellers.

The majority of the city population lives in KolfeKeranyo (15.6%), Yeka (12.6%),Nefas-SilkLafto(11.5%),Bole(11.2%),Gullele(9.76%), Addis Ketema(9.3%),Qirkos(8%) Lideta(7.4%), Arada(7.7%) and Akaki-Kality Sub City (6.7%) Arada and Akaki-Kality have the smallest share from the City's total population.

Table 5: The Addis Ababa City Population Distribution by Sub Cities

Serial number	**Sub city**	**Number of kebeles**	**Population size**			
			Male	**Female**	**Total**	**%**
1	Addis Ketema	9	124741	130351	255092	9.3
2	Arada	10	99392	112617	212009	7.78
3	Lideta	9	96221	105392	201613	7.4
4	Qirkos	11	103314	117677	220991	8
5	Gullele	10	129239	138142	267381	9.76
6	Kolfe Keranio	10	207506	221148	428654	15.6
7	Nifas Silk Lafto	10	148892	167219	316108	11.5
8	Yeka	11	161480	185004	346484	12.6
9	Bolle	11	145057	163657	308714	11.2
10	Akaki Kality	8	88676	92526	181202	6.7
	Total		**1,304,518**	**1,433,733**	**2,738,251**	**100**

Source CSA: (2008). The 2007 Population and Housing Census Report

According to the 2007 Census, Addis Ababa City Administration has a total population of 2,738,251, among this the number of female population is equal to 1,433,733 (52%) and the remaining are males which is 1,304,518(48%). While the sex ratio is 0.91 in the indicated year.

4.2.2 Addis Ababa population projection

Population Projection gives information on the size, structure and characteristics of the population in the future. The resulting projected population figures can be used for drawing development plans &policy making. This topic provides the projected population size of Addis Ababa by sex for the years from 2007-2030.

Estimates of the future population size and growth rate of Addis Ababa with an assumption of fertility decline (medium variant) indicate a substantial increase in the coming decades. Though the growth rate declines gradually, the population is expected to increase from the current 2.73 million to 3.09 million in 2010, 3.65 million in 2015 and will reach 4.7 million by 2030 (Central Stastistics Authority, 2007). This is the consequence of both fertility and high net migration. Due to the expansion of the city area, now a day the ex-rural areas of Addis Ababa became urban area. Rapid population growth hampers socio-economic development efforts and undermines the environmental resource based upon which sustainable development alternatives depend.

4.3 Residential Areas near the LRT Routes

4.3.1 North –South Route

The North to South Railway routes starts at the Menlik II square from the North direction and kality at South direction, passing through Menlik II square-Merkato-Lideta –Legare-Gothera and kality.To forecast the number of passengers (internal trips) on the Railway lines using land use forecasting method, residential areas located near the routes are considered. This North to South route consists of six sub cities and the closest kebeles of each sub cities are identified and listed below.

Arada sub-city:

In Arada sub city four kebeles such as 01/02, 03/09, 13/14 and 10 are closest and have access to the LRT route.

Addis ketema:

In Addis ketema sub city six kebeles such as kebele 01/02/03, 10/11/12, 04/05, 06/07, 16/17 and14/21 are identified.

Lideta sub city:

In these sub city three kebeles such as kebele 15/16/17, 05/08, and 07/14 are identified

Qirkos sub city:

In these sub city six kebeles such as kebele 01/19, 20/21, 13/14, 11/12, 15/16 and 05/06/07 are identified.

Nefas silk lafto sub city:

In this sub city five kebeles such as kebele 10/18, 12/13, 16/17, 9/14 and 16/17 are identified.

Akaki kality sub city:

Since it ends at the beginning of kality in the first phase, only two kebeles 10/11 and 12/13 are identified.

Therefore, from all six sub cities a total of twenty six (26) kebeles are considered.

4.3.2 West -East Route

The Line East-West goes along the important East -West transportation corridor in Addis Ababa which covers 17.35 km. This line goes through city center, and is one of the most important contacting lines between city center and city western parts. The Eastern and central parts of this line go through highly populated areas, the busiest commercial areas and Ayat residential area with large traffic flow; the Western part of the line goes through western city and line includes Torhailoch～Lideta～Lagare～Adwa Square ～CMC ～Ayat.

This route consists of five sub cities and the closest kebeles of each sub cities are identified and listed below.

Kolfe Keranyo sub city:

in kolfe keranyo sub city because this west to east line starts from Torhiloch in the first phase, only a single kebele is closer to it and that is kebele 13.

Lideta sub city:

In these sub city seven kebeles such as kebele 01, 02/03, 35, 05/38, 16, 17 and 07/14 are identified.

Qirkos sub city:

in Qirkos sub city five kebeles are identified and these are; kebele 01,15,13,14 and kebele 30.

Bole sub city:

in bole sub city ten kebeles are identified and these are kebele 12, 13,14,15,16, 18, 21, 28,35and 36.

Yeka sub city:

in yeka sub city four kebeles such as kebele 13, 14, 20 and 21 are identified.

Similarly, from all five sub cities a total of twenty seven (27) kebeles are considered

CHAPTER FIVE:-RESULT AND DISCUSSION

After collection of the necessary research data the analysis of the data and its interpretation will

Then follow. Therefore the analyses of the collected information from the different sources are

Organized and the land activity rate of trip production modeling along with the growth rate modeling methods are used to come up with the results.

Residential area estimation

To estimate the residential land use area closer to the LRT North to South route, the area of single kebeles in each sub city should be known.

Assumption

The Area of each kebeles in their respective sub city is assumed to have the same magnitude.

In Arada sub city

Area of single kebele (A_{sk}) =Area of Arada sub city/ Number of kebeles in Arada sub city

A_{sk} $=11.56km^2/10=1.16km^2$

Since there are four kebeles in this sub city near the route the total residential land use area in the sub city (A_t) will be $A_t=1.16x4=4.64km^2$.

In Addis ketema sub city

Area of single kebele (A_{sk})$=9.98km^2/9=1.11km^2$ and total area in this sub city will be $A_t=1.11km^2x6=6.66km^2$.

In Lideta sub city

Area of single kebele (A_{sk}) $=12.40km^2/9==1.38km^2$ and total area in this sub city $A_t=3x1.38km^2=4.14km^2$

In kirkos sub city

Area of single kebele (A_{sk}) =16.26 km^2/11=1.48 km^2 and total area in this sub city A_t=6x1.48 km^2=8.88 km^2

In Nefas silk Lafto sub city

Area of single kebele (A_{sk}) =63.59 km^2/10=6.36 km^2 and total area in this sub city A_t=5x6.36 km^2=31.8 km^2

In Akaki- kality sub city

Area of single kebele (A_{sk}) =126.13 km^2/8=15.77km^2 and total area in this sub city A_t=2x

15.77km^2=31.54 km^2

Therefore on the line from north to south the area of residential kebeles in all six sub cities will be A_T=4.64km^2+6.66km^2+4.14km^2+8.88 km^2+31.8 km^2+31.54 km^2=87.66 km^2=8,766 hectares.

5.1 Trip Calculation for North to South Route

According to the Institute of Transportation Engineers (ITE) standard, the total trips per hectare of residential land use is given in the interval from 38 -128 trips per day per hectare as a minimum and maximum for low to high population densities. Considering both the minimum and maximum values we will have two cases in trip calculation.

The Minimum total trips produced on the north to south route=38 trips per day per hectare×8766 hectares=333,108 trips per day and the Maximum total trips produced on the north to south route=128 trips per day per hectare×8766 hectares= 1,122,048 trips per day. In Addis Ababa, among the total trips produced the share of private cars is only 4.7% (Addis Ababa Transport Authority, 1998). Therefore reducing this we will have the net total on foot trips produced per day.

For minimum case Vehicle trips=0.047×333,108trips per day=15,656 vehicle trips per day will be produced.

The remaining 333,108 trips per day-15656=317,452 trips per day will be person on foot trips,

For Maximum case Vehicle trips= 0.047×1,122,048 = 52,736 vehicle trips per day will be produced. The remaining 1,069,311 trips per day will be person on foot trips.

Therefore on foot person trip is in the range of 317,452-1,069,311trips per day.

Trip projection

To forecast the trip production for the future times, the equations mentioned before are used (Tom V, 2006).These are;

$$T_i = f_i t_i \quad \text{...(2)}$$

$$f_i = \frac{P_{id}\, V_{id}\, I_{id}}{P_{ic}\, V_{ic}\, I_{ic}} \quad \text{..}(3)$$

where' c' denotes the current year and 'd' denotes the design year.Setting the design year for five years and perform the calculation based on the above equations.
According to the report in 2010 G.C the Addis Ababa city per capital income is 6,857.8 birr and is growing annually by 9.2%, which is below standard set for medium income person 13,500 birr (997 USD) as per the world bank of 2007 report**.**

Calculating the required parameters such as population (P),Income (I) and Vehicle ownership (V) for the base year 2014 G.C and for the forecast year of 2019 G.C.

P_{2014}=3.55Milion person,I_{2014}=9,381.48 Birr,V_{2014}=81,368 Private vehicles

P_{2019}=4.03 Milion person,I_{2019}=12,536.08 Birr,V_{2019}=101,858 private vehicles

Substituting this values in to equation (3) we have the following

$$f_i = \frac{4.03 \times 12,536.08 \times 101,858}{3.55 \times 9,381.48 \times 81,368} = 1.9$$

Subistituting these value in to equation (2) above We will have the Minimum trips $T_i = t_i \times f_i$=317,452×1.9=603,159 person trips per day and the Maximum trips $T_i = t_i \times f_i$ =1,069,311×1.9=2,031,691person trips per day Will be produced after five years.

Using the same procedures we can calculate the trips produced for the first four years as follows and the result is also shown in table 6.

Trip production forecast for the Year 2015 (G.C)

The growth factor f_i is calculated as

$$f_i = \frac{P_{2015} V_{2015} I_{2015}}{P_{2014} V_{2014} I_{2014}} = \frac{3.65 \times 10,012.4 \times 85,466}{3.55 \times 9,381.48 \times 81,368} = 1.2$$

And Trips T_i are calculated as $T_i = t_i \times f_i =$1.2×1,069,311=1,283,173 person trips maximum and minimum of 1.2×317,452=380,942.Similarly we have the following for the remaining years.

For the Year 2016 (G.C)

$$f_i = \frac{P_{2016} V_{2016} I_{2016}}{P_{2014} V_{2014} I_{2014}}$$

Substituting the values we will have the following.

$$f_i = \frac{3.77 \times 10,643.3 \times 89,568}{3.55 \times 9,381.48 \times 81,368} = 1.3$$

and $T_i = t \times f_i =$ 1.3×1,069,311=1,390,104person trips maximum and Minimum=1.3×317,452=412,688person trips.

For the Year 2017 (G.C)

$$f_i = \frac{P_{2017} V_{2017} I_{2017}}{P_{2014} V_{2014} I_{2014}} = \frac{3.86 \times 11,274.24 \times 93,662}{3.55 \times 9,381.48 \times 81,368} = 1.5$$

and $T_i = t_i \times f_i$ = 1.5×1,069,311=1,603,967person trips maximum and Minimum=1.5×317452=476,178person trips.

For the Year 2018 (G.C)

The growth factor f_i is calculated as

$$f_i = \frac{P_{2018} V_{2018} I_{2018}}{P_{2014} V_{2014} I_{2014}} = \frac{3.95 \times 11,905.16 \times 97,768}{3.55 \times 9,381.48 \times 81,368} = 1.7$$

And the trips T_i are calculated as

$T_i = t_i \times f_i$ = 1.7×1,069,311=1,817,829 maximum and Minimum=1.7×317,452=539,668person trips. Similarly for the designed year **2019 G.C**

$$f_i = \frac{4.03 \times 12,536.08 \times 101,858}{3.55 \times 9,381.48 \times 81,368} = 1.9$$

and $T_i = t_i \times f_i$

Considering the two cases i.e. the minimum and the maximum trips we will have the following.

Minimum trips $T_i = t_i \times f_i$ =317,452×1.9=603,159 person trips per day and

Maximum trips $T_i = t_i \times f_i$ =1,069,311×1.9=2,031,691person trips per day Will be produced.

Table 6: The North-South Route Minimum and Maximum Trip production for five years

Year (GC)	Minimum trips produced	Maximum trips produced
2014	317,452	1,069,311
2015	380,942.	1,283,173
2016	412,688	1,390,104
2017	476,178	1,603,967
2018	539,668	1,817,829
2019	603,159	2,031,691

Table 6 shows the minimum and maximum trip production forecasting made for consecutive five years beginning from 2014G.C to the design year of 2019G.C on the North-South LRT route.

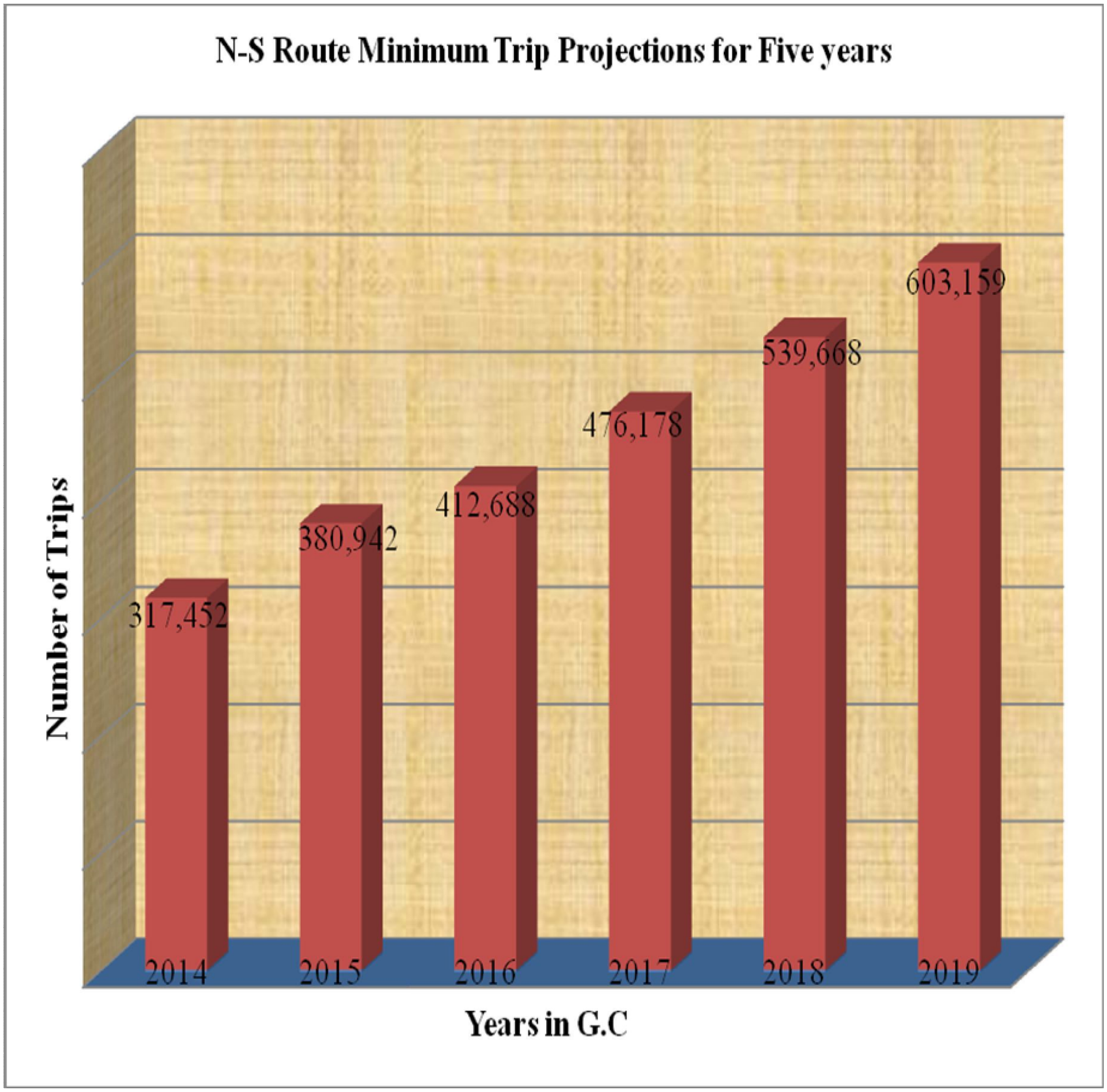

Figure 2: The North-South Route Minimum Trip Production Projections for five years.

The result shown in figure 2 is the minimum trip production forecasting made on North-south LRT route for consecutive five years beginning from 2014G.C to the design year of 2019G.C.

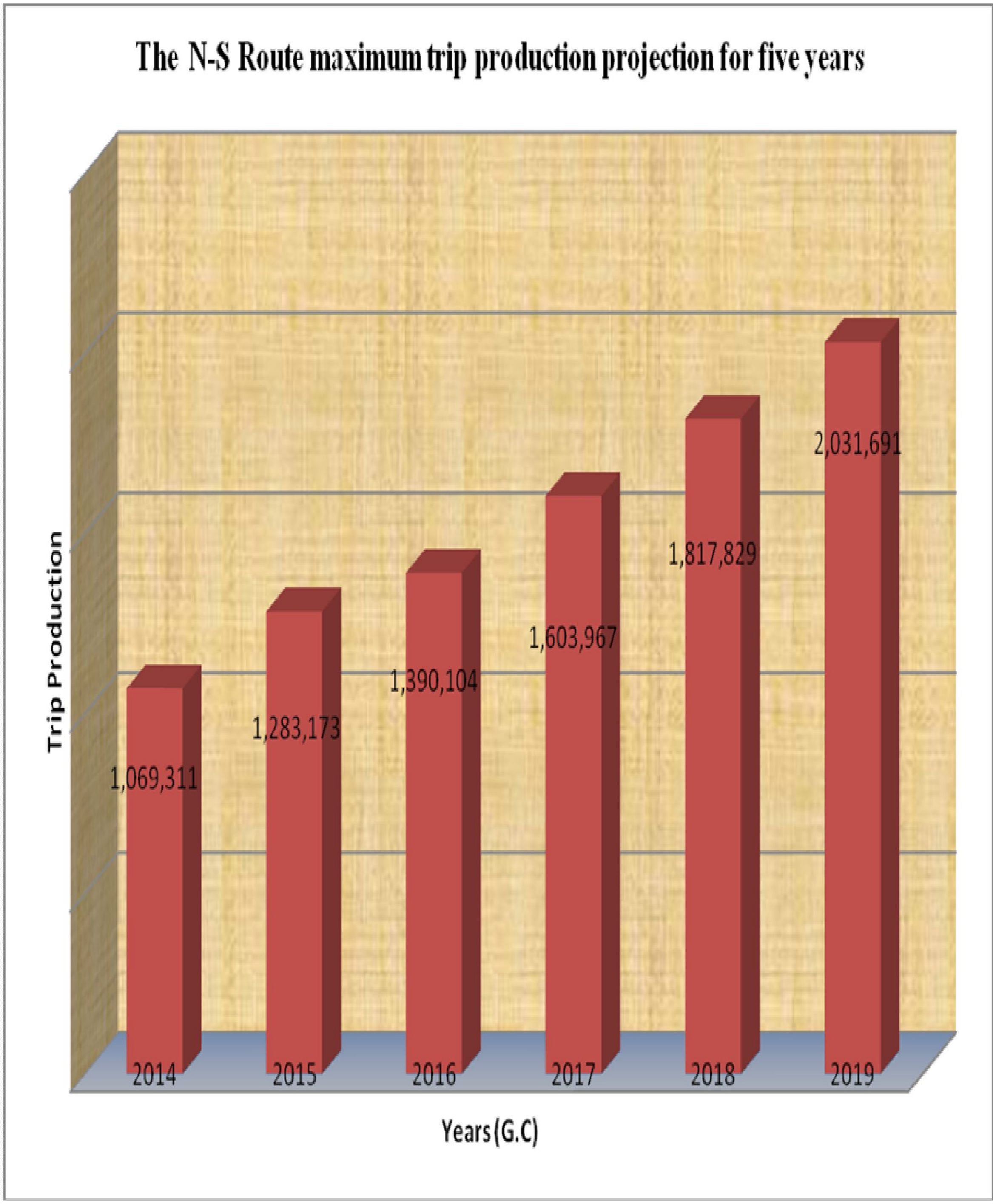

Figure 3: The North-South Route Maximum Trip Production Projections for five years.

The result shown in figure 3 is the maximum trip production forecasting made on North-south LRT route for consecutive five years beginning from 2014G.C to the design year of 2019G.C.

5.2 Trip Calculation for East West Route

Using the ITE standard of trips which is in the range of 38 -128 trips per hectare per day as a minimum and maximum, considering both values we will have two cases in trip calculation.

The Minimum total trips produced on the West–East route =38 trips per day per hectare×16,350 hectares=621,300 trips per day and The Maximum total trips produced on this route is=128 trips per day per hectare×16,350hectares= 2,092,800 trips per day.

In Addis Ababa, among the total trips produced the share of private cars is only 4.7%. Therefore reducing this we will have the net total minimum and maximum on foot trips produced per day.

For minimum case we have Vehicle trips=0.047×621,300trips per day=29,201vehicle trips per day will be produced. The remaining 621,300 trips per day-29,201=592,099 trips per day will be person on foot trips,

For maximum case we have Vehicle trips= 0.047×2,092,800 = 98,361 vehicle trips per day will be produced. The remaining 2,092,800 -98,361 =1,994,439 trips per day will be person on foot trips. Therefore on foot person trip is in the range of 592,099 - 1,994,439 trips per day.

Trip projection

To forecast the trip production for the future, the same equations and procedures are used (Tom V, 2006). These are

$$T_i = f_i t_i \quad \text{.........} (2)$$

$$f_i = \frac{P_{id} V_{id} I_{id}}{P_{ic} V_{ic} I_{ic}} \quad \text{.........} (3)$$

where' c' denotes the current year and 'd' denotes the design year.Setting the design year for five years and proceed the calculation based on the above equations.

According to the report in 2010 G.C the Addis Ababa city per capital income is 6,857.8 birr and is growing annually by 9.2%, which is below the standard set for medium income person 13,500 birr (997 USD) as per the world bank 2007 report.

Using the already Calculated parameters such as population (P),Income (I) and Vehicle ownership (V) for the base year 2014 G.C and for the forecast year of 2019 G.C.

P_{2014}=3.55Milion person,I_{2014}=9,381.48 Birr,V_{2014}=81,368 Private vehicles

P_{2019}=4.03 Milion person,I_{2019}=12,536.08 Birr,V_{2019}=101,858 private vehicles

Substituting this values in to equation (3) we have the following

$$f_i = \frac{4.03 \times 12,536.08 \times 101,858}{3.55 \times 9,381.48 \times 81,368} = 1.9$$

Subistituting these value in to equation (2)We will have the Minimum trips $T_i = t_i \times f_i$=592,099 ×1.9=1,124,988 person trips per day and the Maximum trips $T_i = t_i \times f_i$ =1,994,439 ×1.9=3,789,434 Person trips per day will be produced after five years. Using the same procedures we can calculate the trips produced for the first four years as follows and the result is shown in table 7.

Trip production forecast for the year 2015 G.C

The growth factor f_i is calculated as

$$f_i = \frac{P_{2015} V_{2015} I_{2015}}{P_{2014} V_{2014} I_{2014}} = \frac{3.65 \times 10,012.4 \times 85,466}{3.55 \times 9,381.48 \times 81,368} = 1.2$$

And Trips T_i are calculated as $T_i = t_i \times f_i$=1.2×1,994,439 =2,393,326 person trips maximum and minimum of 1.2×592,099 =710,518.Similarly we have the following for the remaining years.

Trip production forecast for the 2016 G.C

$$f_i = \frac{P_{2016} V_{2016} I_{2016}}{P_{2014} V_{2014} I_{2014}} = \frac{3.77 \times 10,643.3 \times 89,568}{3.55 \times 9,381.48 \times 81,368} = 1.3$$

and $T_i = t_i \times f_i =$ 1.3×1,994,439 =2,592,770person trips maximum and Minimum=1.3×592,099 =769,728person trips.

Trip production forecast for the year 2017 G.C

$$f_i = \frac{P_{2017} V_{2017} I_{2017}}{P_{2014} V_{2014} I_{2014}} = \frac{3.86 \times 11,274.24 \times 93,662}{3.55 \times 9,381.48 \times 81,368} = 1.5$$

and $T_i = t_i \times f_i =$ 1.5×1,994,439=2,991,658person trips maximum and Minimum=1.5×592,099 =888,148person trips.

Trip production forecast for the year 2018 G.C

$$f_i = \frac{P_{2018} V_{2018} I_{2018}}{P_{2014} V_{2014} I_{2014}} = \frac{3.95 \times 11,905.16 \times 97,768}{3.55 \times 9,381.48 \times 81,368} = 1.7$$

and $T_i = t_i \times f_i =$ 1.7×1,994,439 =3,39,0546 maximum and Minimum=1.7×592,099 =1,006,568 person trips.

Trip production forecast for the year 2019 G.C we will have maximum of 3,789,434 and minimum of 1,124,988person trips per day.

Table 7: The East-West Route Minimum and Maximum Trip production projections.

Year (G.C)	Minimum trips produced	Maximum trips produced
2014	592,099	1,994,439
2015	710,518	2,393,326
2016	769,728	2,592,770
2017	888,148	2,991,658
2018	1,006,568	3,39,0546
2019	1,124,988	3,789,434

The result indicated on the above table 7 is the minimum and the maximum trip production forecasting made for five years on the East-West LRT route.

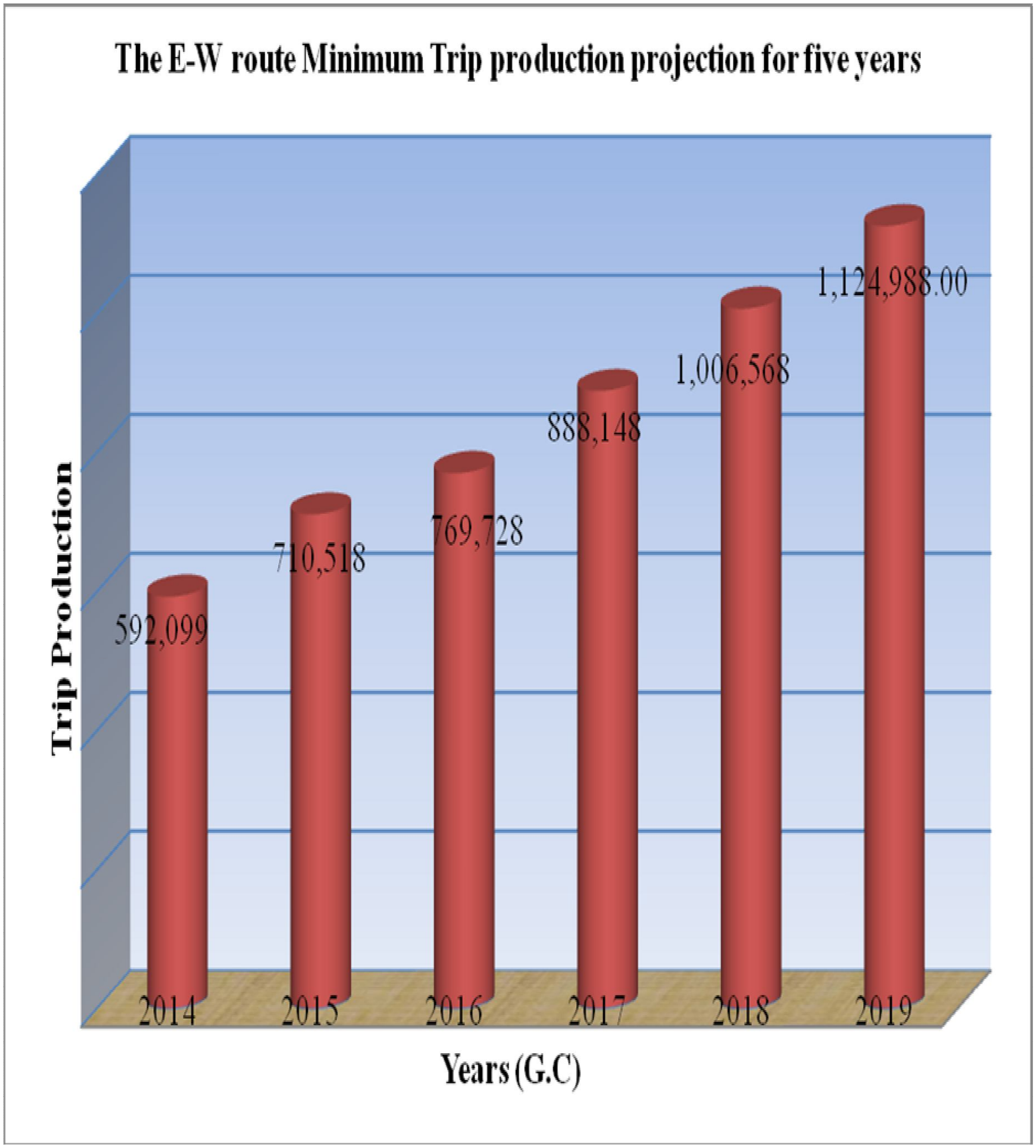

Figure 4: The East –West Route Minimum Trip production projection for five years.

The above results indicated in Figure 4 shows the minimum trip production forecasting made for five years beginning from the base year of 2014G.C to the design year of 2019G.C on the East-West LRT route.

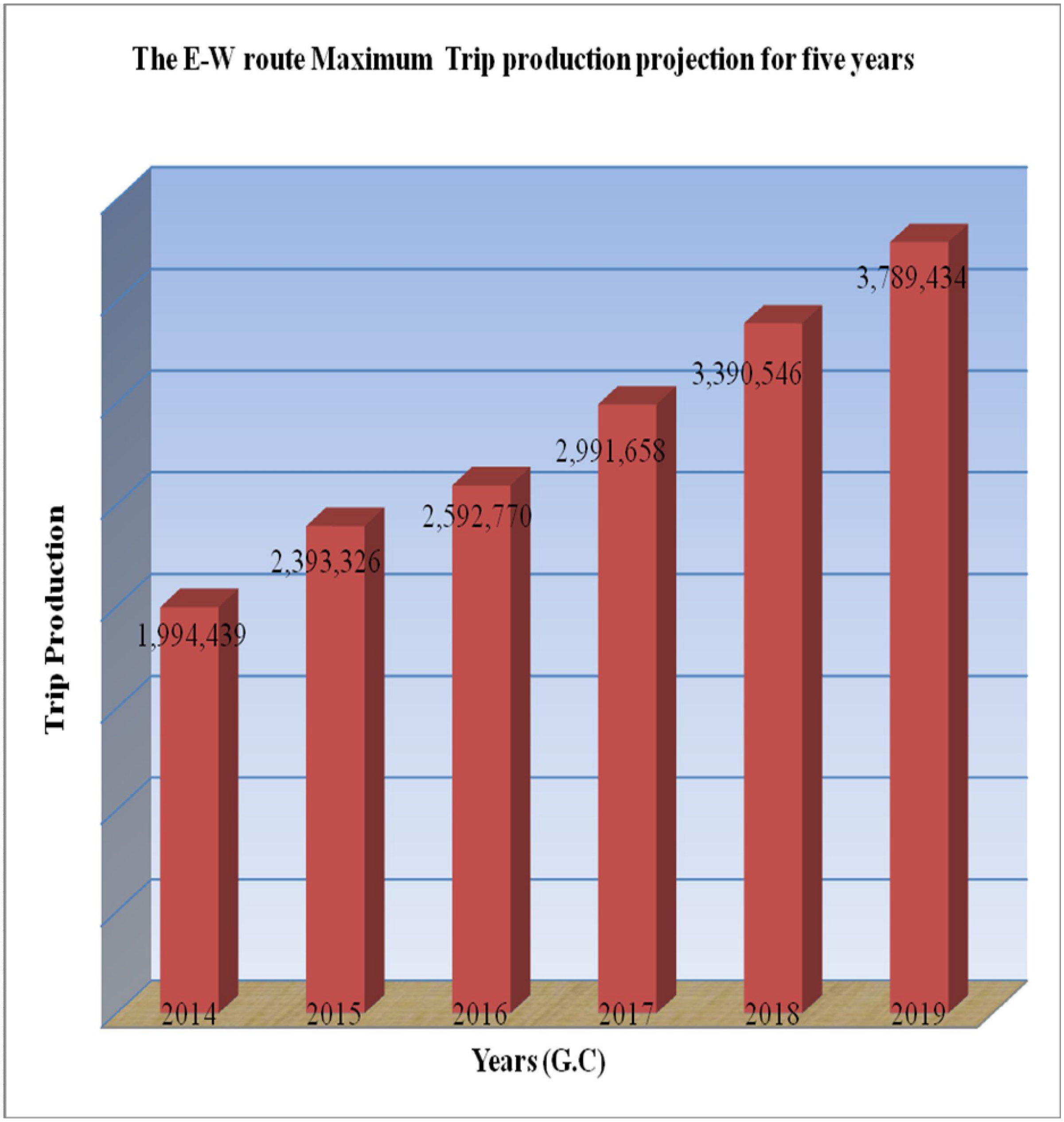

Figure 5: The East –West Route Maximum Trip production projection for five years.

The above results indicated in Figure 5 shows the maximum trip production forecasting made for five years beginning from the base year of 2014G.C to the design year of 2019G.C on the East-West LRT route.

5.3 Summary of the Result

The results calculated and shown in figures above of both North-South and East-West LRT routes are made with the help of the land activity rate and the growth factor model for five consecutive years from 2014G.C to 2019G.C as a minimum and maximum trip values per day.

In the North to South LRT route, the minimum trip production for the base year of 2014G.C is 317,452 trips per day which is lower than the ERC forecast of 536,935 trips/day and the deign year of 2019G.C minimum trip production forecast is estimated to be 603,159 trips per day which is slightly higher than the ERC estimate of 536,935. On the other hand the maximum trip production for the base year of 2014G.C is 1,069,311 trips per day which is almost twice as much as the ERC estimate and the design year of 2019G.C maximum trip production forecast is 2,031,691 trips per day which is almost four times higher than the ERC estimates.

Similarly, for the East to West route the minimum trip production for the base year is 592,099 trips per day which lower than the ERC forecast of 734,393 trips per day and the design year minimum trip production forecast is estimated as 1,124,988 trips per day which is 1.5 times higher than 734,393 trips per day. On the other hand the maximum trip production for the base year is 1,994,439 trips per day which is almost three fold 734,393 trips per day and the design year maximum trip production forecast is 3,789,434 trips per day which is five times higher than the ERC forecast.

CHAPTER SIX:-CONCLUSION AND RECOMMENDATION

6.1 Conclusion

To forecast the current or base year and future person on foot trip productions on LRT routes, the land activity rate of trip based modeling method is used to estimate the base year trip production and the growth factor model is used to model for future trip forecasting. These methods consider basic factors that affect trip production such as zonal population size, private car ownership and other land use characteristics. Based on these models and the procedures involved the numbers of trips are calculated both on North-South and East-West LRT routes as a minimum and a maximum values in interval for the consecutive five years.

The North–South route forecasting shows a minimum of 603,159 person trips and a maximum of 2,031,691 person trips whereas the East-West route forecasting shows a minimum of 1,124,988 person trips and a maximum of 3,789,434 person trips generated after five years in 2019G.C.

6.2 Recommendation

As the socio- economic condition of the city increase, there will be a continuous increase in Transportation and LRT Transportation demand in particular.

Modernization of the LRT Transport is measured by its efficiency and effectiveness and this is achieved by incorporating travel demand analysis. Among the different types of demand analysis techniques, the best that meets the problem of developing countries is the land activity rate and the growth factor method where there is no historical demand datas.the major attribute of this technique is that it incorporates the socio-economic data of the residents which is very determinant for the analysis.

The trip production analysis is made by considering the data on residential people as the only trip generators, but industrial areas, commercial areas, schools etc. can also be the source of trip productions. Therefore if data is available on the above mentioned trip generators in the future accurate and realistic trip estimation can be made.

Besides, only internal trips i.e. trips generated due to residents located near the LRT routes are considered which has the largest share and accounted as 85% of the total trips, but external trips far from the routes which has the minimum share accounted as 15% of the total trips should also be considered. Finally, I recommend the Ethiopian Railways Corporation (ERC) to apply this model to carryout the trip analysis.

6.3 Contribution of the thesis

The academic contribution of this research is to explore and indicate the travel demand forecasting model that best fits for new Railway stations of developing countries, where there is no or insufficient data considering the traffic analysis zones (TAZs) population and their land activity rate that involves the current and future socio economic characteristics of the people. And the Ethiopian Railways Corporation (ERC) will be benefited from the result of this thesis to perform the transportation planning. And also the findings of the study could serve as an important base for transportation professionals and policy makers to make decision on policy and investment in the Railway transport industry.

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APPENDICES

Appendix A: Table of estimates and actual Population projection of Addis Ababa from 1961 – 2030 (in millions)

Year	Population		Total	Year	Population		Total
	Male	Female			Male	Female	
*1961	0.230	0.218	0.448	2016	1.82	1.95	3.77
1967	0.337	0.369	0.706	2017	1.87	1.99	3.86
*1978	0.553	0.613	1.166	2018	1.91	2.04	3.95
*1984	0.685	0.737	1.422	2019	1.95	2.08	4.03
*1994	1.020	1.089	2.109	2020	1.99	2.12	4.11
*2007	1.304	1.433	2.73	2021	2.03	2.16	4.19
2008	1.36	1.49	2.85	2022	2.06	2.19	4.25
2009	1.42	1.55	2.97	2023	2.10	2.23	4.33
2010	1.48	1.61	3.09	2024	2.12	2.26	4.38
2011	1.54	1.66	3.20	2025	2.15	2.28	4.43
2012	1.59	1.72	3.31	2026	2.18	2.31	4.49
2013	1.65	1.78	3.43	2027	2.20	2.34	4.54
2014	1.71	1.84	3.55	2028	2.23	2.36	4.59
2015	1.76	1.89	3.65	2029	2.25	2.39	4.64
				2030	2.28	2.42	4.70

Source: Central Statistics Authority

Appendix B: Table of Major Demographic Indicators of Addis Ababa (2009)

Indicators	**%**
Population Size (in millions)	2.7
Annual Population Growth Rate (%)	2.1
Population Doubling Time (years)	33.3
Percent of Urban Population	100
Population Density (persons/km2)	5,071
Sex Ratio (%)(Male: Female Ratio)	91

Source: Population and Housing Census 2007 & Demographic and Health Survey, 2005

Appendix C: Trip forecast formula

$$T_i = f_i t_i$$

Where; f_i is the growth factor

t_i is the current base year trip and

T_i is the future forecasted trip.

Appendix D: Growth factor formula

$$f_i = \frac{P_{id} V_{id} I_{id}}{P_{ic} V_{ic} I_{ic}}$$

Where;

f_i-is growth factor

p- is the amount of population

V- Is the vehicle ownership

I- is average income

i_c- stands for current year

i_d- stands for design year.