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SCHOOL OF GRADUATE STUDIES

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A STUDY ON RAILWAY TRANSPORT DEMAND MODEL IN ETHIOPIA

(A Case Study on Addis Ababa-Djibouti Line)

BY

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A STUDY ON RAILWAY TRANSPORT DEMAND MODEL IN ETHIOPIA

(A Case Study on Addis Ababa-Djibouti Line)

A Thesis Submitted To

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BY: DAWIT FEKADU

(RAILWAY)

APPROVED BY BOARD OF EXAMINERS

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SIGNED DECLARATION

This thesis is my original work and all sources of materials used for the thesis have been duly acknowledged.

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Addis Ababa University

September, 2014

The Thesis has been submitted for examination with my approval as an advisor

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Alemayehu Ambo (PHD)

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ABSTRACT

The growing Population and Economy of Ethiopia require efficient transport system. However, the country's transport infrastructure with the exception of air transport is not developed; the Country has poor road and rail transport network and density, one of the least in Africa, with many challenges; financial, maintenance, professionals, and management problems.

Rail transport which started operations in 1901 is pioneer in the country; however, its fate seems unfortunate. The road transport system has relatively better technological and professional advancement. Despite the past shortcomings of railway transport, the Country has now formulated an ambitious plan to develop a new railway network system with a length of 5,000 km.

This paper tries to fill the gap in the railway system planning and modelling unlike the country's road transport; it is not developed but rather diminished and has not established working manuals and standards. There have also been planning and management problems and as a result, the previous Ethio-Djibouti Railway Company suffered huge losses in traffic and finance and eventually was forced to quit operations.

The Direct Demand Model which is developed in this research is simple and can produce traffic demand on single computation. It was, selected and analysed with variables of: economy, population, travel distance and time, load capacity, environment, topography, energy, and other variables (price, income, logistics, travel culture/behaviour, urbanisation, multimodal/intermodal, technology, information communication technology(ICT), transport demand management (TDM), and season etc); the model produced a 58/42 and 55/45 FREIGHT and PASSENGER modal split for the year 2020; the result agrees with the AAU 2011 study of 60/40 Modal Split. In addition the model validated for road freight with Pearson Coefficient-r=0.98 and $r^2 = 0.96$**.**

The observation of Ethio-Djibouti rail line exhibits: a decline of rolling stocks and traffic with loss in its revenue. This research has produced model from investment and strategic plan view of land transport.

ACRONYMS

4SM	Four Step Model
AADT	Annual Average Daily Traffic
AAiT	Addis Ababa Institute of Technology
AAU	Addis Ababa University
ABA	Activity Based Approach
B5	5% Biodiesel Content of Transport Diesel
CDE	Compagnie Du Chemin De Fer Djibouto-Ethiopien
CSA	Central Statistical Agency
CO2e	Carbon Dioxide Equivalent
CRGE	Ethiopia’s Climate-Resilient Green Economy Initiative
$\mathbf{D}_{\mathbf{rail/road}}$	Demand of Rail/Road
E15	15% Ethanol Content of Transport Gasoline
E.C	Ethiopian Calendar
EMME/2	Transport Modelling Programs, INRO of Canada- 1987
EPSE	Ethiopian Petroleum Supply Enterprise
ERA	Ethiopian Roads Authority
ERC	Ethiopian Railways Corporation
ETB	Ethiopian Birr
GHG	Greenhouse Gases (Mainly CO2, N2O, and Methane)
GDP	Gross Domestic Product
GTP	Growth and Transformation Plan
ICT	Information Communication Technology
IMF	International Monetary Fund
MT	Metric Tones
Mt	Million Metric Tones

MW	Mega Watt
O-D	Origin-Destination
OECD	Organization for Economic Co-Operation and Development
P-km	Passenger- kilometre
TDM	Travel Demand Management
T-km	Tone-kilometre
Sq.km/Km^2	Square-kilometre
USD	United States Dollars

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1. INTRODUCTION

1.1 BACKGROUND STUDY

Ethiopia is an ancient and historical country, known as ancestral home of early human species (Lucy-found in Afar Region, 3.2 million years old), symbol of independence for African nations (not colonized by European power), and known for its long distance runners. Ethiopia has a population of more than 90 million (CSA-2014 estimates) with 80 different ethnic groups, second populous nation in Africa. Ethiopia is Located[1] in east Africa, approximately 3^o-15^o N latitude and 33^o-48^o E longitude, and area coverage of 1.13 million sq km.

Ethiopian topography[2] has great diversity of terrain elevation ranges from 110 meters below sea level at Danakil Depression to 4,620 meters above sea level at Ras Dashen Mountain, a massive highland complex of mountains and dissected plateaus, divided by the Great Rift Valley, which runs generally from northeast to southwest and is surrounded by lowlands, steppes, or semi-desert.

Diversity of terrain leads to wide variations in climate, soil, natural vegetation, and settlement pattern. Elevation and geographic location produce three climatic zones: the cool zone above 2,400 meters where temperature ranges from near freezing to 16° C; the elevation that ranges from 1,500 meters to 2400 meters is within both the tropical and arid temperature zones with daytime temperatures ranging from 27 to 50° C.

Ethiopia is one of the least developed nations with agriculture based economy and ranked as one of the poorest nations in the world. Ethiopia was a powerful country during the Aksumite Kingdom. However, its per capita income and standard of living plummeted as a result of many factors, including poor transport infrastructure, backward farming methods, archaic manufacturing industries and very sluggish economic growth. Nevertheless since the last two decades, in this respect, the Country has exhibited a stable growing economy with 8.9% and 7% and more in 2012/13 and 2013/14 according to World Bank, and IMF 2014 reports the gross domestic product (GDP) grew by 9.7%, 7.5%, and 7.5% in 2013, 2014 and 2015 respectively. The growth in road infrastructure was significant in contributing to rapid economic development.

Railway infrastructure in Ethiopia dated back to 1901 when started to operate from the Port of Djibouti to Dire Dawa. The first road was built in 1903. Air transport and shipping /maritime transport activities started to operate in 1946 and 1964 respectively. In fact, the Ethiopian Airlines is a world class airline and one of the best and the first in the African continent.

The Ethiopian road network increased from 24,961 km in 1996/97 to 85,966 km in 2012/13, with 8% average annual growth. Similarly, road density increased from 22.8 to 57.5 kilometres per thousand square kilometres (km/1000 km^2) (WT consultant). Despite these improvements

[1] See Appendix-A: Location Map of Ethiopia

[2] See Appendix-B: Topography Map of Ethiopia

Ethiopian's road network is low compared to most African countries and the rest of the world, (World Bank, 2014 Report).

Rail traffic densities on Sub-Saharan railways are generally low. South Africa has 21,565 km long rail with 17.7 km/1000 km^2 rail density; Egypt, Democratic Republic of Congo, and Tanzania have rail lengths of 5,063 km, 5,684 km (1,028 km not operating), and 3,574 km respective. However Ethiopia has a total of 681 km rail line which is 0.6 km/1,000 km^2 rail density, one of the lowest in Africa (Bullock, 2009)

The Ethio-Djibouti railway line which used to run from the port of Djibouti to the capital city of Addis Ababa has become inactive due to static technology and poor service which lost traffic and halted providing services.

The current economic development of the country and population growth generates huge demand for transport; both mass transit and freight transport.

Most of the time, demand and supply of transport are unbalanced. Before the implementation of a given transport service (transport infrastructure, facility, regulation and policy), demand usually surpasses supply. Even after the provision of reasonable transport infrastructure, demand still surpasses supply in a developing country like Ethiopia, because of poor service, neglected maintenance, and poor transportation management.

Poor transport planning, and demand forecasting results in traffic congestion, delay, and damage of transport infrastructure and creates imbalance between demand and supply. This has been witnessed in Ethiopia in both road transport and the Ethio-Djibouti railway line. Different reasons: low quality of infrastructure, maintenance problem, poor planning, inadequate management, financial constraint, and the like are the common phenomenon in the problematic provision of transport services in Ethiopia.

And this research is focused in developing rail and road transport demand model. The demand model of the railway and road transport deals with wide range of variables: economy, population, environment, energy, topography, travel time and distance, load capacity, and others. The Addis Ababa-Djibouti rail line is given particular emphasis to illustrate the railway line route of the nation since it handles most of the Country's import and export, with 90% trade passes through port of Djibouti.

1.2 STATEMENT OF PROBLEM

Congestion and damage of transport infrastructure in Ethiopia is due to a lack of proper transport planning, demand forecasting, and traffic management as witnessed on the Road and the Ethio-Djibouti Railway line transport corridor between Addis Ababa and the Port of Djibouti. Therefore, this research:

- tries to investigate the unique variables which characterise the Ethiopian railway travel demand; and

- assess and investigate the historical traffic trend of the Ethio-Djibouti railway line and develop a model to rationally forecast the future railway transport demand for Ethiopia in general and for Ethio- Djibouti railway line in particular.

1.3 LITERATURE REVIEW

Railway History

Rail transport has long history from past to date. It begins from wagon ways in mines on wood rail in Germany in the 1550s (http://en.wikipedia.org/wiki/History_of_rail_transport), and 17th century transportation when colliery and quarry on stone slab or timber baulks were drawn by horses (Bonnett, 1996); transport of passengers starting from early 19th century (O'Flaherty et.al, 2003), and recent development of fast passenger trains with 300km/hr and more. Some literature states that rail line has been in existence since 600 BC Greece, a guided track way (http://en.wikipedia.org/wiki/History_of_rail_transport).

According to World Bank 2014 data, developed and emerging nation has better rail way network system; OECD members had 548,609 km in 2012, United States of America had 228,218 km in 2012, European Union had 213, 307 km in 2012, Russian Federation had 84, 249 km in 2012, China had 66, 298 km in 2012, India had 64, 460 km in 2012, Canada had 52, 002 km in 2012, Germany had 33, 509 km in 2012, France had 30, 013 km in 2012, Brazil had 29, 817 km in 2012, Japan had 20,140km in 2012, and United Kingdom had 16, 423km in 2012.

African Railway

Railway development has followed a similar pattern across Africa. First, isolated lines reached inland from ports to link with trading centres or mines, with branch lines; then, built over time. In their current state, railways can be expected to make only a minor contribution toward solving the transport problems of the continent. The first railways were built in South Africa in the 1860s and 1870s, with lines heading inland from the ports of Cape Town and Durban. The total rail network for Africa is around 82,000 kilometres, of which about 69,000 km are currently in use, with the remainder closed due to war damages, natural disasters, or general neglect and lack of funds. South Africa has 21,565 km (more than a quarter of the Continent) of railway line which is 17.7 km/1000km^2, leading the rail infrastructure in Africa, followed by Egypt, Democratic republic of Congo, Tanzania with respective rail lengths of 5,063 km, 5,684 km (1,028 km not operating), and 3,574 km (Bullock ,2009).

Rail traffic densities on Sub-Saharan railways are generally low. South Africa also dominates general rail freight handling with more than 80 percent of the freight traffic on the non- mineral lines. South Africa and Egypt dominate the passenger business, with more than 85 percent of passenger-km. The traffic density of the Maghreb systems (Morocco, Algeria, and Tunisia) ranges between 2 million and 4 million (similar to many European systems), but only three Sub-Saharan African railways have traffic densities with more than a million and many average less than 300,000 passenger-km. Sub-Saharan African railways are therefore generally lightly loaded by world standards, and most networks struggle to generate enough funds to maintain and renew their infrastructure as required (Bullock, 2009).

Ethiopian Railway

Ethiopia is one of the first African countries to build and owe railway infrastructure in the beginning of early 20th century, with the initiative of Emperor Menelik II and with the assistance of France. It is 784 km in length stretching from the port of Djibouti at the coast of the Red Sea to Addis Ababa, the capital city of Ethiopia. (http://www.train-franco-ethiopien.com/histoire_en.php).

Out of the total rail line which runs from Djibouti to Addis Ababa, 681 km stretches from the Djibouti border to Addis Ababa. Thus, Ethiopia has a total of 681 km rail line with 0.6 km/1,000 km^2 rail density, one of the least in Africa (Bullock, 2009).

The previous railway line which ran from the port of Djibouti to the capital city Addis Ababa served well but it was not able to cope with the growing demand. In fact, due road transport development and its inadequacy to serve its purpose, it lost its traffic and halts the service (Addis Ababa University, 2011 report). Now after over 100 years of the Ethio-Djibouti rail line establishment, Ethiopia is implementing an ambitious plan of building over 5,000 km of national rail line and with light rail transport of 34 km in the capital city (http://www.erc.gov.et/), through government funding and investment loan.

Transport Planning

Transport planning is a comprehensive, multi-disciplinary, cooperative, pro-active and dynamic process of establishing goals and objectives, assessing current conditions and gaps, forecasting future demands, developing appropriate strategies, evaluating alternatives, determining benchmarks and priorities and preparing activity plan that encompasses diverse views and homogeneous interests for the achievement of safe, efficient and affordable movement of persons and goods throughout the life-cycle of the transport system.

Transportation helps shape an area’s economic health and quality of life. Not only does the transport system provide for the mobility of people and goods, it also influences patterns of growth and economic activity by providing access to land. The performance of the system affects public policy concerns like air quality, environmental resource consumption, social equity, land use, urban growth, economic development, safety, and security. Transportation planning recognizes the critical links between transportation and other societal goals. The planning process is more than merely listing highway and transit capital projects. It requires developing strategies for operating, managing, maintaining, and financing the area’s transportation system in such a way as to advance the long-term goals (FTA and FHA).

Transport Modelling

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 optimise 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; it only supports and sometimes plays an important role in transport planning (Ortuzar and Willumsen, 2001).

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 (Ortuzar and Willumsen, 2001).

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 behaviour of system or individuals, one can infer rules which determine the behaviour and then use those rules to predict unobserved behaviour. The process of what rules to include in the model is **Specification**, and the process of reproducing what is being observed is **Caliberation**, and to check for result against time and place is **Validation** (O'Flaherty et al 2003).

Only a model that is validated on wide range is said to be transferable and causal rather than simply correlative (coincidence or correlation between input and output variables). Models range from simple encapsulating empirical relationship to perform sophisticated mathematical function or detailed simulation. That is from simple hand calculation, calculator, simple spreadsheet program to computer program with hundred of lines of codes (O'Flaherty et al 2003).

Years of experimentation in the United States of America (USA) in the 1960s have resulted in a general structure which has been called the classic transport model. The model called: four stage model/sequential travel demand model (O'Flaherty et al, 2003) or referred to as conventional approaches (G. McNally 2000). The general form considers zoning and network system, collection and coding of planning, calibrating and validation data. In four steps: trip generation (trip attraction and production of zone), trip distribution (trips allocation in particular destination), modal spilt (involve choice of mode), and trip assignment (assigned trip by each mode in corresponding network). Moreover the four stage model is seen as concentrating only on a limited range of travellers responses (Ortuzar and Willumsen, 2001).

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).

It was clear from the beginning when derived nature of transportation was understood and accepted yet not reflected in the 4SM. However, the 1970s brought fundamental changes in urban, environmental, and energy policy, and with it the first reconsideration of travel forecasting; it was this period that the Activity Based Approaches (ABA) was first studied in depth. But trip-base methods do not reflect: the link between trip and activity, temporal constraints and dependencies of activity scheduling, nor include activity behaviours that generate trip, and little policy-sensitivity (G. McNally, 2000).

The ongoing concerns of modellers to produce accurate model has resulted in continued attempt to develop models which accord with the insight revealed by behavioural 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 behaviour (O'Flaherty et al 2003).

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. And criticism on the 4SM improve the approaches through the application of disaggregate models and equilibrium assignments. Though the activity approaches lack solid theoretical basis, with diverse theoretical, methodological, and empirical approaches used (G. McNally, 2000).

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

Model Reviews

Wirasinghe and Kumarage, 1998:

Developed **Aggregate Total Demand Model** for intercity passenger travel in Sri Lanka, from simple gravity demand model including: socio-economic variables of population, urbanization, and Estate; Impedance variables of wait time and transfers, and abstract generalized cost; and intrinsic variables.

Umamil and Sugie, 2003:

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).

Couto and Maia, 2009:

Developed **Log-Linear Function** for **Aggregate Freight Rail Demand Model** of European countries with six variable groups: price, time, quality of service, alternative mode and its price, exogenous variable of (demographic, topographic, environmental and other).

Addis Ababa University, 2011 report:

The application of big models, including macro-generation and sequential transport demand models criticized as not suitable in most cases particularly for freight for many reasons: firstly, the model was originally developed for urban transportation, and secondly, the models used currently are considered to be inadequate as they are originally developed for passenger travel demand forecasting. At present a lot of efforts are being made to revise and improve the freight part of the model although so far a generally acceptable freight model has not yet been developed. The report forecast railway transport for the Addis Ababa-Djibouti rail line using **Linear Regression and Compound Growth Models for freight transport, O-D survey and ERA traffic data for passenger transport**.

Freight demand forecast used GDP, foreign trade (import and export), and GTP (the country's growth transformation plan) of the nation. In addition ERA freight data and O-D survey were used to validate the freight forecast. Passenger demand forecast used: past trend, O-D survey, ERA traffic data, and calibrating function.

COWI, 2006 report:

Study Ethiopian transport network and developed a model using **4SM model,** (generation, distribution, modal split, and assignment), and **EMME/2 software**. The model development considered: linear regression model for generation, gravity model for distribution, distribution plus generalized cost for modal split, and traffic plus generalized cost in equilibrium theory for route assignments. It also used Socio-Economic data (population, import/export, and other) and Traffic data (traffic counts, O-D data, capacity and travel time and others).

1.4 MODEL SELECTION

A Simultaneous/Direct Demand Model, a single step computation and calibration of: generation, distribution, and modal split, was selected for use as in case of Umamil and Sugie, 2003. It avoids the extensive need for data as in the 4SM. The route assignment is addressed since the nature of the travel is an inter-city, inter-region, inter-country travel with a use of one single route for road travel, two closely dependent routes, and one route planned for railway travel construction and it allows inclusions of transport behaviour and other variable in the form of dummy variable for the model development.

In this paper direct demand model used variables of: economy, population, travel distance and time, load capacity, environment, topography, energy, and other variables (price, income, logistics, travel culture/behaviour, urbanization, multimodal/intermodal, technology, ICT, TDM, and season etc), for analysis.

Population

Ethiopia is the second populous country in Africa with a total population of about 90 million (2014 CSA estimate). The country's population grows by around 2.3% annually while the urban population grows by around 4.5% annually (CSA abstract). It is presumed that population growth generates greater demand for transport network.

Ethiopian road network increased from 24,961 km in 1996/97 to 85,966 km in 2012/13 with 8% average annual growth. Similarly the road density increased, from 22.8 km to 57.5 km/1000 km^2 of area and from 0.44 km to 0.72 km/1000 population, between 1996/97 to 2011/12, by about 7 percent per annum (WT-consultant).

However, the Ethiopian road density is not developed as most of the African countries and as the rest of world. For instance, the Tanzania road density was 9 km/100 km^2 in 2011, Ghana's road density was 46 km/100 km^2 in 2011, Kenya's road density was 28 km/100 km^2 in 2011, United State's road density was 62 km/100 km^2 in 2011, United Kingdome's road density was 172 km/100 km^2 in 2011, and Middle East and North Africa road density was 10 km/100 km^2, and world's road density was 33 km/100 km^2 in 2011 (World Bank 2014).

The Ethio-Djibouti railway had halted service (Addis Ababa University, 2011 report). The rail density during the time of its operations was 0.6 km/1000 Km^2 and was one of the lowest in Africa (Bullock, 2009).

Economy

Ethiopia's economy is based on agriculture, service, and domestic-industry sectors with respective GDP contribution of 47%, 42%, and 11% for the years 2004/05-2011/12. Similarly the country economy, in the past, 2004/05-2011/12, grew by more than 10% (National Bank of Ethiopia, 2011/2012 report). The International Monetary Fund (IMF) provided the country's past GDP growth rates as 9.7% and the World Bank put 8.9% GDP growth, one of the fastest growing economies in Africa, without the export of Oil.

Ethiopia's sea and land transport of imports and exports grew by average of 12 % and 5 % from 2005 to 2012 respectively and are assumed to grow in similar trend for the future (Custom and Revenue Authority).

Ethiopia is a landlocked country which depends on its neighbours' ports, mainly on Djibouti Port, for its international-sea trade. All the neighbouring countries, except South Sudan, have ports and port facilities.

The port of Djibouti is the major route for Ethiopia's international-sea import and export trade, in 2010, the ports of Djibouti, Berbera and Port Sudan handled 93, 5 and 2 percents, respectively (Addis Ababa University, 2011 report).

As part of the economic policy, Ethiopia integrates environmental factors with aims to reduce green house gases (GHG) emissions through different measures: policy towards fuel efficiency, electric and hybrid vehicle, electric railway line, including E15 and B5 biofuel and biodiesel. Of all the alternatives, implementation of electric railway line has a greater GHG emission mitigation capacity (Federal Democratic Republic of Ethiopia, 2011 CRGE report).

Environment

Transport has several impacts on the environment. Emissions contribute to air pollution and climate change; noise causes nuisance and health risks and infrastructure has serious impacts on landscape and ecosystems (Huib van Essen, 2008).

The main air pollutants[3] include: hydrocarbons (HC) and nitrogen oxides (NOx), carbon monoxides (CO), and particulates (PM-10 or PM-2.5), sulfur dioxide (So2), sooth, and volatile organic compound (VOC), and their climate effect described in Co2 equivalent-Co2e. And all mode of transport (road, rail, air, marine, and pipe) are prone to air pollution[4].

Ethiopia's economy is agriculture-based with 48%-50% of GDP contribution which depends on seasonal rain and employs 85% of the population with an 80% share of export (Environmental Policy of Ethiopia).

Ethiopia's total emissions are around 150 Mt CO2e contributing less than 0.3% of global emissions. Of the 150 Mt CO2e in 2010, more than 85% of GHG emissions came from the agricultural and forestry sectors. They are followed by power, transport, industry and buildings, which contributed 3% each. Road transports constitute 3% of GHG emission and are projected to grow from around 5 Mt CO2e in 2010 to 40 Mt CO2e in 2030 (Federal Democratic Republic of Ethiopia, 2011 CRGE report).

If current practices prevail, GHG emissions in Ethiopia will more than double from 150 Mt CO2e to 400 Mt CO2e in 2030. But with the implementation of Green economy, the Country will curb the emission by 250 Mt CO2e in 2030 and remain 150 Mt CO2e. The largest initiatives with the greatest abatement potential are the construction of an electric rail network (9 Mt CO2e)

[3] See Appendix-C: Air Pollutant Environmental Damage

[4] See Appendix-D: Transport Modes Air Pollution Factor

followed by the introduction of fuel efficiency standards for all vehicles (3 Mt CO_2e). This assumes the construction of more than 5,000 km of rail tracks and new fuel efficiency standards for 30% of passenger vehicles and 10% of freight vehicles by 2030. Emissions from fuel: – Diesel: 2.67 kg CO_2e/litre – Gasoline: 2.42 kg CO_2e/litre (Federal Democratic Republic of Ethiopia, 2011 CRGE report).

Ethiopia plans to use its resources, specially land and water for improvement of its agriculture and economic progress which require huge energy supply and so the nation plans to use its water resources to good use for hydropower development. However agriculture and hydropower developments are prone to global warming and environmental pollution.

Energy

Ethiopia's transport and some-industry sector use fossil fuel for energy requirements. The country's fuel consumption grew by 5-6% annually in the past and is expected to jump to 10 % annual growth in the future. Import of fuel and petroleum product will reach 2,329,907.23 MT with corresponding cost of about 1.8 billion USD in 2012/2013, (Ethiopian Petroleum Supply Enterprise, 2014 unpublished report).

The fossil fuel demand would call for significant resources and put pressure on foreign currency reserves which is currently absorbing more than 4% of the GDP, roughly equals the foreign currency and gold reserves and would increase to around 7% of GDP in 2030 (Federal Democratic Republic of Ethiopia, 2011 CRGE report). In this regard, the Ethiopian Railway Corporation economic plan of using electric energy for the railway transport has been estimated to save the same amount of currency allocated for the purchase of petroleum fuel.

Ethiopia has exploitable hydropower potential of 45,000 MW from water, 1.3 million MW of wind generating capacity, and more than 7,000 MW of producing geothermal energy. Until 2010, the overall production of electricity has remained 2,000 MW. With expansion works, electricity production must have reached 2, 117 MW by 2012/13, (www.mowr.gov.et).

Topography

Ethiopia's topography has great diversity of terrain, a massive complex highlands, mountains and dissected plateaus. Topography ranges from 110 meters below sea level in the Dallol depression to mountain peaks of 4620 meters above sea level at the top of Mount Dashen.

The eastern margin of the plateau is elevated to between 3,000 m and 4,000 m, towards the West, while the plateau surface descends to between 1,200 m and 1,000 m. The Western highlands are massive with an average height of 2,000-2,500 m. The western and the eastern highlands are divided by the Rift Valley.

Railway construction in the mountainous areas increases construction works: earth work and the like, and similarly increases construction costs as a result of construction of culverts, bridges, and tunnels.

For instance, the construction of the Addis Ababa-Djibouti line was planned to be constructed along two sections: SEBETA-MIESO and MIESO-NEGAD (Djibouti port). The Sebeta-Mieso section consists of 38.54 km total bridge and 710m of tunnel with USD 1,153,652,106 and USD 312,350,087 respectively with the corresponding percentages of 3.48 and 0.64 of the total project construction cost. Mieso-Negad (Djibouti port) consists section consists of 6.47 km total bridge and culverts. These imply that the topography is hilly and mountains on the Sebeta-Mieso section especially the Sebeta-Adama portion with 25.44 km of bridges, which about are 22.996% of the section length, 110.627 km (CREG and CREEC, 2011 feasibility report).

Load Capacity

Population growth and Economic development produce greater demand for Passenger and Freight transport system; large demand is likely to produce large load of traffic on the transport infrastructure.

Travel Distance and Time

Time as transport service quality parameter affects the overall performance of the transportation system. Distance has its own time value, distance and time can be used as a single time model variable.

Other Model Variables

Transport Cost, Multimodal/Intermodal, Technology, and Travel Behaviour/ Travel Culture; with potential of changing the transport trend and demand of both road and rail: The following are other model variables:

Transport Price: transport fare, with time and preference, influences the modal choice of transport and influence the profitability and future investment of the transport and infrastructure provider. Transport price change can affect trip frequency, route, mode, destination, scheduling, vehicle type, parking location, type of service selected, and location decisions of traffic (Todd Litman, 2013).

Multimodal and intermodal: for optimum utilization of transport infrastructure integration is crucial for the transport systems.

For instance, travel time for TRUCKS include: load time at the origin, travel time on the road network, and time of discharge at the destination. Similarly, travel time for RAIL includes: load time of the truck at its origin, travel time of the truck to the railway station, transhipment time of the goods from truck to train, travel time of the train, transhipment of the goods from train to another truck, travel time of the second truck to the destination, and finally time of discharge of the goods at the destination.

Efficient land transport requires effective integration of rail and road, and effective implementation of multimodal and intermodal is indispensable.

Technology advancement: technological advancement especially in field of ICT reduces the need for physical travel. High value goods with less unit tonnage reduce the need for freight transport.

Travel behaviour: economic development improves the level of living standard and income explained in car ownership and less need for mass transport.

Transport Demand Management (TDM): after infrastructure construction, proper travel demand management needs to be in place for efficient service provision.

TDM measures are concerned with the alteration of travel behaviour in order to enhance the efficient use of the existing road infrastructure and facilities (Mbara, 2002). Various policies and programs are specifically intended to affect travel activity, in most cases, to reduce urban-peak motor vehicle traffic (Todd Litman, 2013).

Urbanization: economic development is significant in big cities with dense population and with effective means of mass transit to supply large volume of consumer goods.

Urbanization, the demographic transition from rural to urban, is associated with shifts from an agriculture-based economy to mass industry, technology, and service. One hundred years ago, two out of every ten people lived in an urban area. By 1990, less than 40% of the global population lived in cities, but as of 2010, more than half of the world population live in urban areas. By 2030, six out of every 10 people will live in a cities, and by 2050, this proportion will increase to 7 out of 10 people. Currently, around half of all urban dwellers live in cities with population between 100,000 – 500,000 people, and fewer than 10 % of urban dwellers live in megacities (defined by UN HABITAT as a city with a population of more than 10 million) (www.who.int).

Most of the rapid urbanization changes are taking place in cities of the developing world particularly in Africa where urban population is growing at an unprecedented rate. Currently, the continent is experiencing an average growth rate of 4.5% per annum. For example, urbanization growth rates for Kenya, Tanzania and Zimbabwe in the eighties were 7.7%, 6.6% and 5.9% respectively. This growth in population is a result of a combination of both natural growth and rural urban migration (Mbara, 2002). The national population growth rate of Ethiopia was around 2.30% between 2001 and 2011 and that of urban centres was around 4.5% during the same period (CSA Abstract).

1.5 TRAVEL DEMAND RESPONSIVENESS IN ETHIOPIA

The effects that transport system changes have on mobility is referred to as responsiveness or sensitivity to specific variable or factor, measured using elasticity's (Todd Litman, 2013). Elasticity is simply defined as a change in percentage in the dependent variable induced by a 1 % change in the independent variable.

A transportation firm can take advantage of marginal price increases or decreases to add to its revenue by knowing the current elasticity of demand for its particular mode. The effects depend heavily on knowledge of supply and demand conditions (Dybing, 2002). That is if the elasticity of demand (independent variable) is lower than the elasticity of supply (dependent variable) it will have high effect on the supply; and on the other hand, high demand elasticity than supply elasticity will have small effect on the supply.

The Ethiopian elasticity of foreign trade with respect to the GDP was 2.12 for ten years (1998/99-2008/09) reflecting a very elastic nature of trade responses to GDP growth that is about 2 times that of GDP growth (Addis Ababa University, 2011 report).

2. OBJECTIVES

The theme of this paper is to understand the nature and history of railway transport demand in Ethiopia and analyse demand planning and forecast the future traffic demand of railway transport.

- **General Objective**

Firstly, the general objective of the thesis is to analyse railway traffic generated and road traffic attracted and identify determining factors in railway demand. Secondly, the general objective is to investigate the traffic trend of the “Ethio-Djibouti railway line” and use the analysis as an input for the new railway lines.

- **Specific Objective**

I. The First specific objective of the thesis is to develop Railway Transport Demand Model and;

II. The Second specific objective is to Examine and Draw Lesson from Ethio-Djibouti railway.

- **Research Scope**

The Ethiopian Roads Authority Manual, 2002 and the Addis Ababa City Road Authority Manual, 2004 have established nationwide standards and procedures to compute road transport demand. Conversely, railway demand computation lacks published standards. But the paper will not establish standard for the railway demand computation of the country, which is large requiring the involvement of various experienced professionals, engineers and economists, with considerable time, and finance.

The Addis Ababa-Djibouti rail line is given emphasis to illustrate the railway network of the country since it handles most of the nation's imports and exports, more than 90% trade passes through the port of Djibouti. In addition, it has 100 and more years of experience of both land transport modes, road and rail, and can provide a better insight to the travel demand for other part of the country.

In view of the foregoing, this thesis is focused on modelling demand of the railway and road transport using a wide range of variables: economy, population, policy, environment, energy, topography, travel time and distance, load capacity, and others.

3. RESEARCH METHODOLOGY

3.1 Study Area

The focus of this research paper is to assess **Railway Transport Activities in Ethiopia**, in particular the **Addis Ababa - Djibouti Rail Line** and develop a demand model to predict/forecast future demand trends.

The Addis Ababa-Djibouti corridor is the major import and export corridor of the Country handling more than 90% of the foreign trade (Addis Ababa University, 2011 report). Most Ethiopian motorised transport is road network which is close to 95% (COWI, 2006 report). The only railway transport of the country is from Addis Ababa to Djibouti which is currently out of service. Out of the 781 km of the rail line 681 km is in Ethiopia. On the other hand, the length of the Addis Ababa-Dewele/Djibouti border road is 743 km.

LAND TRANSPORT ROUTE

ROAD CORRIDOR: Nodes of Cities, Towns, Woredas, and Kebeles

ADDIS ABABA – AKAKI – BISHOFTU – ADAMA – AWASH – MIESO – ASEBETEFERI – KOBO – KULUBI – DENGEGO – DIREDAWA - DEWELE[5].

NEW RAILWAY CORRIDOR: Nodes of Major stations (Intermediate Stations) along the route:

SEBETA – DEBREZEYET – MOJO – ADAMA – METEHARA – MIESO – BIKE – DIREDAWA – ALISABIEH - NEGAD[6]**.**

3.2 Study Design

- The Study Design encompasses descriptive and analytical study that will be used for investigation and interpretation of research work. The descriptive study used for the investigation of the Ethio-Djibouti railway line travel trend to establish relationship between the old Ethio-Djibouti and the new the Addis Ababa-Djibouti rail lines.

- The Analytical/Explanatory study is performed to establish cause and effect relationship between the independent and dependent variables in demand model development.

3.3 Data Collection

The basic data used in the research is Secondary data of prominent and big data sources of the nation and international organizations like: Central Statistical Agency (CSA) of Ethiopia, National Bank of Ethiopia (NBE), Ethiopian Roads Authority (ERA), Ethio-Djibouti Railway, Ethiopian Railway Corporation (ERC), Ethiopian Petroleum Supply Enterprise (EPSE), World Bank, United Nations (UN), and Others. Tertiary data is used from WT-Consultant, and CREGC and CREEC

[5] See Appendix-E-1: Addis-Djibouti Road Routes

[6] See Appendix-E-2: Addis-Djibouti Rail Route

contractor. Primary data collection was not considered since it would require a large volume of data involving huge amount of finance, time and expertise.

3.4 Description of Model

Analytical study of railway transport demand model form cause and effect relationship. In this regard, observation of Ethio-Djibouti railway line travel trend dictates descriptive study.

3.4.1 Transport Demand / $D_{rail/road}$ is a dependent variable on the primary and secondary variable through transport demand function/ f_d ;

$$D_{rail/road} = f_d(Eco, Pop, Env, Eng, Top, LDc, Tdt, -Etc)$$

Where

D $_{rail/road}$= transport demand, and $\mathbf{f_d}$= transport demand function

Primary variable
- **Eco**=economy/trade;
- **Pop**=population;

Secondary variable
- **Env**= environment;
- **Eng**=energy;
- **Top=**topography;
- **LDc=** load capacity;
- **Tdt**= travel distance and time;
- **Etc**= other variables;

Passenger Model Adoptions and Freight Model Development

Direct Demand Model is used for the analysis and computation of travel demand on the Addis-Djibouti corridor. The model is presumed to have the capacity to compute: travel generation, distribution, and spilt in a single computation.

Umamil and Sugie, 2003 **Developed Simultaneous/Direct Demand Model** 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).

In this research the Umamil and Sugie direct model used as an initial base for the adoption of model in this research paper, Umamil and Sugie developed their model for inter-city travel. And in this paper the model is adopted for inter-country travel with inclusion diverse variable and different parameter for passenger model and new model development for freight model.

Freight kilometres – Tkm (Source: developed from Umamil and Sugie, 2003 inter-urban passenger model)

$$T_{ijm}=e^{\alpha 0+A0}\,(T_iT_j)^{\alpha 1}\,(I)^{\alpha 2+A2}\,(C_{ij})^{\beta 1}\,(t_{ij})^{\beta 2}\,(L_{ij})^{\beta 3}\,(C_{ijm}/C_{ijg})^{\Upsilon 1}\,(t_{ijm}/t_{ijg})^{\Upsilon 2}\,(L_{ijm}/L_{ijg})^{\Upsilon 3}$$

Passenger kilometres – Pkm (Source: adopted from Umamil and Sugie, 2003 inter-urban passenger model)

$$T_{ijm}=e^{\alpha 0+A0}\,(P_{av})^{\alpha 1}\,(I)^{\alpha 2+A2}\,(C_{ij})^{\beta 1}\,(t_{ij})^{\beta 2}\,(L_{ij})^{\beta 3}\,(C_{ijm}/C_{ijg})^{\Upsilon 1}\,(t_{ijm}/t_{ijg})^{\Upsilon 2}\,(L_{ijm}/L_{ijg})^{\Upsilon 3}$$

Where:

Tijm=Traffic for mode-m;
TiTj=Product of Import and Export;
Pav=Average Population in the corridor;
Cijm=Cost of mode-m;
tijm=Time of mode-m;
Lijm=Load of mode-m;
Cijg=Total Cost of Road+Rail;
tijg=Total Time of Road+Rail;
Lijg=Total Load of Road+Rail;
I=per capita Income;

Parameters: **α0, α1, α2, β1, β2, β3, ϒ1, ϒ2, ϒ3**, and parameters for **dummy variables: A0, A2.**

The dummy variables, A0 and A2, in the equation above represents: the contribution of variables in the model computation which are not included in the numerical value of variable entry of the model analysis; and for those variables which are not quantifiable due to their inherent characteristics; and for those variables beyond the scope of the research area of interest.

3.4.2 The Ethio-Djibouti Railway is a pioneer in the history of the Ethiopian transport operations, with the Ethio-Djibouti railway opening the provision of service in 1901 from the Port of Djibouti to Dire Dawa. However, the once big and efficient means of transport ceased operations because of inadequacy in its technological advancement, poor planning and fast growth of road transport that led to loss of traffic and profit to the Company. The variable in the analysis include rolling stocks, traffic and the profit condition of the railway as analyse in the next method of analysis.

The Ethio-Djibouti Railway use in this research is beyond historical value, it used in the input analysis of average passenger-km travel for energy cost estimation, passenger train transport pollution cost estimation, and in the analysis of rail transport time variable; and other uses are its traffic analysis which demonstrates the competitive nature of the rail mode, and to draw a general learning point for planning, managing and demand forecasting from its long history as well.

3.5 Method of Analysis

Quantitative Approach was used for travel demand model computations and Qualitative and Quantitative Approach was used for observation and interpretation of Ethio-Djibouti railway line.

3.5.1 Addis Ababa-Djibouti: travel demand model development and travel model variable analysis and description of variable relationship.

Model Variables and Data Analysis

Population

Ethiopia is the second largest populous country in Africa with a total population of about 90 million (2014 CSA estimate). It is obvious that population growth raises the need for greater demand of transport infrastructure and related facilities.

In the passenger travel model, the population in road transport corridor which connects major Cities, Towns, Woredas and Kebeles were considered. For the analysis of the model, averages of populations/$\mathbf{P_{av}}$ of the route corridor were considered in the production of passenger travel demand.

The available traffic from the Ethiopian Railway Corporation was for the year 2025 and to fill the 10 and more year’s gap form now; projection made for 2020, considering 4.5% annual growth rate of the corridor from urban population growth (CSA) P_{av} population and this resulted in 473,992. It was 330,000 in 2012.

Economy

Ethiopia's economy in the recent past grew by more than 10% (National Bank of Ethiopia, 2011/2012) and the IMF provided the country's past GDP growth rate at 9.7% and World Bank put 8.9% GDP growth rate, one of the fastest growing economy in Africa, without the export of oil.

The Addis-Djibouti corridor is the major import and export corridor of the country which handles more than 90% of foreign trade. Foreign trade in terms of import and export was used for model analysis. Similarly, the GDP, especially per capital income I, was used as a variable to illustrate the ability of people to purchase transport services.

Since the available traffic of the Ethiopian Railway Corporation is for the year 2025 but projection made for 2020, considering 9% and 5% annual trade growth rates of Import and export commodities respectively (Ethiopian Custom and Revenue Authority) and thus total foreign trade would be 1,819.66 (10,000 MT). Considering 10 % as annual growth (National Bank of Ethiopia, 2011/2012) per capital income growth rates the projection was made for 2020 estimated to be 735 USD.

Time

Time as service quality parameter affects the overall performance of transportation system. Distance has its own time value, distance and time used as a single time model variable. Time in transport includes many factors: trip time, waiting time, transfer time, customs processing time, border crossing time and many more. To avoid extraneous of the time variable, journey time of road was used from WT-Consultant Study which are, 12 and 3 days for road freight and passengers respectively.

Considering the previous Ethio-Djibouti rail average km travelled per passenger 200 km and per tone 470 km (CSA); considering design speed of 120 km per hour for passenger train and 80-100 km per hour freight train the time for both direction travels is assumed. In this research the freight travel cover the full 757 km track where as the passenger travel is mostly local as witnessed from the analysis of the Ethic-Djibouti 58 years data and average passenger-km of 250 is used for this reason the travel time of rail freight and passenger presumed to be 4 day of freight in both direction and 1 day travel for passenger in both direction.

Load Capacity

One of the economic sector which is under active development in Ethiopia is transport infrastructure which stimulates economic development. The Ethiopian economy requires efficient transport infrastructure which could support the growing economy characterized by huge freight volume and the growing population. Ethiopia requires efficient passenger transport facility and system to support the growing population and its economy.

The average annual daily traffic (AADT) of road transport and the forecasted 2025 annual traffic of railway were used to estimate the load carrying capacities of road mode and railway mode in the model.

Recent O-D survey was not available for AADT data. Therefore, assumptions were based on the Addis Ababa University, 2011 Report. The Report states that the corridor handled more than 3,000,000 passengers and a total import and export of 9,042,900 MT for the year 2012. Based on the report, it was assumed that the road infrastructure would handle 25% additional load without system failure. Hence, the 2020 estimated traffic was projected at 3,750,000 passengers and 11,713,463 MT; these estimations are based on the average annual growth of 6% passenger and 8% freight car from year 2005-2012 (ERA) and for detail see-Appendix-I.

The traffic forecast for the railway transport was based on 16-20 pairs of passenger trains with each pair handling 280,000 passengers (up to 5,600,000 passengers) annually and freight tonnages of 20,000,000-25,000,000 annually (CREG and CREEC, 2011 report).

From the model computation there is significant amount of traffic modal shit from road mode to the rail mode; Road Mode Freight Shift of 4,081,178 tones and Road mode Passengers shift of 1,322,089 passengers. In percentage 34.84% of Road Freight Capacity=11,713,463 MT; and 35.26% of Road Passenger Capacity=3,750,000 passengers.

Cost

According to CREGC and CREEC 2011 reports, the transport cost of Ethiopia is 1.6 times that of Africa and 4.6 times that of the world. Hence the country needs an efficient transport system to help its fast growing economy. For the development of the model, the cost variables included: Construction Cost (including the topography effect), Life Cycle Cost (Maintenance cost/not including replacing cost, and operating cost), Environmental Cost (equivalent Co2/Co2e-pollution cost), and Energy Cost for both modes of transport. To fully understand the cost variable life cycle cost is considered; Life span of an infrastructure is the period of time in which the structures serves its purpose, without series structural damage or complete failure accompanied by necessary maintenance. And the cost parameter which relate to the life span of infrastructure is its Life Cycle Cost; and Life Cycle Cost Analysis is crucial to understand the economic feasibility of infrastructure investment.

In Life Cycle Cost Analysis the course of action should be taken that result in the lowest total costs over the life span of a production facility. And In order to be able to estimate life cycle costs, the factors influencing the performance of the infrastructure have to be identified as well as their relationships. The driving factor causing maintenance and failures is the degradation of the asset (Zoeteman, 2001).

And According to ECORYS Transport, 2005

Infrastructure costs consist:

- Investment Expenditures = Costs of New/Expansion Infrastructure;
- Renewal Expenditures = Cost of Replacing of Infrastructure to Prolong Its Life Time;
- Maintenance Expenditures = Cost of Repairing in Life Time;
- Operational Expenditures = Cost Not Related to Maintaining or Renewal.

And infrastructure costs can be classified in their temporal nature; Capital Costs and Running Costs. Capital costs are yearly depreciation costs concerning investments, renewals and maintenance of infrastructure assets, and yearly interest expenditures; Running costs yearly recurring (other) maintenance and operational expenditures.

With regard to maintenance and renewal expenditures, many European countries distinguish ‘regular’ and ‘non-regular’ costs. For example in The Netherlands the terms fixed and variable maintenance expenditures are applied, structural and operational maintenance in Austria, routine and periodic maintenance in Sweden and routine and special maintenance in Spain.

ECORYS Transport, 2005; propose to categorize ‘non-regular’ costs as renewal expenditures, prolonging the lifetime without adding new functionalities and ‘regular costs’ as maintenance expenditures, for maintaining the functionality of existing infrastructure within its original lifetime.

The average life time expectancy of road infrastructure differs between the distinguished countries. For the time being it is therefore advised to follow the conclusion of Euro state regarding the life time expectancy for roads, i.e. 55 years. Depreciation is advised to be linear and the interest rate 5% (ECORYS Transport, 2005).

And the design life of the Addis-Djibouti rail line is reported 30 years according to (CREG and CREEC, 2011 report) but to see design life of the component item of rail infrastructure see Appendix-F.[7]

And for the Strategic model analysis: Costs of construction, Maintenance Cost, Environmental Pollution, and Energy were considered for both rail and road transport modes.

- **Construction Cost- Including Topography**

The construction cost of Railway Infrastructure is much higher than the construction of the Trunk Roads (with ERA road hierarchy). The current unit cost of trunk roads is 776,317 USD per km (WT-consultant) and the construction cost of a new single-track non electrified railway is at least $1.5 million per km in relatively flat terrain and $5 million or so in more rugged country requiring more extensive earthworks (Bullock ,2009).

The Addis Ababa-Djibouti railway line is envisaged to be constructed in two sections: SEBETA-MIESO and MIESO-NEGAD (Djibouti port). The 318 km Sebeta-Mieso section consists of 39.34 km total bridge and 710 m tunnel with respective costs of USD 1,153,652,106 and USD 31,230,087.43 which comprise 23.48% and 0.64% of the total project construction costs. The 439.20 km Mieso-Negad (Djibouti port) section consists of 6.47 km total bridge and culverts.

This shows that the topography is hilly and mountains in the Sebeta-Mieso section, especially the Sebeta-Adama section with 25.440 km bridges length which is 22.996% of the section length, 110.627 km (CREG and CREEC, 2011 feasibility report).

Hence, the construction costs of the Addis Ababa-Dewele-Port of Djibouti Road (843 km) is estimated at USD 785,322,574, including the 20% bridge and other topographical effects; or (USD 1,314,411,887 -including Addis-Adama Expressway)**,** and the construction costs of the 757 km main line rail track, including track, bridges, culverts, terminals, and others was estimated at USD 7,638,550,201 (CREG and CREEC, 2011 feasibility report).

- **Maintenance Cost**

The cost of maintaining Paved Road Surface for Ethiopia in the past 15-years (1996/97-2011/12) for Routine Maintenance increased 12% annual average growth and was 41,220 ETB/km in 2011/12, and 10% average annual increase for Periodic Maintenance (presumed 5-years) and reached 534,421 ETB/km in 2011/12 (WT-consultant).

[7] Appendix-F: Maintenance Cost Computation Base on Baumgattner, 2001

And yearly Maintenance cost for Addis-Djibouti road is calculated as 74,052 ETB/km or 4,160 USD/km and considering additional 25% for bridge and the new Addis-Adama Expressway Yearly Maintenance cost calculated as 5,200 USD/km for year 2012, using average annual growth of 10% as that of the past trend (1996/97-2011/12) (WT-consultant), the average yearly maintenance cost of 2020 calculated as 11,147 USD/km. And cost of yearly Maintenance for the 843 km Addis-Djibouti Road computed as 20,143,684 USD.

According to Bullock 2009, Reconstructing an existing Rail line for which the right-of-way and earthworks already exist typically costs at least $350,000 per km if new materials are used and rather less, say $200,000 per km, if secondhand material. Since the model analysis consider maintenance not reconstructing the rail, maintenance cost calculated based on the Baumgartner, 2001 detail cost estimate the rail annual maintenance cost calculated as 83,337 USD/km and accounting rolling stocks and miscellaneous works the yearly maintenance cost of rail is estimated to be 100,000 USD/km. And the cost of yearly Maintenance for the 781 km Sebeta-Djibouti Rail computed as 78,100,000 USD.

- **Environment- Pollution Cost**

In Ethiopia road transport constitutes 3% of GHG emission. Emissions are projected to grow from around 5 Mt CO2e in 2010 to 40 Mt CO2e in 2030. Emissions from fuel comprise of 2.67 kg CO2e/litre from diesel and 2.42 kg CO2e/litre from and gasoline (Federal Democratic Republic of Ethiopia, 2011 CRGE report).

The average fuel economy for vehicles in Ethiopia in 2005 and 2008 were 11.5 km/l (8.7 l/100 km) with corresponding CO2 emission of 217 and 221 gm CO2/km while in 2010 the fuel economy slightly increased to 12 km/l (8.3 l/100 km) with a corresponding CO2 emission of 212 gm CO2/km for light duty vehicles of gross weight of less than 3.5 tones (Alemu, 2012). Hence the estimation of 500 gm Co2/km for passenger transport and 700 gm Co2/km for freight transport seems justified because the pay load of freight vehicles ranges from 7 tones – 30 tones (Addis Ababa University, 2011 report). And study conducted for the United Kingdom's shows most pollutions are caused by transport is associated with heavy good vehicles with the ratio 86: 14 between heavy good vehicles and vans; and Road transport accounts for 92% of the total transport Co2 emissions United Kingdom's (McKinnon).

And by taking similar value of costs: for the observation of Co2e by forest and amount of cost incurred by road mode emitting Co2e to the atmosphere, emission of CO2e from road transport equals the forest offset cost; then we can calculate the emission cost of road transport. And the Forestry offset average cost 7.8 USD-Co2e/tone (Ecosystem Marketplace, 2013).

Hence, the road transport bears additional pollution cost of USD 2,435,473.43 annually and USD 73,064,202.91 for road transport in 30 years of service. Conversely, the rail mode carries no pollution cost since it would be an electrified rail line.

- **Energy- Cost of Fossil Fuel and Electric Power**

Ethiopia's transport and industry sectors use fossil fuel for energy requirements. The Country's fuel consumption grew by 5-6%[8] annually in the past and expected to jump to 10[9] % annual growth in the future. Import of fuel and petroleum products reached an amount of 2,329,907.23 MT and 1,837,111,213.3 USD in 2012/2013.

Fuel price contribute about 23% of the transport cost and the effect of fuel price has small impact on the transport cost recent price hike of 86% increase the transport cost only by 7% and result reduction of transport demand and fuel consumptions by 2% and 3% respectively (Delsalle, 2002).

The truck shipper is faced with a limited quantity of capacity per load and, therefore, has fewer bushels over which to spread the increased variable cost across. The rail provider, however, has the opportunity to increase train capacity to limit the increased cost compared to the trucking firm. And truck providers are likely to not be able to reduce price to acquire a higher market share due to the fact that they are pricing near marginal cost (Dybing, 2002).

In general for road freight movements fuel costs are 20-30% of total transport costs, and in rail freight operations 15-25% in case of diesel and 15% in case of electric traction. The costs of energy are around 25% of total costs for car users (80% of variable costs), around 5% for bus companies, 5-10% for rail passenger transport (electric) (ECORYS Transport, 2006).

To account for the energy cost of the road and rail modes, percentage of transport price was used to illustrate their fossil fuel and electric usage costs. Average tariffs of: 1.30 Birr/ton/km and 0.32 Birr/Passenger/km (WT-consultant) were used for road transport. And tariffs of: Birr 0.50/ton-km and Birr 0.55 Birr/passenger-km were used for of the rail transport (CREG and CREEC, 2011 report). Hence, the road energy cost was estimated 196,724,795 USD/ton-km for freight transport using only 20% of transport price and 1,188,449 USD/passenger-km for passenger transport using 5% of the transport price for the forecast of year 2020. Similarly, the rail mode costs were estimated to be 58,040,035 USD/ton-km for freight using 15% of transport price and 4,150,139 USD/passenger-km for passenger using 10% of transport price; and percentages are based on the ECORYS Transport, 2006.

[8] Appendix-G-1: Ethiopian Petroleum Supply Enterprise/EPSE - Fuel and Petroleum Products Import (1998-2013)

[9] Appendix-G-2: Ethiopian Petroleum Supply Enterprise/EPSE - Petroleum Products Importation Plan From 2014 to 2025 (2006 to 2017 E .C)

Other Variables

It includes: Transport Cost, Multimodal/Intermodal, Technology, and Travel Behaviour, Urbanization, Maintenance cost, and TDM and others; with potential of changing the trend and demands of transport of both road and rail. All these variables and others are considered as dummy variables in the model development as additional parameters. The contribution of other model variables included in the form of parameters which alter the overall traffic demand; for instance 10% (**A0=0.1**) additional constant coefficient parameter to account for the other variable over rearranging potential of the travel demand and additional income parameter 5% (**A2=0.05**) to account for the influence they have on the purchasing power of individual user.

3.5.2 The analysis of Ethio-Djibouti railway line used in the analysis of the planned railway model for the computation time variable for rail mode, and to account for the environmental pollution cost and energy cost of passenger rail travel and in the qualitative aspect of other variable as in dummy variable for planning and management input. Its assets and activities are depicted below:

Rolling Stocks

The 58-Years Data[10] available from the Ethiopia Statistical Agency from 1945-2002 E.C, for the 100 and more year old rail line, it had around 69-Steam Locomotive and Loco Tractor, 12-Diesel Electric Locomotives, 70-Passenger Cars, and 729-Freight Cars in the 1940's and 1950's E.C. In the 1980's E.C, it organised its locomotives with 7-Steam Locomotive and Loco Tractor, 34-Diesel Electric Locomotive, 63-Passenger Cars, and 678-Freight Cars.

The interpretation of the 58 year CSA data of Ethio-Djibouti rail line illustrates that the rolling stock was made logical transition from steam-based locomotive with little diesel-electric locomotive during 1945-1949 E.C to more diesel-electric based locomotive during 1951-1980's. Passenger and freight cars showed declines in their numbers from the 1945-2002 E.C.

Traffic

The data obtained from the Ethiopian Central Statistical Agency/CSA illustrated the average kilometre travel by passenger is about 200 km and the average kilometre travelled by every tone of freight is around 470 km.

Passenger traffic

The numbers of railway passengers were good with more than 1.4 million in 1975 E.C. Unfortunately; it lost almost all its passengers traffic to road transport and remained with 35 thousand in 2002 E.C.

[10] Appendix-H: Franco-Ethiopia/Ethio-Djibouti Railway (1945-2002 E.C)

Freight traffic

Freight traffic faced similar fate with that of passenger traffic from a maximum of 471 thousand tonnes to 1.4 thousand tonnes during the 1968.

Revenue and Expenditure

The Ethio-Djibouti rail line was not a financial success in its long year of service, but it used to be self sufficient and at times profitable in the early days, spanning from 1945-1975, but after that its loss, Revenue minus Expenditure, became pronounced and much bigger. The Ethio-Djibouti railway line had not been a financial success from the data observed during 1945-2002 E.C. It was self sufficient to some extent, making profit during 1945-1975 E.C; but, after that it lost profitability, especially in the late 1990’s E.C and 2000’s E.C.

4. ANALYSIS OF RESULTS

4.1 Direct Demand Model

The model contains variables which assumed to have a determining role in transport system and in the model calibration and developments. This incorporated variable of: economy in respect of foreign and local trade; population; loads in terms of annual passenger and freight volumes; time in terms of travel and turnaround and border crossing; and costs disaggregated into construction, environment pollution, and energy in terms of transport tariff. Dummy variables were used to account for other variables.

Basic Assumptions Made In the Model are:

- Traffic data available for the railway is in short-term for year 2025 which is 10 and more years ahead but the rest of the data are relatively current. So to fill the gap, forecasting was made for 2020 with presumption the railway line will start operation in 2020 in full capacity;
- The load capacity for the road transport was assumed to accommodate additional 25% of the 2012 traffic volume for the future with the current total travel time since it has handled Total 89,748 AADT in 2011 and it handled 74,534 AADT in base year 2012 which 20.4 % the additional 4.6% seems justifiable ; and
- the pollution of road transport was anticipated to be 500 gm and 700 gm of CO_2 per km travel of passenger and tone respectively for heavy vehicles with payload capacity of 7-30 tones; based on the study of (Amibe, 2012 study) light duty vehicles consumes 8.3 liter/100 km with a corresponding CO2 emission of 212 gram CO_2/km.

Software

Micro-Soft Excel computer program was used for the calibration computation and development of the model. The model produced a modal spilt of 58/42 freight demand and 55/45 of passenger demand of rail/road transport for the Year 2020; which agree with the AAU 2011 report 60/40 of rail/road transport mode split. The validation made for the road freight transport for the years 2005 to 2012 and produced a forecast with good degree of precision with Pearson Correlation Coefficient, r=0.98 and Square Mean Error, r^2= 0.96.

The following figures: 4-1, 4-2, 4-3, 4-4, 4-5, 4-6, and 4-7 illustrate the full process of model developments including Specification, Calibration and Validation.[11]

[11] Appendix-I: DIRECT DEMAND MODEL DEVELOPMENT PROCEDURE

DIRECT DEMAND MODEL

1. GENERAL DESCRIPTIONS

PASSENGER'S MODEL $T_{ijm}=e^{\alpha0+A0}(P_{av})^{\alpha1}(I)^{\alpha2+A2}(C_{ij})^{\beta1}(t_{ij})^{\beta2}(L_{ij})^{\beta3}(C_{ijm}/C_{ijg})^{\Upsilon1}(t_{ijm}/t_{ijg})^{\Upsilon2}(L_{ijm}/L_{ijg})^{\Upsilon3}$

FREIGHT MDEL $T_{ijm}=e^{\alpha0+A0}(T_iT_j)^{\alpha1}(I)^{\alpha2+A2}(C_{ij})^{\beta1}(t_{ij})^{\beta2}(L_{ij})^{\beta3}(C_{ijm}/C_{ijg})^{\Upsilon1}(t_{ijm}/t_{ijg})^{\Upsilon2}(L_{ijm}/L_{ijg})^{\Upsilon3}$

ROUTE **ADDIS-DJIBOUTI**

LAND TRANSPORT MODE'S **RAIL**
ROAD

MODEL SPECIFICATION

MODEL DESCRIPTIONS

PASSENGER'S MODEL $T_{ijm}=e^{\alpha0+A0}(P_{av})^{\alpha1}(I)^{\alpha2+A2}(C_{ij})^{\beta1}(t_{ij})^{\beta2}(L_{ij})^{\beta3}(C_{ijm}/C_{ijg})^{\Upsilon1}(t_{ijm}/t_{ijg})^{\Upsilon2}(L_{ijm}/L_{ijg})^{\Upsilon3}$

FREIGHT MDEL $T_{ijm}=e^{\alpha0+A0}(T_iT_j)^{\alpha1}(I)^{\alpha2+A2}(C_{ij})^{\beta1}(t_{ij})^{\beta2}(L_{ij})^{\beta3}(C_{ijm}/C_{ijg})^{\Upsilon1}(t_{ijm}/t_{ijg})^{\Upsilon2}(L_{ijm}/L_{ijg})^{\Upsilon3}$

Variable's	Descriptions
Tijm	Traffic for respective mode-m from origin-i to destination-j
TiTj	Product of Import and Export from origin-i to destination-j
Pav	Urban Population in the route corridor
Cijm	Cost of mode-m from origin-i to destination-j
tijm	Time of mode-m from origin-i to destination-j
Lijm	Load of mode-m from origin-i to destination-j
Cijg	Total Cost of Road+Rail from origin-i to destination-j
tijg	Total Time of Road+Rail from origin-i to destination-j
Lijg	Total Load of Road+Rail from origin-i to destination-j

Parameters	Descriptions
α0	calibrating parameter
α1	respective growth of population and trade
α2	income/GDP growth
β1	Cost considering factor
β2	Time considering factor
β3	Load considering factor
ϒ1	av. (Passenger + freight) cost factor
ϒ2	av. (Passenger + freight) time factor
ϒ3	av. (Passenger + freight) load factor

LAND ROUTE DESCRIPTIONS

ROAD ROUTE-1
ADDIS – AKAKI – BISHOFTU – ADAMA – AWASH – MIESO – ASEBETEFERI – KOBO – KULUBI – DENGEGO – DIREDAWA -DEWELE.
ROAD ROUTE-2
ADDIS – AKAKI – BISHOFTU – ADAMA – AWASH – MILLE - GALAFI.
ROAD ROUTE-1 SELECTED FOR ANALYSIS
ADDIS – AKAKI – BISHOFTU – ADAMA – AWASH – MIESO – ASEBETEFERI – KOBO – KULUBI – DENGEGO – DIREDAWA - DEWELE.
RAIL ROUTE
SEBETA – DEBREZEYET – MOJO – ADAMA – METEHARA – MIESO – BIKE – DIREDAWA – ALISABIEH - NEGAD.

MODE DESCRIPTIONS

ROAD TRANSPORT CHARACTERSTICS

Road	**Trunk Road**
Design Life	-
Length	743 km Addis-Dewele/Djibouti border
Vehicles	Passenger Vehicles: 3-50 person capacity and Freight Vehicles: 3.5-30 ton
Energy Source	Fossil Fuel
Pollution	Diesel-2.67 kg CO2e/liter
	Gasoline-2.42 kg CO2e/liter

RAIL TRANSPORT CHARACTERSTICS

Track	**Standard Gauge**
Design Life	30 years
Length	757 km main line track with a total 781 km track from Addis-Negad/Djibouti Port
Train	Passenger: SS9 locomotive-170km/hr
	Freight: HXD3B locomotive-120km/hr
Energy Source	Electricity
Pollution	-

Figure 4-1: Direct Demand Model-Model Specification-General specification

2. DATA ENTRY AND ANALYSIS

1	PRIMARY VARIABLE'S	1.1 TRADE AND ECONOMY 1.2 POPULATION
2	SECONDARY VARIABLES'	2.1 LOAD 2.2 TIME 2.3 COST

MODEL SPECIFICATION

PRIMARY VARIABLE'S

I Total Foreign Sea Trade/Sea-Road Transport — 10,000 T

No	Foreign Trade	2005	2006	2007	2008	2009	2010	2011	2012	2020****
1	Import	418.77	416.17	487.62	742.91	812.13	694.49	729.38	844.82	**1683.35**
2	Export	69.44	65.92	76.52	76.23	85.61	106.21	110.40	92.26	**136.31**
3	Import+Export	488.21	482.09	564.14	819.14	897.74	800.70	839.78	937.08	**1819.66**

Source: Custom and Revenue Authority

II Population

2012-Population Estimation

No	Route	Administrative Level	Population
1	A.A	Capital City/	3,040,740
2	Akaki	Sub-city	201,216
3	Bishoftu	Town/Wereda	123,230
4	Adama	Town/Special zone	271,562
5	Awash	Town/Wereda	20,902
6	Mieso	Town/Wereda	16,450
7	Asebeteferi	Town/Wereda	41,522
8	Kobo	Town/Wereda	6,986
9	Kulubi	Town/Wereda	6,315
10	Dengego	Kebele	2,500
11	DireDawa	City/City admin.	262,884
12	Dewele	Town/Wereda	5,339

Source: CSA

III GDP and Per capital Income

In Billion ETB

No	Item		Years							
			2004/2005	2005/2006	2006/2007	2007/2008	2008/2009	2009/2010	2010/2011	2011/2012
1	**Sector**	Agriculture	130.50	144.80	158.50	170.30	181.20	195.00	212.50	222.90
		Industry	26.60	29.30	32.10	35.40	38.80	43.00	49.80	58.30
		Service	94.40	106.90	123.30	143.10	163.20	184.70	207.20	229.10
2	Total		249.20	278.50	311.30	346.70	381.70	421.80	469.40	510.30
3	Less *FISM*		1.20	1.60	1.80	2.40	2.70	2.90	3.20	2.90
4	**Real GDP**		**248.40**	**277.00**	**309.70**	**344.30**	**378.90**	**418.90**	**466.20**	**507.40**
5	**Growth in Real GDP**		**12.70**	**11.50**	**11.80**	**11.20**	**10.00**	**10.60**	**11.30**	**8.80**
6	**Real GDP per capital-'000 ETB**		**3.60**	**4.00**	**4.30**	**4.60**	**4.90**	**5.30**	**5.80**	**6.10**
7	ETB		3600	4000	4300	4600	4900	5300	5800	6100
8	USD in ETB		8.65	8.68	8.90	9.57	11.26	13.59	**16.99**	**17.80**
9	USD		416.18	460.83	483.15	480.67	435.32	389.99	341.38	342.70

Source: NBE-2012 report

PRIMARY VARIABLE'S ANALYSIS

No	Data Entry	Required Entity	Model Entry	Result-2020*	Unit
I	Foreign Trade	Import-Tj+Export-Ti	TiTj	18,585,967,720,522	T^N
II	Population Data	Population Average	Pav	473,992	**P
III	GDP and Per capital Income	Per capital	I	735	***USD

* *Uniform projection made to the year 2020 to make equivalent with the available rail data*

** *Urban population with 4.5% annual growth-Source: CSA*

*** *10% annual growth of Per capital Income-Source: NBE-2012 report*

**** *9% and 5 % annual growth for import and export respectively-Source: Custom and Revenue Authority*

N *AAU 2011 report: Addiss-Galafi-90% Foreign Trade*

Figure 4-2: Direct Demand Model-Model Specification-Data Entry

SECONDARY VARIABLE'S

I Load Capacity — **AADT-2012**

No	Route	Length-km	Cars	Land Rover	Small Bus	Large Bus	Small Truck	Medium Truck	Heavy Truck	Truck-Trailer
1	A.A-Akaki	24	2236	3099	3088	1881	2594	3236	3376	3624
2	Akaki-Bishoftu	32	1897	2767	2689	2057	2626	3085	3233	3559
3	Bishoftu-Adama	51	1656	2173	2722	1032	1932	2385	2503	3093
4	Adama-Awash	125	170	425	478	199	487	524	626	1620
5	Awash-Mieso	74	31	148	186	90	120	145	64	140
6	Mieso-Asebeteferi	24	31	154	221	86	83	158	75	78
7	Asebeteferi-Kobo	111	24	118	182	84	127	115	92	88
8	Kobo-Kulubi	27	15	115	272	65	118	146	71	85
9	Kulubi-Dengego	31	38	173	603	88	373	320	165	140
10	Dengego-DireDawa	20	38	181	655	70	247	192	165	140
11	DireDawa-Dewele	224	5	43	19	17	50	46	52	115
	Total	**743**	**6,141**	**9,396**	**11,115**	**5,669**	**8,757**	**10,352**	**10,422**	**12,682**
	Load		**18,423**	**46,980**	**266,760**	**283,450**	**30,650**	**59,006**	**125,064**	**380,460**
	Passenger#	**615,613**		**981,194**	**6 % annual growth**					
	Freight##	**595,180**		**1,101,636**	**8 % annual growth**					

Source: ERA

No	Load Factor	Cars	Land Rover	Small Bus	Large Bus	Small Truck	Medium Truck	Heavy Truck	Truck-Trailer
1	Freight-Tones/T	-	-	-	-	3.5	5.7	12	30
2	Passenger-P	3	5	24	50	-	-	-	-

Source: AAU report, 2011

Annual Passenger Volume-2010	3,000,000	form AAU 2011 Study O-D survey
Assumptions Annual Passenger Volume-2020	5,372,543	6% annual growth similar AADT-Source:ERA

Annual-Flow Density & Train Pairs

No	Section	passener-10,000 short term	passener-10,000 long term	passenger train pairs short term	passenger train pairs long term
1	Sebeta-Debrezeyet				
2	Debrezeyet-Mojo	256	447	9	16
3	Mojo-Adama				
4	Adama-Metehara	140	223	5	8
5	Metehara-Mieso				

Source: CREGC and CREEC report, 2011

Annual-Traffic Volume -10,000 tone

No	Section	short terms/2025 up	short terms/2025 down	long terms/2035 up	long terms/2035 down
1	Sebeta-Debrezeyet	583	73	1380	253
2	Debrezeyet-Mojo	614	82	1418	262
3	Mojo-Adama	686	92	1570	278
4	Adama-Metehara	780	108	1693	296
5	Metehara-Mieso	806	111	1732	301

Source: CREGC and CREEC report, 2011

Up=loaded direction Djibouti-AddisAbaba

Down=Addis Ababa-Djibouti

Rail Future Capacity

Passenger	**20**	train pairs
Freight	**20,000,000**	tones

CREGC and CREEC

II Time

No	Item	Value	Unit
1	**Travel and Turnaround Time of Heavy Goods of Road Mode**		
	Addis – Mille – Djibouti	12	days
2	**Travel Time of Inter City Bus Service of Road Mode**		
	Addis Ababa - Mekele - Adigrat/871 km	40	hrs
	Addis Ababa - Jima - Bedele - Metu/600km	40	hrs
3	**Time to Cross Border**		
	Road - Mille - Djibouti	13	hrs
	Rail - Eth - Djibouti	2	hrs

Interpreting Similar Travel Pattern for the Addis-Djibouti 743 km Inter City Bus Service: 40 hrs

Source: WT-consultant report,2011

\# *6 % annual passenger growth up to the year 2020 based on the previous ERA traffic data*

\## *8 % annual freight growth up to the year 2020 based on the previous ERA traffic data*

Figure 4-3 Direct Demand Model-Model Specification-Data Entry

SECONDARY VARIABLE'S

III	**Cost**				
1	**Construction cost/Cc**				
	Trunk Roads-843 km	WT-consultant report,2012		776,317	USD/km
	Assumptions bridge and culvert in crease the cost by 20%			931,581	USD/km
	Including **612 million USD/80 km Addis-Adama Express way**			1,314,411,887	USD
	Standard Gauge Rail	CREGC and CREEC report,2011			
	Addis-Mieso/318 km	including: bridge,Tunnel,rollingstock		15,448,194	USD/km
	Mieso-Negad/439.20 km	including: bridge		5,882,801	USD/km
	Addis-Mieso/318 km	excluding: bridge,Tunnel,rollingstock		10,583,558	USD/km
	Mieso-Negad/439.20 km	excluding: bridge		5,704,199	USD/km
	Addis-Negad	including: bridge,Tunnel,rollingstock		9,775,505	USD/km
		including: bridge		7,689,888	USD/km
				7,638,550,201	USD
2	**Maintenance Cost/Mc**	Road=Routine+5-year Periodic		20,143,684	USD
		Rail=		78,100,000	USD
	Road/WT consultant-USD/km=	11,147	Rail/Baumgartner-USD/km		100,000
3	**Energy cost/Ec**				
	Road Transport Tariff		WT-consultant report,2011		
	Trunk Freight-birr/tone/km	1.33	Average		196,724,795
	Export route Freight	1.26	1.30		USD
	Trunk Passenger-birr/km	0.3	Average		1,188,449
	Export route Passenger	0.33	0.32		USD
	Rail Transport Tariff		CREGC and CREEC report,2011		
	Freight-birr/tone/km	0.50		58,040,035	USD
	Passenger-birr/passenger/km	0.55		4,150,139	USD
4	**Pollution cost/Pc**				
	Road Transport Pollution				
	Passenger	Cars+Land Rovers+Buses-considering the 2020 passenger volume			
	Total Passenger Vehicle	176,974			
	Travel Addis-Adama+Djibouti	225 km			
	Total travel additional 25-km	250 **km**	---------------------	Ethio-Djibouti Rail Traffic	
	Assumption of 500gm Co2/km	22,122 **Co2-ton-km**			5,176,495.76
	Freight	Trucke+Truck+Trailers-considering the 2020 import and export			
	Total Freight Vehicle	697,266			
	Local travel Addis - Djibouti	743 km			
	Total Freight travel km/80%	594 **km**			
	Assumption of 700kg Co2/km	290,118 **Co2-ton-km**			
	Total-Co2-in the corridor	312,240 **Co2-ton-km**			67,887,707.15
	USD-Co2e/tone	7.8	State of the Forest Carbon Markets 2013		
	Similar Cost=	73,064,202.91 USD			
	Rail Transport Pollution	Since the planned Rail is electrified the pollution cost is almost zero			

SECONDARY VARIABLE'S ANALYSIS

No	Data Entry	Required Entity	Model Entry	Result-2020+
I	**Load**			
	Road-Freight/tone	**Import+Export+Local Tonnage**	**Lij**	**11,713,463**
	Road-Passenger-P	**Local + International Passenger**	**Lij**	**3,750,000**
	Rail-Freight/tone	**Import+Export+Local Tonnage**	**Lij**	**20,000,000**
	Rail-Passenger	**Local + International Passenger**	**Lij**	**5,600,000**
II	**Time**			
	Road-Freight/days	**Total Travel Time**	**tij**	**12**
	Road-Passenger/days	**Total Travel Time**	**tij**	**3**
	Rail-Freight/days	**Total Travel Time**	**tij++**	**4**
	Rail-Passenger/days	**Total Travel Time**	**tij+++**	**1**
III	**Cost**			
	Road-Freight/USD	**CC+MC+Ec+Pc**	**Cij**	**1,599,168,073**
	Road-Passenger/USD	**CC+MC+Ec+Pc**	**Cij**	**1,340,920,516**
	Rail-Freight/USD	**CC+MC+Ec+Pc**	**Cij**	**7,774,690,236**
	Rail-Passenger/USD	**CC+MC+Ec+Pc**	**Cij**	**7,720,800,340**

+ Data's Projected to year 2020 to compare with the available 2020 rail data
++ 4-days travel time of freight account for travel + cross border time and turn around time
+++ 1-day passenger travel time since most of travel are local travel

Figure 4-4: Direct Demand Model-Model Specification-Data Entry

MODEL CALIBRATION
MODEL COMPUTATION
DIRECT DEMAND MODEL

FREIGHT

$$T_{ijm}=e^{\alpha0+A0}(T_iT_j)^{\alpha1}(I)^{\alpha2+A2}(C_{ijm})^{\beta1}(t_{ijm})^{\beta2}(L_{ijm})^{\beta3}(C_{ijm}/C_{ijg})^{\Upsilon1}(t_{ijm}/t_{ijg})^{\Upsilon2}(L_{ijm}/L_{ijg})^{\Upsilon3}$$ T-km

PASSENGER

$$T_{ijm}=e^{\alpha0+A0}(P_{av})^{\alpha1}(I)^{\alpha2+A2}(C_{ijm})^{\beta1}(t_{ijm})^{\beta2}(L_{ijm})^{\beta3}(C_{ijm}/C_{ijg})^{\Upsilon1}(t_{ijm}/t_{ijg})^{\Upsilon2}(L_{ijm}/L_{ijg})^{\Upsilon3}$$ P-km

No	Parameters	Freight	Passenger	Remark
1	**α0**	1.21	1.11	calibrating variable + 0.1 dummy
2	**α1**	0.05	0.045	4.5 % population and 5 % trade growth
3	**α2**	0.15	0.15	10 % GDP growth + 0.05 dummy
4	**β1**	0.13	0.11	reciprocal Rail: Road Cost ratio
5	**β2**	0.33	0.30	Rail: Road Time ratio
6	**β3**	0.59	0.67	reciprocal Rail: Road Load ratio
7	**ϒ1**	0.12		av. (Passenger + freight) cost effect
8	**ϒ2**	0.31		av. (Passenger + freight) time effect
9	**ϒ3**	0.63		av. (Passenger + freight) load effect

FORECAST MADE FOR YEAR 2020

FREIGHT

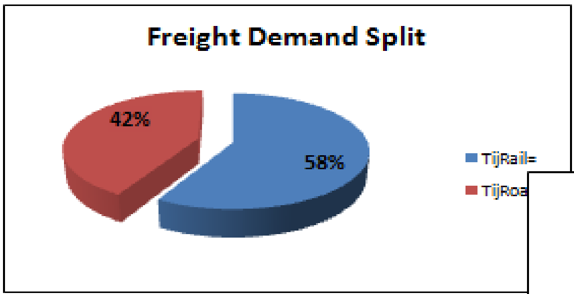
Rail-T_{ijRail}=	3,147,477	**T-km**		**Hence**	
Road-T_{ijRoad}=	2,273,921	**T-km**		Rail Generated Freight/ tones =	6,483,149
Rial+Road=	5,421,398	T		Road Mode Freight Shift/ tones =	4,081,178
Foreign Trade=	**18,196,612**	**T**		Total Rail Freight Traffic =	10,564,327
Ratio=	**3.356443**				
Natural logarithm=	**α0+A0=**	**1.21**			
T_{ijRail}=	**10,564,327**	**T-km**	**58 Percent**		
T_{ijRoad}=	**7,632,285**	**T-km**	**42 Percent**		

PASSENGER

Rail-T_{ijRail}=	967,242	**P-km**		**Hence**	
Road-T_{ijRoad}=	797,512	**P-km**		Rail Generated Passengers =	1,622,543
Rial+Road=	1,764,754	P		Road mode Passengers shift =	1,322,089
Total-Passenger:	**5,372,543**	**P**		Total Rail Passenger Traffic =	2,944,632
Ratio=	**3.044**				
Natural logarithm=	**α0+A0=**	**1.11**			
T_{ijRail}=	**2,944,632**	**P-km**	**55 Percent**		
T_{ijRoad}=	**2,427,911**	**P-km**	**45 Percent**		

CONCLUSION'S

Results 57/43 and 55/45 FREIGHT and PASSENGER comply with the AAU 2011 study of 60/40 Modal Split. OK!!!



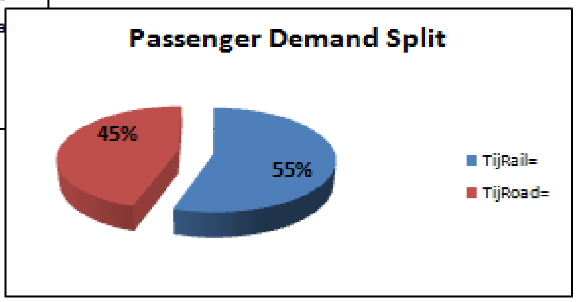


Figure 4-5: Direct Demand Model-Model Calibration-Computation

Freight Traffic Projection-2021-2050

No.	Year	Total Freight Traffic	Rail Mode	Road Mode
1	**2021**	19,779,783	58%	42%
2	**2022**	21,502,714	58%	42%
3	**2023**	23,377,845	58%	42%
4	**2024**	25,418,733	58%	42%
5	**2025**	27,640,146	58%	42%
6	**2026**	30,058,171	58%	42%
7	**2027**	32,690,340	61%	39%
8	**2028**	35,555,750	61%	39%
9	**2029**	35,926,419	61%	39%
10	**2030**	35,979,409	61%	39%

Passenger Traffic Projection-2021-2050

No.	Year	Total Passenger Traffic	Rail Mode	Road Mode
1	**2021**	5,694,896	55%	45%
2	**2022**	6,036,589	55%	45%
3	**2023**	6,398,785	55%	45%
4	**2024**	6,782,712	55%	45%
5	**2025**	7,189,675	55%	45%
6	**2026**	7,621,055	55%	45%
7	**2027**	8,078,318	55%	45%
8	**2028**	8,563,017	55%	45%
9	**2029**	9,076,799	55%	45%
10	**2030**	9,621,406	55%	45%

NOTE ON THE PROJECTION OF TRAFFIC 2021-2050

1 Import & Export 9% & 5% respective annual growth from the past data of Ethiopian Custom and Revenue Data-2005-2012 for the years 2021-2026 with installed road and rail capacity

Rail		
Freight	20,000,000	tones
Passenger	5,600,000	passengers
Road		
Freight	11,713,463	tones
Passenger	3,750,000	passengers
Total capacity		
Freight	31,713,463	tones
Passenger	9,350,000	passengers

2 But beyond years 2006 the Import & Export the installed capacity of land transport fail to accommodate the growing Import & Export load so adjustment need to improve the road and rail capacity and assuming the road transport fail to enhance it load factor the rail mode assumed to accommodate more load and its included in the CREGC and CREEC report,2011

Rail		
Freight	25,000,000	tones
Passenger	5,600,000	passengers
Road		
Freight	11,713,463	tones
Passenger	3,750,000	passengers
Total capacity		
Freight	36,713,463	tones
Passenger	9,350,000	passengers

3

Year		Value		
2027	Import Value - 9% annual growth=	30,772,332	Total	
	Export Value-5% annual growth=	1,918,008		32,690,340
2028	Import Value - 9% annual growth=	33,541,842	Total	
	Export Value-5% annual growth=	2,013,908		35,555,750
2029	Import Value - 8.5% annual growth=	33,811,815	Total	
	Export Value-5% annual growth=	2,114,603		35,926,419
2030	Import Value - 8% annual growth=	33,759,075	Total	
	Export Value-5% annual growth=	2,220,334		35,979,409

4 But beyond years 2030 road transport infrastructure need improvement in its capacity to accommodate the very optimistic economic growth of greater than 10% GDP (National Bank of Ethiopia).
The 2012 freight= 9,370,770 tones and the 2030 freight calculated=35,979,409 which is almost 4times the 2012 volume
From this the year 2030 forecast will work for the coming years of 2031-2050 with the assumption road mode of transport will improve and the freight growing is for the years of 2031-2050 will remain with in the 2030 range

Figure 4-6: Direct Demand Model-Model Projection-Forecast

MODEL VALIDATION
DIRECT DEMAND MODEL

Freight Transport-Model Validation

No	Year	Foreign Trade-T	Local Trade-T/10%	Total Freight	DIRECT DEMAND°	Test
1	2005	4,393,910	439,391	4,833,301	8,339,464	***Pearson r***
2	2006	4,338,783	433,878	4,772,661	8,114,305	***0.98***
3	2007	5,077,242	507,724	5,584,966	9,236,799	***r^2***
4	2008	7,372,274	737,227	8,109,501	12,377,846	***0.96***
5	2009	8,079,660	807,966	8,887,626	13,090,782	
6	2010	7,206,279	720,628	7,926,907	10,828,558	
7	2011	7,558,027	755,803	8,313,829	12,611,271	
8	2012	8,433,693	843,369	9,277,063	13,679,562	

° *The Model consider only Road mode of transport*

Figure 4-7: Direct Demand Model-Model Validation-Road Mode

4.2 Ethio-Djibouti

The analysis of Ethio-Djibouti rail line; and its analysis used in the model for the computation of rail passenger energy cost and pollution cost, and travel time (see Appendix-H and Appendix-I); input for planned rail planning and management; and show the profitability of rail transport specially that of passenger rail transport.

As can be seen from the graph below, the operations of the Ethio-Djibouti rail line was efficient from year 1945 up to late 1980's; However, It suffered huge losses of traffic and finance and continued down wards until its final complete stoppage of service in 2002. Traffic loss of passengers went down sharply from 1,430,000 in 1975 to 35,000 passenger in the year in 2002 and freight from 471,000 tons 1968 to 1400 tons in 2002 which were an annual average loss of about 9% and 5% respectively.

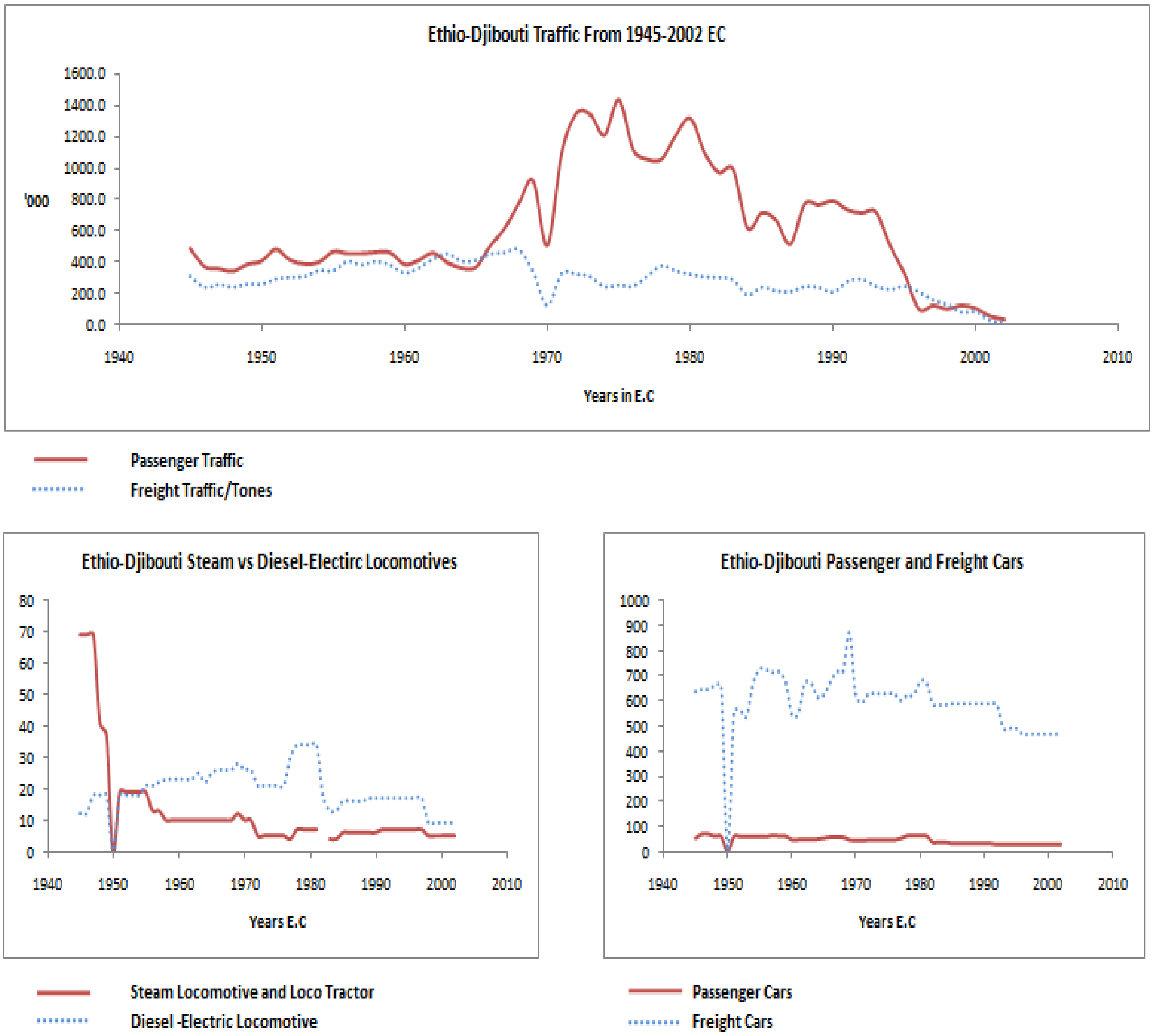


Figure 4-8: Ethio-Djibouti Traffic, Locomotives, and Train Cars

5. CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

The research examined road and rail transport between Addis Ababa and Djibouti. In this research the Umamil and Sugie direct model used as an initial base for the adoption of model in this research paper, Umamil and Sugie developed their model for inter-city travel. And in this paper the model is adopted for inter-country travel with inclusion diverse variable and different parameter for passenger model and new model development for freight model.

In the process a model was developed using the following as inputs: economy, population, travel distance and time, load capacity, environment, topography, energy, and other variables (price, income, logistics, travel culture/behaviour, urbanization, multimodal/intermodal, technology, ICT, TDM, and season etc). Consequently following were outputs of the analyses: Direct Demand Model with a modal spilt of 58/42 freight demand and 55/45 of passenger demand of rail/road transport for the year 2020, which agree with the AAU 2011 report 60/40 of rail/road transport mode split. And the model forecasted road freight transport for the years 2005 to 2012 with good degree of precision proved with Pearson Correlation Coefficient, r=0.98 and Square Mean Error, r^2= 0.96.

The research studied the Ethio-Djibouti railway line: traffic, rolling stocks, and its revenue and expenditure and the study shows that the railway line halt service due to: poor planning, poor technology and loss of profit. The history of the Ethio-Djibouti rail line is a tangible proof for: proper service provision, rational planning, and effective management for the planned new railway infrastructure to economically sustain for years to come.

From the Research the Planned Railway Line has a great role in the improvement of the transport system in the country, and provides a solution for the pressing problem of transport shortage and congestion (rail has larger load capacity, safe and fast/frequent); decrease the pollution of road transport; and save the amount of foreign currency the country allocate for the import of fossil fuel for road transport. And rail can be the required tool for efficient transport system integration for better foreign and local traffic flow in the country through multimodal and intermodal transport system. Though Rail system seems expensive relative to road transport, and lack policy and structures, with well planned management system the benefit can out weight the risk.

5.2 Recommendations

- The research studied the investment and strategic plan view of the land transport, rail and road mode; in addition the model can produce market model to demonstrate the profitability of the two land transport modes.
- The Direct Demand Model developed in the model can be replicated to other modes of transport: Air transport, Pipe transport, and Water/Marine transport; both in strategic planning as well as in market analysis.
- From the investigation of the old Ethio-Djibouti railway an emphasis and citation are needed, for the planned railway line, in the areas of: service provision and planning, advancement of technology in infrastructure, and manpower capacity building; for a better service provision and profitability.

6. PROPOSED FUTURE RESEARCH AREAS

- Assumptions made in the variable analysis: load capacity, co2e emission, and other variables (transport price, logistics, travel culture/behaviour, urbanization, multimodal/intermodal, technology, ICT, TDM, and season etc) needs further investigation to better understand their explicit influence in the transport demand analysis of the variables in question.
- Local traffic from other routes joining the corridor in study and dry ports (Mojo and Semera) need further study to know the exact traffic flow along the corridor.
- The study area is the major import and export corridor, Addis-Djibouti. This can be extended to include other inter-regional and inter-urban corridors of the country to produce travel demand and modal split of the transport modes.
- The Direct Demand Model produced in the research, used the two land modes of land transport rail and road. This can be replicated to other modes of transport: Air transport, Pipe transport, and Water/Marine transport and other related transport modes. This can be used in both in strategic planning as well as in market analysis and thus further study can be made in these areas to benefit the country transport and enhance the national transport network system. Forecast.
- Further study is needed in the area of rail policy and management frame work: for instance the Ethiopian Road Authority builds the road infrastructure and responsible for its maintenance in Federal level, but the Minister of Transport with its subsidiary branches and authority's controls and facilitates the vehicles and traffic operation. And for effective rail system a defined policy and frame works are need in the responsibility of rail transport system.

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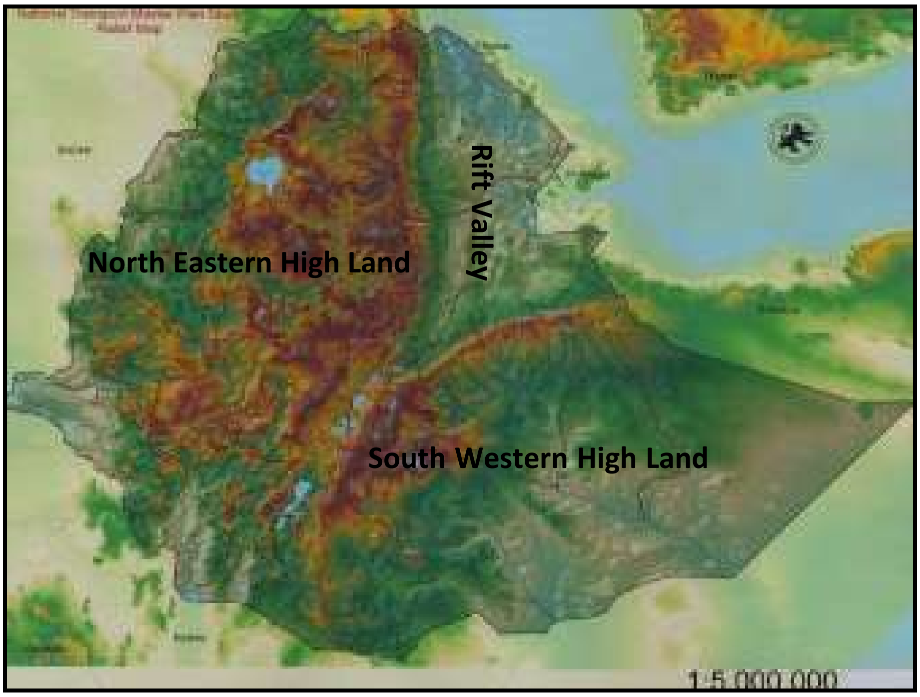
APPENDICES

Appendix-A: Location Map of Ethiopia

Appendix-B: Topographical Map of Ethiopia



Appendix-C: Air Pollutant Environmental Damage

Pollutant*	Source	Impact on: Humans	Vegetation	Global Climate	Materials
Carbon monoxide (CO)	Incomplete combustion	Inadequate oxygen supply; heart, circulatory, nervous system		Indirect through ozone formation	
Carbon Dioxide (CO_2)	Combustion			Major greenhouse gas	
Hydrocarbons (HC - includes methane, isopentane, pentane, toluene, etc.)	Incomplete combustion, carburetion	Some are carcinogenic Ozone precursor	Build-up in soil, feed, food crops	Methane has high greenhouse potential, leads to ozone formation	
Nitrogen oxides (NOx)	Oxidation of N_2 and N-compounds in fuels	Respiratory irritation and other problems.	Acidification of soil and water, overfertilizing	NO_2 has high greenhouse potential, leads to ozone formation	Weathering, erosion
Particulates	Incomplete combustion, road dust	Respiratory damage, various toxic content	Reduced assimilation		Dirt
Soot (diesel)	Incomplete combustion	Carcinogenic			Dirt
Ozone (formed by interaction of other pollutants)	Photochemical oxidation with NOx and HC	Respiratory irritation, ageing of lungs	Risk of leaf and root damage, lower crop yields.	High greenhouse potential	Decomposition of polymers

Source: Based on Button p. 30, Table 3.6; Kürer pp. 486-490

* *Sulphur oxides from diesel engines (trucks and vessels) are also of some concern.*

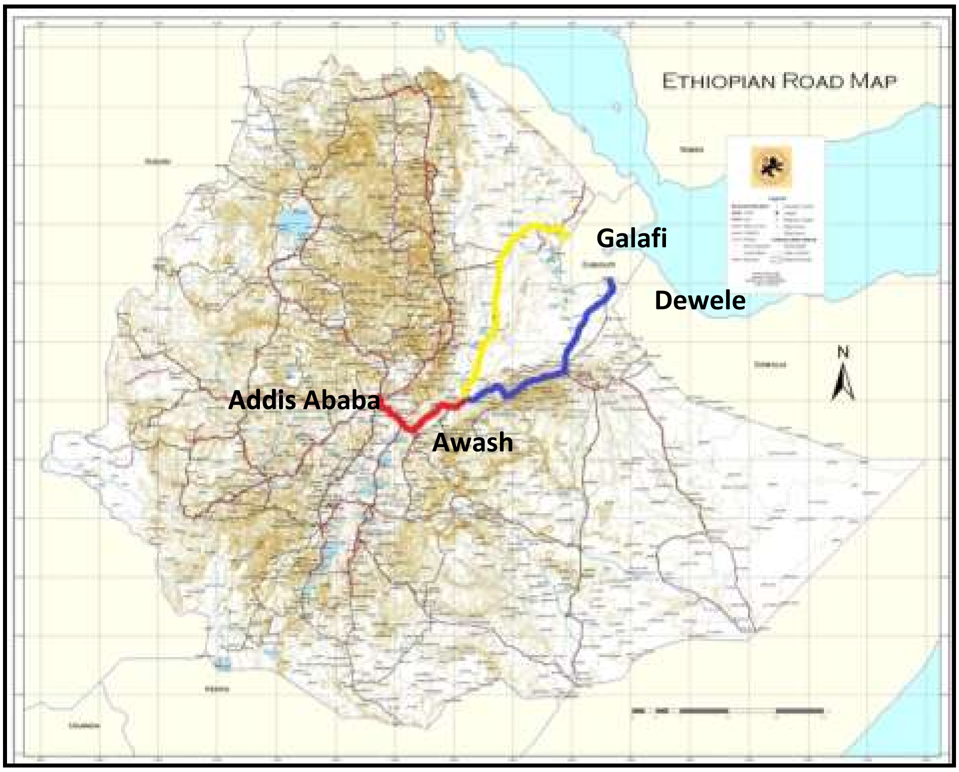
Appendix-D: Transport Modes Air Pollution Factor

Pollutant	in grams/tonne-km Truck	Rail	Marine
CO	0.25-2.40	0.02-0.15	0.018-0.20
CO2	127-451	41-102	30-40
HC	0.30-1.57	0.01-0.07	0.04-0.08
NOx	1.85-5.65	0.20-1.01	0.26-0.58
SO2	0.10-0.43	0.07-0.18	0.02-0.05
Particulates	0.04-0.990	0.01-0.08	0.02-0.04
VOC	1.10	0.08	0.04-0.11

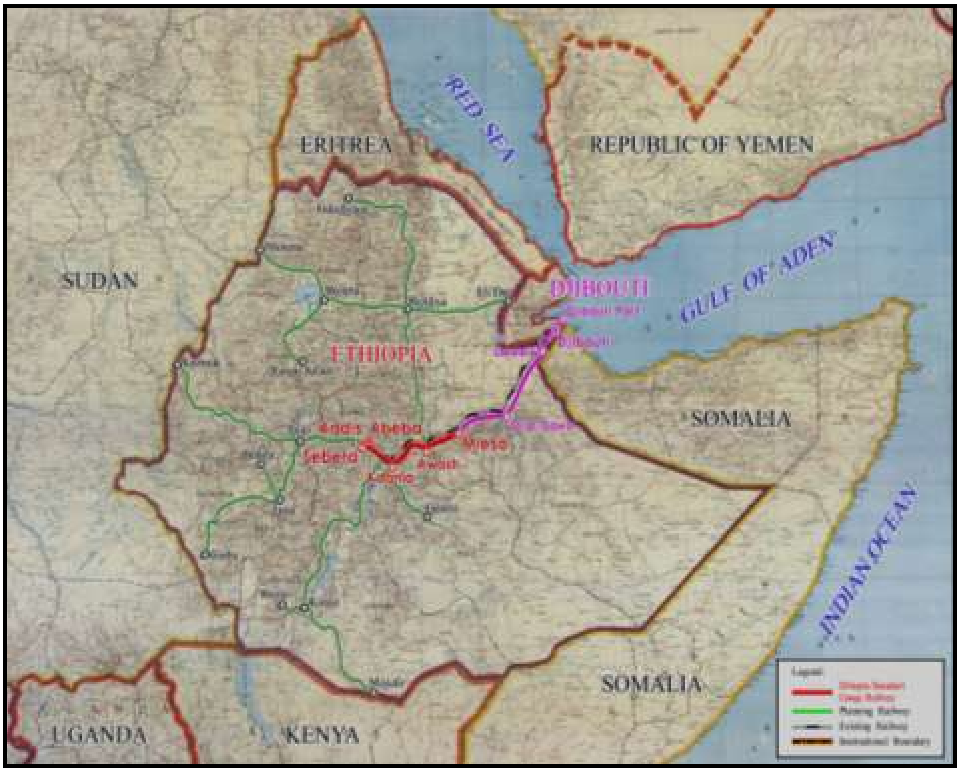
Source: Based on OECD 1997 THE ENVIRONMENTAL EFFECTS OF FREIGHT,p. 29, Table 18

Appendix-E: Addis-Djibouti Land Road Routes

Appendix-E-1: Addis-Djibouti Road Routes



Appendix-E-2: Addis-Djibouti Rail Route



Appendix-F: Rail Maintenance Cost Computation Based on Baumgattner, 2001

	Maintenance cost Computed base on Baumgattner, 2001				**In USD**
	Investment Cost	**7,638,550,201**	**USD**		
I	**Static Unit**	*92.61*	*314.995 km*	*92.61*	*463.402 km*
		Addis-Mieso	*4,912,448,400*	**Mieso-Negad**	*2,726,101,801*
No	Item	**Investment**	**Maintenance Cost**	**Investment**	**Maintenance**
0	Demolition and Land Accussation	26,527,221	-	14,720,950	-
1	Subgrade	727,533,608	3,637,668	979,815,509	4,899,078
2	Bridge and Culverts	1,153,442,884	11,534,429	80,910,701	809,107
3	Tunnels and Open Cut Tunnels	30,457,180	152,286	-	-
4	Track	545,773,017	9,539,850	302,869,910	13,902,060
5	Comminucation & Signal	230,393,830	4,607,877	127,854,174	2,557,083
6	Electricity and Electric Traction	350,748,816	7,014,976	194,643,669	3,892,873
7	Buildings	149,338,431	1,493,384	82,873,495	828,735
8	Water Supply & Drainage	-	-	-	-
9	Over Pass Highway Bridges	-	-	-	-
10	Temporary Works	384,153,465	-	213,181,161	-
11	Miscellaneous works	951,050,010	-	527,773,309	-
			37,980,470		26,888,936
		64,869,406	**USD**	**83,337**	**USD/km**
II	**Dynamic Units 7.39% of Project Cost**				
1	Passenger Locomotive				
2	Freight Locomotive				
3	Passenger Rolling Stock				
4	Freight Rolling stock				
5	Locomtive Signals& Other Equpments				
	The ERC is expected to Budget 100,000 USD/km rail line &rolling maintenance			*78,100,000*	*USD/year*
				1,952,500,000	*ETB*

	Design Period and Maintenance Costs			
	Item	**Design Life/years**	**Maintenance Cost**	
I	**Static Unit**			
	Subgrade	-	0.50%	Source: Baumgartner, 2001
	Bridge and Culverts	50-100	1%	Source: Baumgartner, 2001
	Tunnels	50-100	0.50%	Source: Baumgartner, 2001
	Track	10-25	30,000 EUR/km	Source: Baumgartner, 2001
	Comminucation & Signal	30		Source: Baumgartner, 2001
	Electricity and Electric Traction	40-60	2%	Source: Baumgartner, 2001
	Buildings	50	1%	Source: Baumgartner, 2001
	Water Supply & Drainage	-	2%	Source: Baumgartner, 2001
	Over Pass Highway Bridges	50	-	Source: Baumgartner, 2001
	Temporary Works	-	-	Source: Baumgartner, 2001
II	**Dynamic Units**			Source: Baumgartner, 2001
	Passenger Locomotive			Source: Baumgartner, 2001
	Freight Locomotive	20	-	
	Passenger Cars		-	Source: Baumgartner, 2001
	Freight Cars	25		
	Locomtive Signals& Other Equpments			

Appendix-G: Ethiopian Petroleum Supply Enterprise/EPSE

Appendix-G-1: EPSE - Fuel and Petroleum Products Import (1998-2013)

No	Year	LPG		**MGR**		Jet/Kerosene		**Gasoil**		LFO		HFO		Grand Total		Increment in %	
		qt. MT	C&F USD	**qt. MT**	**C&F USD**	qt. MT	C&F USD	**qt. MT**	**C&F USD**	qt. MT	C&F USD	qt. MT	C&F USD	qt. MT	C&F USD	qt. MT	C&F USD
1	**1997/98**	4400.810	1,971,161.44	**122,995.23**	**22,540,361.86**	252,302.07	40,617,202.04	**557,640.08**	**82,348,459.40**	107,575.68	12,117,997.20	0	0	1,040,513.06	157,624,020.5		
2	**1998/99**	1,303.63	1,076,693.82	**135,469.49**	**19,707,422.42**	238,835.61	32,900,282.17	**542,936.36**	**62,333,035.10**	96,025.43	9,201,853.12	0	0	1,013,266.89	124,142,592.8	(2.62)	(21.24)
3	**1999/2000**	1,282.62	620,003.13	**142,526.10**	**38,178,896.72**	224,176.82	51,109,330.12	**548,786.85**	**107,213,620.2**	61,566.48	9,818,216.78	54,953.93	9,145,792.13	1,032,010.19	215,465,856.0	1.85	73.56
4	**2000/2001**	0	0	**129,964.40**	**39,361,905.00**	225,431.24	59,840,896.27	**610,834.62**	**148,077,003.2**	49,149.21	8,132,014.36	61,972.70	9,832,447.33	1,077,352.17	265,244,266.2	4.39	23.10
5	**2001/2002**	0	0	**133,111.34**	**27,435,401.22**	259,786.27	56,175,287.19	**623,197.01**	**121,014,270.3**	40,688.39	6,117,277.56	80,893.79	12,131,931.99	1,137,676.80	222,874,168.3	5.60	(15.97)
6	**2002/2003**	0	0	**148,555.24**	**38,708,836.08**	259,630.20	64,990,080.43	**679,281.45**	**156,621,192.9**	41,864.88	7,935,831.07	93,803.74	16,795,880.07	1,223,135.50	285,051,820.6	7.51	27.90
7	**2003/2004**	0	0	**130,415.5**	**40,072,742.6**	294,698.8	88,046,666.9	**688,527.2**	**186,232,574.3**	40,769.8	7,920,008.5	90,078.2	16,552,861.3	1,244,489.50	338,824,853.5	1.75	18.86
8	**2004/2005**	0	0	**146,094.0**	**58,719,743.8**	334,637.8	154,533,198.8	**773,256.1**	**315,556,720.4**	43,184.7	9,213,260.9	110,048.2	23,603,974.6	1,407,220.82	561,626,898.4	13.08	65.76
9	**2005/2006**	0	0	**137,192.6**	**78,146,970.8**	370,401.1	217,222,639.5	**811,689.2**	**403,308,004.9**	41,520.9	13,996,405.8	117,197.8	35,273,179.0	1,478,001.57	747,947,200.0	5.03	33.18
10	**2006/2007**	0	0	**143,743.0**	**84,245,805.1**	402,311.3	246,366,769.1	**905,477.8**	**519,146,278.8**	42,254.78	14,291,536.3	116,428.9	38,139,482.2	1,610,215.70	902,189,871.6	8.95	20.62
11	**2007/2008**	0	0	**139,093.0**	**116,129,644.8**	482,173.0	449,776,779.5	**1,073,147.7**	**938,033,763.4**	49,692.1	25,450,125.6	138,058.6	70,654,415.2	1,882,164.44	1,600,044,728.5	16.89	77.35
12	**2008/2009**	0	0	**150,098.79**	**85,926,963.03**	506,497.35	357,984,568.6	**1,203,566.76**	**750,960,862.3**	36,420.56	17,939,958.33	116,505.89	47,844,701.88	2,013,089.35	1,260,657,054.2	6.96	(21.21)
13	**2009/2010**	0	0	**155,805.82**	**106,316,444.7**	529,856.59	371,611,037.2	**1,237,921.88**	**794,090,551.7**	10,713.91	5,732,120.80	100,967.25	51,626,457.73	2,035,265.45	1,329,376,612.0	1.10	5.45
14	**2010/2011**	0	0	**143,881.53**	**115,579,358.4**	549,223.73	450,803,059.2	**1,183,266.23**	**977,966,819.5**	34,353.10	21,057,874.86	97,190.99	58,981,675.23	2,007,915.58	1,624,388,787.3	(1.34)	22.19
15	**2011/2012**	0	0	**146,670.11**	**145,723,041.8**	535,304.32	552,702,487.7	**1,206,215.71**	**1,162,019,125**	36,492.03	27,973,008.14	107,963.86	78,957,245.50	2,032,646.03	1,967,374,908.5	1.23	21.11
16	**2012/2013**	0	0	**195,661.36**	**171,920,762.1**	619,531.93	530,498,174.0	**1,351,427.87**	**1,042,712,935**	38,022.68	20,886,023.26	125,263.39	71,093,319.29	2,329,907.23	1,837,111,213.3	14.62	(6.62)

Appendix-G-2: EPSE - Petroleum Products Importation Plan from 2014 to 2025

No	Year	Petroleum Products					
		MGR	ADO	Jet/Kero	LFO	HFO	Total in M.Tons
1	2013	195,661	1,351,427.87	619,531.93	38,022.68	125,263.39	**2,329,907.23**
2	2014	215,227	1,486,570.65	681,485.12	41,824.95	137,789.73	2,562,897.95
3	2015	236,750	1,635,227.72	749,633.63	46,007.44	151,568.71	2,819,187.75
4	2016	260,425	1,798,750.49	824,597.00	50,608.19	166,725.58	3,101,106.52
5	2017	286,468	1,978,625.54	907,056.70	55,669.01	183,398.14	3,411,217.17
6	2018	315,115	2,176,488.09	997,762.37	61,235.91	201,737.95	**3,752,338.89**
7	2019	346,626	2,394,136.90	1,097,538.60	67,359.50	221,911.74	4,127,572.78
8	2020	381,289	2,633,550.59	1,207,292.46	74,095.45	244,102.92	4,540,330.06
9	2021	419,417	2,896,905.65	1,328,021.71	81,504.99	268,513.21	4,994,363.06
10	2022	461,359	3,186,596.22	1,460,823.88	89,655.49	295,364.53	5,493,799.37
11	2023	507,495	3,505,255.84	1,606,906.27	98,621.04	324,900.98	**6,043,179.31**
12	2024	558,245	3,855,781.42	1,767,596.90	108,483.14	357,391.08	6,647,497.24
13	2025	614,069	4,241,359.57	1,944,356.59	119,331.46	393,130.19	7,312,246.96

Appendix-H: Franco-Ethiopia/Ethio-Djibouti Railway (1945-2002 E.C)

No	Year E.C	Steam Locomotive and Loco tractor	Diesel-Electric Locomotive	Passenger Car	Freight Car	Auto rails	Others	Passenger - '000	Av. Km per passenger	Freight-'000 tones Import	Export	Internal	Total	Av. Km per tone	Revenue - Expenditure
1	1945	**69**	12	53	639	3	-	485.0	99.3	108.37	140	55.5	303.9	596.6	Positive
2	1946	**69**	12	**70**	648	3	-	371.0	105	100.2	68.3	65.1	233.6	536.3	Negative
3	1947	**69**	18	**70**	648	3	-	357.0	115.7	82.4	75.3	92.5	250.2	505.5	Negative
4	1948	41	18	61	664		-	342.0	123.5	88.8	59.1	86.4	234.3	500.2	Negative
5	1949	37	18	60	664	3	-	385.0	118.4	103	76.4	74.6	254.0	548	Negative
6	1950	-	-	-	-	-	-	406.0	115.2	127.3	47.2	79.4	253.9	527	Positive
7	1951	19	18	60	562	3	-	480.0	110.8	131	62.4	92.6	286.0	530	Positive
8	1952	19	18	60	562	3	-	411.0	129.3	117.2	89.7	88.8	295.7	547	0
9	1953	19	18	60	540	3	-	388.0	134	111.9	105.9	82.8	300.6	560	0
10	1954	19	18	60	675	3	-	398.0	134	116.4	122.2	100.5	339.1	555	0
11	1955	19	21	59	**729**	3	-	465.0	134	127.9	110.7	98.9	337.5	532	Positive
12	1956	13	21	59	**729**	3	-	453.0	149	149.4	122.3	125.9	397.6	548	0
13	1957	13	22	65	717	3	-	453.0	164.8	155.2	129.1	90.9	375.2	538	Positive
14	1958	10	23	62	720	2	-	462.0	172.1	215.4	93.4	88.2	397.0	570	Positive
15	1959	10	23	62	683	3	-	459.0	178.1	181.1	107.2	86	374.3	577	Positive
16	1960	10	23	47	548	3	-	385.0	218.4	163	77	83	323.0	541.8	Positive
17	1961	10	23	47	548	3	-	411.0	202	159	92	105	356.0	533.7	Positive
18	1962	10	23	47	672	3	-	457.0	202	176	119	117	412.0	536	Positive
19	1963	10	25	47	676	3	-	396.0	202.5	236	94	117	447.0	543	Positive
20	1964	10	22	49	617	3	-	361.0	209.1	198.9	96.9	102.1	397.9	212.6	Negative
21	1965	10	25	53	625	3	-	367.0	214	185	141	79	405.0	550	Negative
22	1966	10	26	58	676	4	-	503.0	189	204	154	87	445.0	548	Positive
23	1967	10	26	57	721	5	154	613.0	176	195	158	100	453.0	538	Negative
24	1968	10	26	57	721	5	154	771.0	171	216	179	76	**471.0**	550	Positive
25	1969	12	28	46	875	5	80	915.0	165	209	63	61	333.0	550	0
26	1970	10	26	43	618	4	-	504.0	135	5	1	110	116.0	258	Negative
27	1971	10	26	43	595	5	-	1089.0	157	122	41	158	321.0	461	Negative
28	1972	5	21	45	630	5	8	1340.0	184	108	80	128	316.0	468	Negative
29	1973	5	21	45	630	5	8	1336.0	232	90	71	139	300.0	437	Negative
30	1974	5	21	45	630	5	8	1204.0	255	87	57	93	237.0	454	Negative
31	1975	5	21	45	630	5	8	**1430.0**	252	102	77	68	247.0	493	Positive
32	1976	5	21	45	630	7	14	1114.0	240	93	89	58	240.0	484	Negative
33	1977	4	30	52	603	6	13	1052.0	261	144	90	70	304.0	472	Negative
34	1978	7	**34**	63	624	6	14	1054.0	262	217	81	72	370.0	449	Negative
35	1979	7	**34**	63	624	6	10	1205.0	361	170	101	64	335.0	447	Negative
36	1980	7	**34**	63	678	6	10	1312.0	261	146	100	70	316.0	445	Positive
37	1981	7	**34**	63	678	6	10	1094.6	271.9	147.5	87.2	64.3	299.0	430.2	Negative

38	1982		17	36	590	6	7	968.9	285.9	139	77.9	78.5	295.4	426.9	Negative
39	1983	4	13	36	585	6	7	989.6	294.3	115.5	84	80.2	279.7	435	Negative
40	1984	4	13	36	585	6	7	616.3	331.7	85.9	48.2	51.3	185.4	453.2	Negative
41	1985	6	16	31	590	6	-	710.8	323	100.3	72.7	61	234.0	477	Positive
42	1986	6	16	31	590	6	-	665.5	280.4	94.7	69.3	46.5	210.5	485	Negative
43	1987	6	16	31	590	5	-	513.8	293.3	84.6	72.3	47.7	204.6	454.6	Negative
44	1988	6	16	31	590	5	-	766.1	217.5	108.6	67.7	62.3	238.6	435.9	Negative
45	1989	6	17	31	590	5	-	761.6	206	98.3	75.8	58	232.1	456.7	Positive
46	1990	6	17	31	590	4	-	787.5	151	91.7	69.3	41.3	202.3	446.4	Negative
47	1991	7	17	31	590	5	7	730.0	205	140	50	80	270.0	430	Positive
48	1992	7	17	27	585	5	9	710.0	204	150.7	64.1	70.5	285.3	413	Negative
49	1993	7	17	27	493	5	9	717.0	241	127.8	62	49.5	239.3	374	Negative
50	1994	7	17	27	493	5	15	501.0	254	95	73	52	220.0	286	Negative
51	1995	7	17	27	493	5	15	324.0	253	116	78	46	240.0	404	Negative
52	1996	7	17	27	468	5	15	102.0	276	108.5	75.7	20.1	204.3	395.5	Negative
53	1997	7	17	27	468	3	15	125.0	276	66.6	71.3	14.7	152.6	364.4	Negative
54	1998	5	9	27	468	3	15	103.0	233	60	47	16	123.0	415	Negative
55	1999	5	9	27	468	3	15	126.0	222	23	42	8	73.0	356	Negative
56	2000	5	9	27	468	3	15	106.0	245	27	47	2	76.0	361	Big Neg
57	2001	5	9	27	468	3	15	55.0	256	6	12	2	20.0	355	Negative
58	2002	5	9	27	468	3	15	35.0	143	0.2	1.2	0	1.4	300	Negative

Source: CSA

Appendix-I: Direct Demand Model Development Procedure

The Direct Demand Model concepts adopted from the Direct Demand Model of Umamil and Sugie, 2003 which developed theirs model for the Inter-urban Passenger Travel of Indonesia Considered: Socio-economic variables: urban population, travel time, travel cost, and impedance (mode competition), dummy variable for non quantifiable variables of safety, convenience, freedom, and other.

But the Direct Demand Model in this research aimed at model formulation for Strategic planning of Cross Boundary Travel between Ethiopia and Djibouti both for Passenger and Freight Transport Including diverse variables.

The model in this research paper adopt the Umamil and Sugie, 2003 inter-urban model and develop it for the Ethio-Djibouti Inter-country passenger travel model with greater range of variable and different parameter calibration.

More importantly this research paper develop new Freight demand model for the Ethio-Djibouti Inter-country Freight travel model. For detail reference please see the model developed by Umamil and Sugie, 2003.

The model development consists of 3-steps:

1. **MODEL SPECIFICATION;**
2. **MODEL CALIBRATION AND;**
3. **MODEL VALIDATION.**

1. MODEL SPECIFICATION

This step describes the general form of the model and shows the general formula adopted from Umamil and Sugie, 2003 and the variables and parameters and their corresponding relation, and in the Excel program sheets it describe the modes and the traversed routes.

2. MODEL CALIBERATION

This step comprises the most important part of the model development: it consists of Data Entry and Analysis, and the actual Model Computation and Parameter Calibration.

2.1. VARIABLE ENTRY AND ANALYSIS

2.1.1. Primary Variable

- **I. Trade and Economy**
- **II. Population**

I. Trade and Economy

The trade and economy data entry and analysis focuses on the country foreign trade and per capital income, I.

Foreign trade data of 2005-2012 are obtained from Ethiopian Custom and Revenue Authority. And model only uses land mode of transport and transhipment from sea to land. And considering the 90% port handling of the Djibouti port the analysis conducted. And analysis made for the required traffic year 2020 by considering 9% and 4.5%, from past data tend growth, annual export and import respectively.

Per capital income data obtained from the national bank of Ethiopia, and analysis made by considering the Ethiopian national bank per capital growth trend for the past eight years 2004/05-2011/12 which is 8% and considering optimistic economic outlook 10% per capital annual future growth considered for the traffic year 2020.

II. Population

The model include data of urban population in the road route corridor including: Cities, Towns, Woredas, and kebeles; and data obtained from Ethiopian Central Statistical Agency, for the years 2001-2012 and projections made up to year 2037 with respective annual urban population growth of 4.5%.

2.1.2. Secondary Variable

- **I. Load**
- **II. Time and**
- **III. Cost**

I. Load

To illustrate the load capacity of the mode the AADT of Ethiopian road Authority 2012 traffic data and the Ethiopian Railway Corporation 2025 and 2035 annual section traffic flow included. The AADT data for years of 2005-2012 both for Addis-Galafi and Addis-Dewele roads considered to show the traffic flow and their respective passenger and freight traffic annual growth considered for the analysis of the road mode load carrying capacity that is annual passenger traffic growth of 6% and freight traffic growth of 8%.

Road load capacity

Freight: considered to handle additional 25% annual traffic of 2012 AADT load capacity it is fair assumption since in 2011 it handle from Addis-Ababa to Akaki 40,591 vehicles but in 2012 it handle only 23,134 vehicles both of are beyond the ERA Trunk road AADT capacity of 15,000 vehicles. And freight load capacity obtained from Addis Ababa University 2011 study and including 25%; the road freight load capacity estimated to be 11,713,463 tones.

The load capacity for the road transport was assumed to accommodate additional 25% of the 2012 traffic volume for the future with the current total travel time since it has handled Total 89,748 AADT in 2011 and it handled 74,534 AADT in base year 2012 which 20.4 % the additional 4.6% seems justifiable ; and

Passenger: data for the passenger traffic load obtained from O-D survey of the Addis Ababa University study for the year 2010 around 3,000,000 and respective passenger vehicle traffic annual growth of 6% and 25% additional load capacity of the year 2020. And load carrying capacity of road mode is only 1.25 time that of the year 2010 and estimate to be 3,750,000 passengers. The passenger volume of the 2020 based on the 6% annual growth of passenger traffic vehicles.

Rail load capacity

The load carrying capacity of rail is included in the study of CREG and CREEC, 2011 report; and these data are used for the analysis of the rail load.

II. Time

Road Travel Time

The data used and obtained from WT-consultant report, 2011 include: Travel and turnaround time, Border crossing time both for freight and passenger.

The used data are both way travel time since the data has full freight travel time no association made. But passenger travel in the corridor is absolute other corridor time used considering their travel length that is:

- Addis Ababa - Mekele - Adigrat/871 km of 40 hours
- Addis Ababa - Jima - Bedele - Metu/600 km of 40 hours
- And for the Addis-Djibouti-843 km interpolation made which is 40 hours.

Rail Travel Time

Considering its travel design speed of 120 km per hour for passenger train and 80-100 km per hour freight train the time for both direction travels is assumed.

The freight travel cover the full 757 km track where as the passenger travel is mostly local as witnessed from the analysis of the Ethio-Djibouti 58 years data and average passenger-km of 250 is used for this reason the travel time of rail freight and passenger presumed to be 4 day of freight in both direction and 1 day travel for passenger in both direction.

III. Cost

The cost component of the model is disaggregated in to **construction cost, maintenance cost, energy cost, and environmental cost**.

- **Construction Cost**

The road mode construction cost obtained from WT-consultant report, 2011, and improved with the new Addis-Adama Express way cost obtained from Ethiopian Road Authority, and 20% Bridge cost added to the cost estimate as learned from the rail bridge cost percentage.

The full construction cost of the planned rail line is obtained from the report of CREG and CREEC, 2011.

- **Maintenance Cost**

The maintenance cost of road mode is obtained from WT-consultant report, 2011 and the report estimate is improved with the consideration of the new expressway maintenance and bridge maintenance of additional 25%.

Rail mode maintenance is computed based on the Baumgartner, 2001 study and allowance is made for the other miscellaneous work and the rolling stock items.

- **Energy cost**

Percentage of transport price is used in the calculation of the energy usage cost for both of travel modes based on the studies of: Delsalle, 2002; ECORYS Transport, 2006; Dybing, 2002. And the transport cost of the road mode obtained from WT-consultant report, 2011, and the transport cost of rail mode is obtained from CREG and CREEC, 2011.

- **Environmental pollution cost**

The environmental damage road mode create is included in the model in terms equivalent Co2 cost or Co2e. Light duty vehicles produce 212 gm CO2/km for gross weight of less than 3.5 tones (Alemu, 2012). And In Ethiopia road transport produce around 5 Mt CO2e in 2010 (Federal Democratic Republic of Ethiopia, 2011 CRGE report). The model estimate around 500 gm co2e/km for heavy passenger vehicle and 750 gm Co2e/km for very heavy freight vehicles which constitute only 6.6% of the national transport pollution amount and price of the pollution obtained from State of the Forest Carbon Markets 2013 study report.

And no environmental pollution cost is included for the planned rail line since it is almost non pollutant electrified rail.

2.2. COMPUTATION AND PARAMETER CALIBRATION

FREIGHT

$$T_{ijm}=e^{\alpha0+A0}\,(T_iT_j)^{\alpha1}\,(I)^{\alpha2+A2}\,(C_{ijm})^{\beta1}\,(t_{ijm})^{\beta2}\,(L_{ijm})^{\beta3}\,(C_{ijm}/C_{ijg})^{\Upsilon1}\,(t_{ijm}/t_{ijg})^{\Upsilon2}\,(L_{ijm}/L_{ijg})^{\Upsilon3} \quad \text{T-km}$$

PASSENGER

$$T_{ijm}=e^{\alpha0+A0}\,(P_{av})^{\alpha1}\,(I)^{\alpha2+A2}\,(C_{ijm})^{\beta1}\,(t_{ijm})^{\beta2}\,(L_{ijm})^{\beta3}\,(C_{ijm}/C_{ijg})^{\Upsilon1}\,(t_{ijm}/t_{ijg})^{\Upsilon2}\,(L_{ijm}/L_{ijg})^{\Upsilon3} \quad \text{P-km}$$

No	Parameters	Freight	Passenger	Remark
1	**α0**	1.22	1.13	calibrating variable + 0.1 dummy
2	**α1**	0.05	0.045	4.5 % population and 5 % trade growth
3	**α2**	0.15	0.15	10 % GDP growth + 0.05 dummy
4	**β1**	0.13	0.11	reciprocal Rail: Road Cost ratio
5	**β2**	0.33	0.30	Rail: Road Time ratio
6	**β3**	0.59	0.67	reciprocal Rail: Road Load ratio
7	**ϒ1**	0.12		av. (Passenger + freight) cost effect
8	**ϒ2**	0.31		av. (Passenger + freight) time effect
9	**ϒ3**	0.63		av. (Passenger + freight) load effect

As can be seen from above the process of **Parameter Calibrations** of the model variable is made through:

- First some Intuition by considering the respective parameter association to the variable it relate;
- Second considering The Relation of The Ratio of the actual figure with the result of the model and adjusting it with the natural logarithm;
- Then through Trial and Error procedure then the process of calibration is made full.

After the above considerable time consuming process, the computation for the forecast of the 2020 is made.

To see it strategic planning applicability forecast for the years of 2021-2050 is considered but only forecasts for the years of 2021-2030 seem feasible due to limitation of data and scope of research paper the rest years projection assumed to be similar as that of the last year 2030 forecasts the reasons for this explained in the model development.

3. MODEL VALIDATION

To see the accuracy of the model, validation is made for the road mode freight transport since validation verify good reproduction of past results in our case past road traffic data; but validation is made only for road freight, obviously planned rail is not service before and the passenger data could not be found.

The road freight model validation produce acceptable accuracy result with a Pearson Correlation Coefficient, R and Mean Square Error R^2.

This procedure and model figure in the thesis and analysis result give full extent of the model development process.