ADDIS ABABA UNIVERSITY

ADDIS ABABA INSTITUTE OF TECHNOLOGY

SCHOOL OF CIVIL AND ENVIRONMENTAL ENGINEERING

Assessment of Inland Multimodal Freight Transport Through Djibouti Port.

A Thesis in Railway Engineering

By Ayub Nassr

24-02-2017

Addis Ababa

A Thesis

Submitted in Partial Fulfillment of the Requirements for the Degree of Master of Science

The undersigned have examined the thesis entitled ‘Assessment of Inland Multimodal Freight Transport Through Djibouti Port presented by Ayub Nassr, a candidate for the degree of Master of Science and hereby certify that it is worthy of acceptance.

Abel Kebede		
Advisor	Signature	Date
Internal Examiner	Signature	Date
External Examiner	Signature	Date
Chair person	Signature	Date

DECLARATION

I certify that research work titled "Assessment of Inland Multimodal Freight Transport Through Djibouti Port" is my own work. The work has not been presented elsewhere for assessment.

Ayub Nassr

ABSTRACT

The purpose of multimodal transport is to minimize transportation time and transportation cost. Modern transport and freight distribution system all over the world are tending towards the adoption of best practices those are reliable, timely and cost effective. Multi-modal transportation is a logistics problem in which a set of goods have to be transported to different places, with the combination of at least two modes of transport, without a change of container for the goods.

Ethiopia has been implementing the "multimodal" transport system, through Djibouti port using water and inland transport system, but the inland transportation is unimodal for long period of time. But due to the construction of new Addis-Djibouti railway line the transportation system will change to multimodal inland transportation system. Hence, this study focuses on model development of freight transportation cost and synchronization of railway with road transport service and also analyse the potentials of coordinated rail & road for freight transportation from Djibouti port to different parts of Ethiopia.

The findings of this research reveal that synchronizing rail & road for hinterland bound goods would be potentially save 19.39% and 42.56% of freight transportation cost for the year 2016 & 2022 respectively and the time of transportation will be reduced when compared with current unimodal transportation. The implications of this finding indicate integrated road and rail modes of transport for port-hinterland freight distribution would make the nation's transportation system to be faster & more cost-effective. This research also presents an effective mathematical procedure for maximal synchronization to be employed as a useful tool for the scheduler in the process of creating timetables. It attempts to maximize the number of simultaneous freight vehicle arrivals at the connection (transfer) nodes of the network. Transit schedulers, taking into account the satisfaction and convenience of the system's users, appreciate the importance of creating a timetable with maximal synchronization, which enables the transfer of freight from one route to another with minimum waiting time at the transfer node. The finding of this research also shows the optimum number of wagons and trains for the next five years by forecasting the amount of freight which can be imported to Ethiopia through Djibouti port.

ACKNOWLEDGMENT

I would like to thank my advisor Ato Abel Kebede for his willingness to be my advisor & making this work possible. I am very grateful for his guidance, support and encouragement throughout this research.

I would like to thank Ato Behailu Demeke manager of operational department of Ethiopian National Railway transport service for supplying me the necessary data and information about the Ethiopian National Railway service.

TABLE OF CONTENTS

List of tables

List of figures

List of abbreviations

MTO	Multimodal transport organizer
WT	Waiting time
ESLSE	Ethiopian shipping and logistic service enterprise
AVT	Average volume of transportations,
SPSS	Statistical Package for Social Science
TEU	Twenty Feet Equivalent Unit
AVT	Average volume of transportations, in quintals;
D_d	Delivery distance from railway terminal to destination city
D_r	Distance from the delivery terminal to the sea port and vice versa
EC	Ethiopian calendar
ERC	Ethiopian Railway Corporation
GMA	Geometrical mean analysis
USD	United states dollar

Chapter 1

Introduction

1.1 Background of the study

Economic transformation, and indeed, the development of any country are hardly possible without an efficient transport system (Andrew , 2011) . Freight transportation is a critical element in the overall demand-supply chain of commodities and services in a region. The ability to transport goods quickly, safely, economically and reliable is seen as vital to success of businesses, and to a nation's prosperity and capacity to compete in globalized economy (Douglas, et al , 1998). Freight transportation is critically tied to the economic growth and well-being of a region that freight transportation planning has become a major focus of transportation planning around the world (Ram, 2011). The road freight transport system, the main stream of inland freight transport, is highly congested and is having several infrastructural limitations which make it inextensible to accommodate the drastic increasing freight transport demands and volumes (Muh Patrick , 2007). Rail is also generally recognized as safer and more efficient in terms of land-use and energy efficiency. Therefore, American Association of State Highway and Transportation Officials (AASHTO) increasingly see rail as an alternative transport mode needed to handle the increasing freight traffic that will accompany sustained economic growth even if the road network has the advantage of being able to access almost any location and also it is very flexible, while rail networks have the ability to transport goods long distances at a low cost. The Rail freight transport mode affords significant advantages to an economy over road freight transport particularly for bulk commodities. The advantages include among others, reduced carbon emissions, cost competitiveness, superior safety and reduced road congestion (Giannetoni, 2010).

Most of Ethiopian expenditure is spent for import of goods from abroad through port of Djibouti. So that there is high demand of safe and reliable transportation service for these freight.

Over the years, due to oldest and inefficient Ethio-Djibouti railway service very little attention is given to the railway freight transportation. In this research, it is deal with multi-modal transportation, which is characterized by the combination of two modes for the transportation of goods using road & rail from Djibouti port to hinterland towns of Ethiopia.

The transfer of freight from road to rail has long been a government objective especially from the seaport of Djibouti to Ethiopia via Diredawa. According to the ESLSE the total amount of freight which is unloaded at Djibouti port in the year 2012 and 2016GC is 3,062,330 and 4,966,265 ton but among this freight 2,895,577 & 3,719,205 ton of freight is forwarded to Ethiopia respectively. This means the remaining 166,753 & 1,247,060 ton of freight is stored in Djibouti which is subjected to additional payment for storage in the specified years respectively for Djibouti government. So the construction and effective usage of railway line is an eminent decision for Ethiopian government.

To encourage the transport of freight by rail, the Ethiopian Railway Corporation (ERC) wished to consider the impacts of a number of mechanisms ranging from direct subsidy through to the direction and encouragement of investment. Also modes of transport and infrastructures for the delivery of goods from sea port to dry port assumed to use rail transport because of the deregulation rule. The development of multi-modal transportation has been followed by an increase in multi-modal transportation research. Therefore this research is done to analyze the new Ethio-Djibouti railway and road freight transport condition for freight delivery as a veritable means of cargo distribution in completing the journey from the seaports to dry port along Addis Ababa -Djibouti corridor.

1.2 Statement of Problem

The growing economies of Ethiopia undoubtedly drive the demands for freight transport service to increase in a high rate. Almost 95% of import-export goods to Ethiopia and from Ethiopia is done using the port of Djibouti (Andualem, 2015). But during the transportation of these freight, Ethiopia pay a huge amount of money to the government of Djibouti for long time storage in Djibouti due to shortage of freight transporting vehicles and improper management of them. As the Djibouti port storage charge list shows Ethiopia pays six to eleven (6-11) USD/TEU/day. According to the data gathered from ESLSE the total amount of freight which is unloaded at Djibouti port from year 2012 to 2016GC are 3,062,330, 3,018,969, 3,167,053, 3,340,135 and 4,966,265 ton respectively. But the forwarded freight to Ethiopia in the same year (i.e. from 2012 to 2016GC) is 2,895,577, 2,050,801, 2,271,403, 2,665,725 & 3,719,205 ton respectively. This indicates 166,753, 968,168, 895,650, 674,410 & 1,247,060 ton of freight is stored in Djibouti which is subjected to additional payment of 11,505,957, 66,803,592, 61,799,850, 46,534,290, & 86,047,140 USD from year 2012 to 2016GC respectively. And also according to ESLSE the freight which reach port of Djibouti stay for two month or more and a freight which reach dry port of modjo stay for three weeks and more due to shortage of freight vehicle or due to miss management of the vehicles. These problems (extra cost & delay) enforce Ethiopian government to construct a railway line which will start service in 2017GC. But if there is a poor management system in rail and road coordination there are different problems at the transfer and the delivery station. Among the problems that face during transportation of freight using multimodal/intermodal transportation system are vehicle and freight congestion at transfer station due to lack of proper synchronization and unbalance between the delivery and convey vehicles. In addition to this if there is two mode of transportation system in the same route an ambiguity may occur in the selection of efficient mode of transportation system due to difference in transportation cost and time. Therefore mathematical model which used to relate cost with its determinant is necessary.

1.3 Objective

The general objective of the research is to indicate the effective way for coordinated usage of railway and road transport system for the delivery of freight from Djibouti port to hinterland towns of Ethiopia through dry ports of the country.

Specific objective

- Adopt appropriate model that relates freight transportation cost with distance hauled and weight loaded.
- Determine the costs variation involved in transporting goods using intermodal transport in contrast with the present unimodal system.
- Synchronize the different modes of transport especially rail and road freight transportation at the nodes.
- Forecast the amount of freight which come through port of Djibouti
- Determine the optimum number of railway wagons required for freight transport through Djibouti port.

1.4 Scope

Multimodal transportation of freight from abroad to Ethiopia through Djibouti port use different mode of transportation. Among these water, rail and road transportation system are the major modes of transportation systems which used in the delivery of the freight. But in this research only multimodal transportation between rail and road is considered.

1.5 Significance of the study

The primary merits of the study goes to Ethiopia Railway Corporation and Ethiopian logistic service. It will give a comprehensive starting point for more advanced researches on road-rail freight transportation management. This research also contributes as a guide line for transport companies to create future cost effective, time saving and integrated transport service.

Chapter 2

Literature review

Jonas Floden, (2007) on his Doctoral thesis develops a flexible computer based calculation model for strategic analysis. The model takes its vantage point in the competitive situation between all-road transport and intermodal transport and computes the optimal split between these modes, given appropriate data inputs. The model can be used on an ordinary PC and it delivers results in terms of market shares, costs, transport quality, environmental effects and energy consumption for the intermodal system and the total market under analysis. This strategic decision support model is especially designed to analyses the modal split between road transport and intermodal road-rail transport and it meets the requirements of being both practically useful and theoretically satisfactory.

Martin Heljedal (2007), studied factors influencing the Choice between Road and Multimodal Transportation. These four primary factors which influence modal choice are costs, environment, risks and attitudes. The result of the study showed that the environmental impact of rail transportation is only a fraction of that of the road transportation and could possibly influence the choice of rail transportation in a positive way. However, rail transportation is less cost efficient, flexible and reliable and these aspects despite the advantageous conditions in terms of infrastructure and geographical vicinity to a rail terminal contribute to a negative bias towards rail transportation among companies in the study. Thus, the cost and attitudes factors counteract the choice of rail transportation. In addition, risks, as the final factor, also counteracts the choice, since it is found that respondents consider the risks of disturbances such as delays, theft and accidents to be important when considering mode of transportation and that rail transportation is viewed as lacking compared to road transportation.

The transportation cost of multimodal/intermodal transport system depends on the transportation cost of each mode and loading and unloading cost at each node (Thor-Erik, 2001).

2.1 Overview of Modal Coordination and Competition for freight Transportation

The International Multimodal Transport Association defines multimodal transport as “the chain that interconnects different links or modes of transport – air, sea, and land into one complete process that ensures an efficient and cost-effective door-to-door movement of goods under the responsibility of a single transport operator, known as a Multimodal Transport Operator, on one transport document”.

Modal competition

Each transportation mode has key operational and commercial advantages and properties. However, contemporary demand is influenced by integrated transportation systems that require maximum flexibility in the respective use of each mode. As a result, modal competition exists at various degrees and takes several dimensions. Modes can compete or complement one another in terms of cost, speed, accessibility, frequency, safety, comfort, etc. There are three main conditions that insure some modes are complementing one another:

Thus, there is modal competition when there is an overlap in geography, transport and level of service. Cost is one of the most important considerations in modal choice. A growing paradigm thus involves supply chain competition with the modal competition component occurring over three dimensions as shown in the figure below (Jean-Paul, 2009)

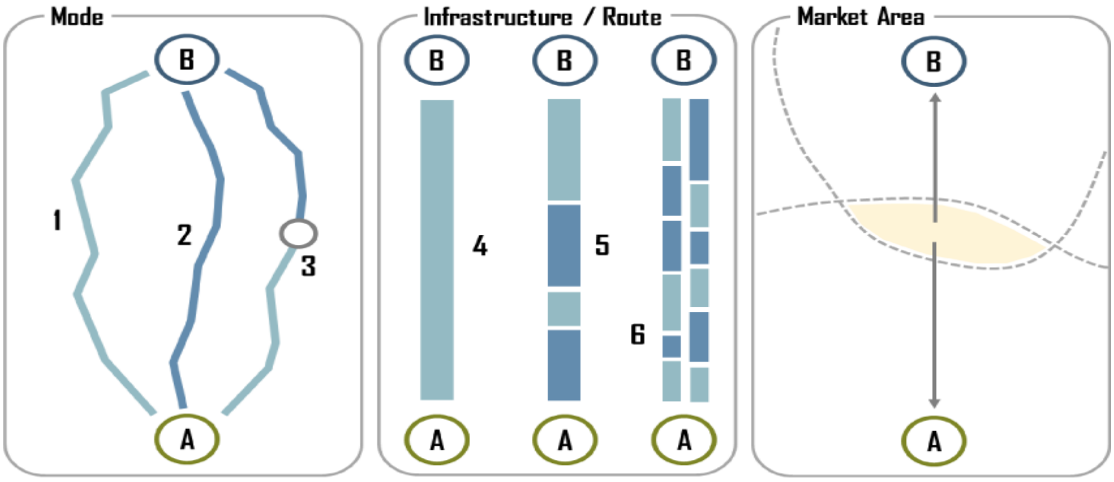

Figure 2-1 Forms of modal competition

Modal choice competition is the most basic consideration in the modal competition process. On the above figure, three modal choice scenarios are considered for two modes. The first two cases (1 and 2) are instances where only one mode is used since it represents the most efficient (or the only available) solution. Case three represents another possible solution where the two modes are used in a combination of two segments with a point of transfer.

Infrastructure or route competition represents another dimension where modal competition occurs over the usage of a specific infrastructure or route. Three scenarios are generally possible. In the first case (4), there is simply no competition as one mode has a monopoly over a route, either because of technical (a subway line for instance) or regulatory (car-only expressways) reasons. The second case (5) represents an exclusive sharing arrangement where two modes are using the same infrastructure, but at different moments. The issue of rail passenger and freight is a relevant example, as both may be using the same infrastructure but not at the same time. A decision has thus to be made about which mode gets priority. The third case (6) illustrates a situation where two modes have a mutual sharing arrangement. Cars and trucks are commonly sharing the same road infrastructure (Jean-Paul, R. (2009).

Market area competition is the third dimension of modal competition, which is highly tied to geographical considerations. In the above example, locations A and B have their own exclusive market areas over which that have a clear advantage. Competition occurs over a portion of the territory where the respective advantages of locations A and B are not clear; the competition margin (Jean-Paul, R. (2009).

Modal coordination (multimodalism)

Multimodalism is characterized by the integration and coordination of various modes of transportation, commonly by means of a metal shipping container, providing point of origin to point of destination under a single set of shipping documents and based on a single through freight rate charged to the shipper, regardless of how many modes of transportation are employed or how many carriers are involved. In the true multimodal movement, the shipper need only deal with one party to arrange for the entire shipment (Palmer, 2008).

A multimodal transport operator acts as a principal and therefore as a "carrier", because the MTO contracts with the shipper to carry goods by one or more modes of transport as may be necessary. The MTO has accepted total responsibility and liability to perform the transport contract; he has become the sole interface point for the shipper's transport function. The MTO is the only responsible party that is able to co-ordinate all modes of transport and organize multimodal transport.

Another issue that is necessary in coordinating freight transport service is maximal synchronization, which is a rather important objective from both the operator's and the user's perspectives, involving as it does creating timetables that will maximize the number of simultaneous arrivals of freight vehicle at the connection (transfer) nodes (A. Ceder, et al, 2000).

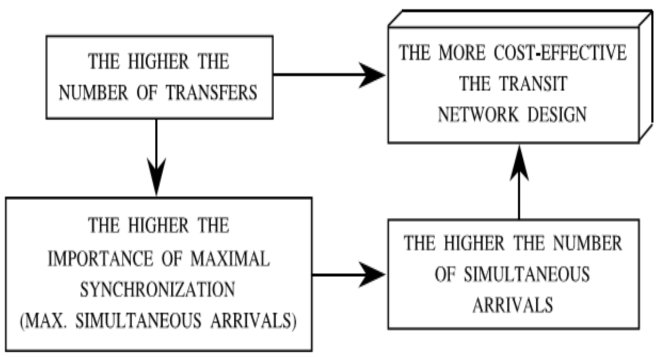

Figure 2-2: The relative importance of synchronization

2.2 Modes of Freight Transportation

There are five major modern modes of transportation namely: railways, roads, maritime, aviation and pipelines each with its own inherent economic, engineering and service characteristics. Each mode is both competitive and complementary for the other which, if combined optimally, provides maximum contribution to the country's development.

There are six transport mode performance characteristics living in any transportation selection decision these are: Speed, Completeness, Dependability, Capability, Frequency and Cost (Vadim , 2010).

2.2.1 Road freight transportation

Road freight transport is more flexible and versatile than other modes because of vast networks of roads. It can therefore offer point-to-point service between almost any origin and destination. It is this flexibility and versatility that has enabled road freight transport to become dominant in most countries (H J Stander, et al., 2002).

Typical strengths of road transport

The strength of road transport in contrast to other modes of transport services are Door-to-door service, Accessibility, Freight protection, Speed and High frequency.

Typical limitations of road transport

Besides its advantage over rail transport service it has also some drawbacks. The following are some of the drawbacks, Limited carrying capacity, High environmental impact, Vulnerability to external factors, High energy consumption, and shared right of way:

2.2.2 Rail freight transportation

In some countries, and especially in Eastern Europe and Asia, rail is the dominant form of transport. Since the deregulation of land freight transport, rail transport has improved significantly in these areas. .

Typical strengths of rail transport

- Almost any type of commodity can be conveyed by rail in special train compositions.
- Large volumes of bulk loads can be carried in single trains over long distances.
- The mode is not as vulnerable to traffic congestion as road transport.
- The mode is less affected by inclement weather conditions than other modes.
- Rail transport is cost and energy efficient over long distances and when the carrying capacity is well utilized.
- The accident safety record of rail transport, especially with the transport of hazardous goods, is good.

Typical limitations of rail transport

- Rail services need to be supplemented with additional feeder and distribution services.
- Rail transport provides terminal-to-terminal service rather than point-to-point service.
- Rail transport cannot offer frequent service as road transport and it has long transit time.
- Rail transport has a high freight damage record.
- Rail transport requires high capital investment.
- Rail transport is vulnerable to pilferage when rail wagons remain stationary in marshaling yards for long periods.
- Directional traffic volume imbalances cause a high degree of empty running.

Some of these disadvantages of rail transport may be overcome through the use of intermodal transport, which offers the advantages of rail transport combined with the strengths of other forms of transport. Freight trains nowadays also travel on timetable schedules, but departures are less frequent than those for road freight transport.

2.3 Dry Port

A dry port is an inland intermodal terminal directly connected to seaport(s) with high capacity transport mean(s), where customers can leave/pick up their standardized units as if directly to a seaport The quality of access to a dry port and the quality of the road/rail/waterway interface determines the quality of terminal performance. The dry ports are mostly located interior from the coast, thus the name dry port, but it does not exclude cities with sea access (Johan , et.al, 2004).

2.4 Freight transportation demand forecast

Many railway planning processes including financial, asset, capital investment and service planning are predicated on the railways' estimate of the freight volumes (demand) to be handled within a given time period. For this information to be meaningful and support the railways' planning processes demand forecasts must not only provide an estimate of the total volumes but also identify the commodities, timing, and the origins and destinations of the traffic. The ability to view and analyze demand across each of these dimensions allows the railways to plan the type and frequency of train service, asset requirements including locomotives, freight cars and train crews and to understand the distribution of traffic across their networks. The ability to view and analyze demand across each of these dimensions allows the railways to plan the type and frequency of train service, asset requirements including locomotives, freight cars and train crews and to understand the distribution of traffic across their networks (QGI Consulting, 2010***)***.

2.4.1 Measurement of transport costs

Transport cost is defined as the aggregate cost of all freight, insurance and other charges incurred in bringing the merchandise from the port of exportation to the first port of entry.

A common practice in the literature related to gravity equations has been to proxy transport costs with the geographical distance between countries. It has been shown that distance seems to be a good proxy for transport costs at aggregate level (Hummel, 1999).

Truck costs are a function of decisions made by a company or owner/operator. The differences in equipment characteristics, and operational structure, along with different trip characteristics, result in a somewhat unique cost structure for a particular movement and/or firm. Firm costs such as fuel, insurance, labor, maintenance and repair costs vary depending on geography, new versus used, and freight being transported (Bierman, et al, 1991).

2.5 Assessment on Freight transportation trend of Ethiopia

Ethiopia is a landlocked country in East Africa. Currently the logistics system of Ethiopia is characterized by poor logistics management system and poor transportation infrastructure. In addition to that the country is mainly dependent on Djibouti port for international trade. Its inland transportation is also underdeveloped as only road transportation is used for main share of freight transport.

The Ministry of Transport is now enforcing a new rule mandating that goods being shipped through the Ethiopian Shipping and Logistics Enterprise use a multimodal (land or road, sea,) transportation service operated solely by state owned ESLSE. The new addendum for the Multimodal Transportation Implementation Directive has ordered all private or state containerized import items that use ESLSE to transport their cargoes to dry ports or warehouses that are authorised by ERCA under the multimodal transport service agreement, which is exclusively operated by ESLSE.

2.5.1 Dry ports in Ethiopia

Ethiopia started developing dry ports following a 2007 study by the Ministry of Transport & Communication, which suggested that the country could save foreign currency from seaport expenses at Djibouti, by building an inland port within the country. The saving, according to the study, could be seven to eight dollars for every container that's transported through Djibouti. Consequently the dry ports of Ethiopia are Mojo Dry Port, 73Km east of the capital, Samara, 580Km north of Addis Ababa, Comet (Addis Ababa), Gelan, in Oromia Special Zone, 25Km east of the capital, Dire Dawa, 317Km east of Addis; Mekelle, 780Km north of Addis and Kombolcha, 380Km north of Addis Ababa.

2.6 Road Freight Transportation in Ethiopia

2.6.1 Road Transport Network and Density

The government of Ethiopia has been engaged in investment of infrastructure development to sustain economic growth, improving product competitiveness and encourage private investors. As a result, the road transport in Ethiopia has been the dominant mode of transport.

The asphalt road network in 2012/13 constituted about 13.1 percent of the total stock of road network in the country. In 2012/13 the total road network reached 22,883Km expanded by 36 % compared to 9,086 Km recorded in 2011/12.

2.6.2 Addis Ababa-Djibouti Road

There are two principal road routes connecting Djibouti and Addis Ababa. The first one passes through Nazreth and Awash and the other passes through Kombolcha.

The corridor analysis in this study however, refers to the Addis Ababa- Nazret-Awash-Djibouti road route. The road is 909 km long passing through Awash valley which has high agricultural potential. Dire Dawa, Nazareth, Modjo and Deberzeit are important towns enroots which are bristling with industrial activity and serve as distribution centers to and from southern parts of the country. As the country's imports are significantly greater than exports, long distance road traffic is unbalanced. As a consequence, efficient transport operation is difficult to achieve and the average load factor of trucks is low, about 60%.

2.6.3 Freight Transport companies & trucks

The efficiency and adequacy of road transport is a function not only of the road network but also Vehicle availability and sustainability for particular tasks in specific conditions. Roads are of no use without road Vehicles. This chapter therefore tries to deal with commercial fleet from various aspects such as Vehicle stock (size), age capacity and ownership. According to the new system trucks are classified in different levels. Every level has unique grades based on their loading capacity and manufacturing date or type of service provided. For instance the associations included on level one are divided into two different grades; the manufacturing date of a truck included:

Level 1 (A) is from 0-10 years and has a capacity to load from 30-40 tons of cargo and level 1 (B) has a similar manufacturing date but the loading capacity is from 20-29.9 tons of cargo.

An association organized under level 1 should have 125 trucks for both A and B grades. The associations included on level 1 must have four offices including the head office at the center and a branch at the port of Djibouti.

Table 2-1 Leveling standards of Ethiopian transport associations

Level		No Truck	Age of Truck	Capacity(ton)	No of office
1	A	125	0-10	30-40	4
	B	125	0-10	20-29. 9	4
2	A	100	0-10	30-40	3
	B	100	0-10	20-29. 9	3
3		75	≤ 20	20-40	2
4		50	≤ 20	20-40	

With the current status a business person involved in the transport sector can own trucks of different ages, because it would be difficult for the business actors to be involved in different associations based on different levels. To eliminate this challenge the authority has allowed the truck owners to be in just one association, based on the majority number of the trucks that they own.

Table 2-2 Transport association and vehicles in Ethiopia

Serial No.	Levels	Numbers of Associations	Number of trucks
1	Level 1	29	4715
2	Level 2	24	2421
3	Level 3	32	2412
4	Level 4	17	1122
Total		102	10670

Among these transportation companies and associations the following companies are mentioned below with their level and number of vehicles.

Table 2-3 Some transport association and their level

Company name	No of vehicle	Level	Owner
Ealshadai	150	1	Association (private)
Jontrans	130	1	Association (private)
Edl	89	3	Association (private)
ESLSE	>210	1	State

2.6.4 Road Transport Cost (Tariff)

Road transport Costs are represented by vehicle operating costs and the cost of time. Road transport Costs include costs of road maintenance, which is paid mostly by fuel taxes for road fund. Freight transport tariffs should be established directly by the market through free competition among operators. The prices will then be aligned to freight transport costs. Freight transport costs depend on different factors: economies of scale in truck size, backhaul possibilities, empty running and idle time due to seasonal variation in demand, restriction in working hours, road conditions, and standard of trucks in terms of design. Among the factors that affect the availability of the transport service, the transport tariff is obviously a fundamental one. It is the price that transports agencies receive for the costs they incur and users pay for the services they get.

2.7 Rail Cargo Transportation in Ethiopia

The significance of railway systems in an economy is paramount. That has led the government to see railway transport as an important alternative in the country's transportation system. Firstly, railways are better suited for serving bulk freight on long distance over 250-300kms and above. Secondly, rail mode of transport is cheaper at critical traffic figure of up to one million tons per year carried for over 1000 kms and can be economically sustaining without government subsidy. The estimated cost for the construction of one kilometer railway in Ethiopia is expected to be three million USD.

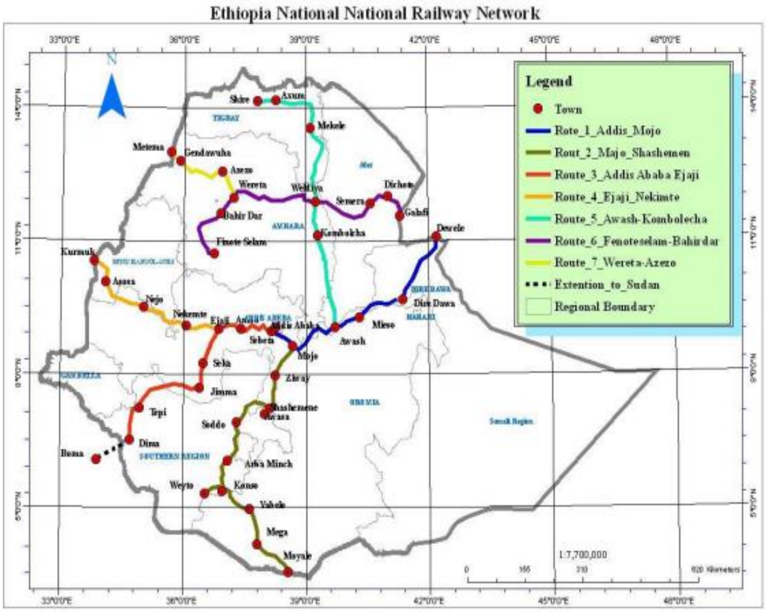

Figure 2-3 Ethiopian National Railway Network (ERC, 2010)

The Ethiopian Railways Corporation has identified eight railway corridors for study, design and subsequent implementation, the total estimated length with buffer of which is some 5060km. The eight railway routes are:

Table 2-4 Ethiopian railway roots data (ERC, 2010)

Root Number	Root Name	Estimated Length(kms)
1	Addis Ababa-Modjo-Awash-Dire Dawa-Dewanle	656
2	Modjo-Shashemene-Arbaminch-Konso-Moyale Including Shashemene-Hawasa and Konso-Weyto	905
3	Addis Ababa-Ijaji-Jimma-Guraferda-Dima including Jimma-Bedele (direct to Boma with further extension to south Sudan)	740
4	Ijaji-Nekemet-Assosa-Kumruk	460
5	Awash-Kombolcha-Mekele-Shire	757
6	Fenoteselam-Bahirdar-Wereta-Weldia-Semera-Elidar	734
7	Wereta-Azezo-Metema	244
8	Adama-Indeto-Gasera	248
	Total	5060

2.8 Freight Transport Demand

National commodity movements considered expresses the demand for freight transport, which consist the following main categories. These are:

- Export product including Coffee
- Import excluding petroleum and petroleum products
- Agricultural products for domestic market
- Industrial products for domestic consumption all over the country.

Table 2-5, Volume of Major Exports,(in millions of Kg.)

Particulars	2012	2013	2014	2015	2016	Percentage Change	
			X	Y	Z	Z/Y*100-100	Z/X*100-100
Coffee	196.1	169.4	198.7	177.8	231.3	30.08999	16.40664
Oilseeds	254.2	367.4	280.2	300.9	322.6	7.211698	15.13205
Leather and its product	5.2	4.4	4.6	6.11	5.4	-11.6203	17.3913
Pulses	16.9	17.7	15.4	17	20.1	18.23529	30.51948
Meat & Meat Products	224.5	226.2	356.1	360.8	321.2	-10.9756	-9.80062
Fruits & Vegetables	91.6	123.5	134.6	160.1	166.2	3.810119	23.47697
Live-animals	112.8	144.9	100.7	125.1	136.1	8.792966	35.15392
Chat	41.0	41.1	47.1	52.21	60.1	15.11205	27.60085
Gold	0.012	0.012	0.0123	0.012	0.0133	10.83333	8.130081
Flower	41.6	46.8	42.3	51.2	44.8	-12.5	5.910165

The import goods contain containers, vehicles, steel, break bulk and other, it is summarized as follow.

Table 2-6 Import goods through port of Djibouti (source ESLSE)

Year	2012	2013	2014	2015	2016
Size (ton)	3062330	3018969	2767053	3340135	4966265

Chapter 3

Research Design and Methodology

3.1 Introduction

Research methodology provides means and ways of breaking through problems to create a better understanding and to achieve a comprehensive solution that meet the aims and objectives laid in place as the goal of a study. The methodologies used in this thesis are literature review, data collection, data organization, model development and model validation for rail and road freight transport coordination.

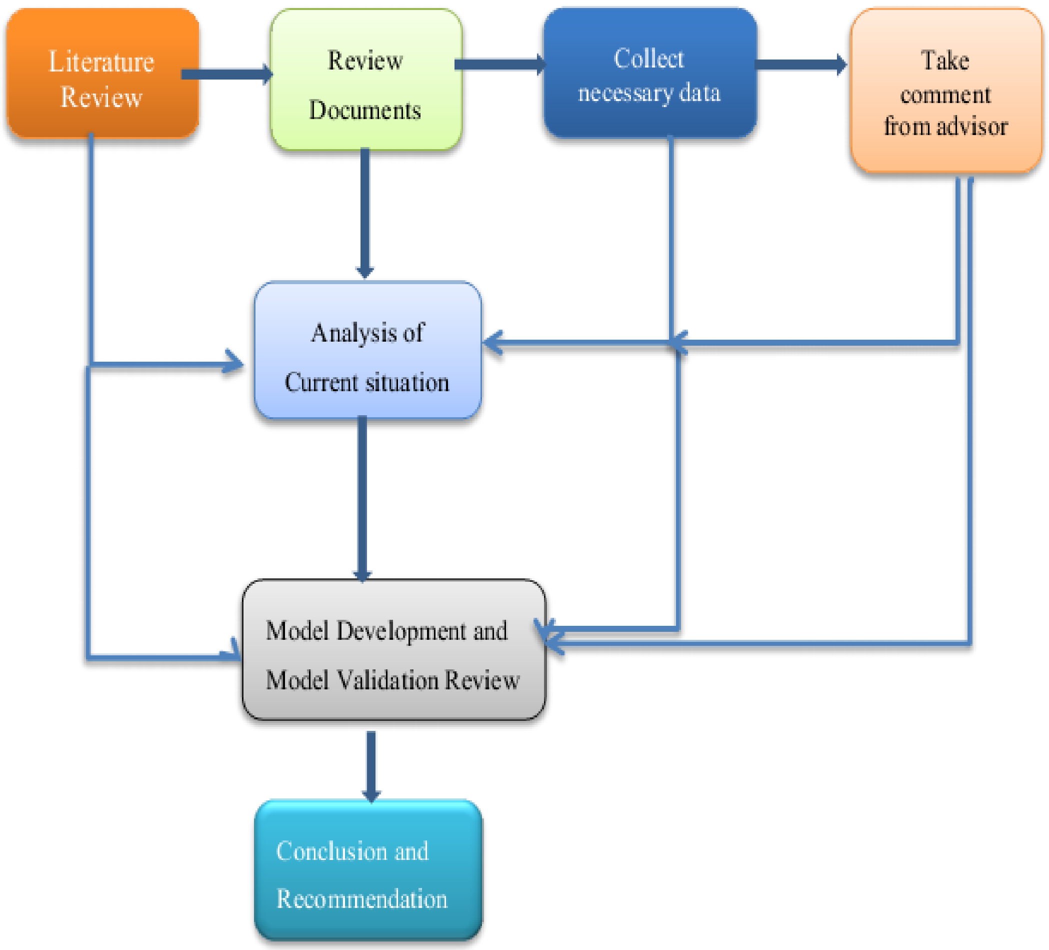

Figure 3-1 Flow chart showing the methods used for the study

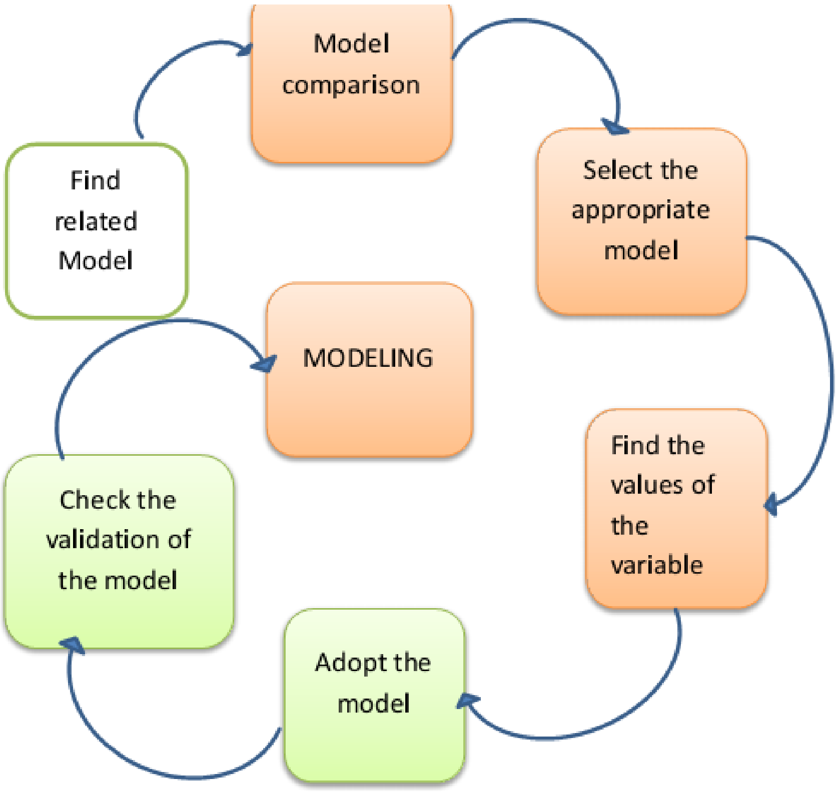

Figure 3-2 Modeling process and steps

3.2 Research design

Research design can be thought of as the logic or master plan of a research that throws light on how the study is to be conducted.

The main focus entity of this study was the multimodal transportation of freight through Djibouti port using Ethiopian railway line and the road transport which are the only freight forwarding systems in the route.

For this study the route from Djibouti port to hinterland cities of Ethiopia is classified in to two, because of congestion due to the presence of high freight vehicle on the route of Djibouti to Addis Ababa. The route from Djibouti to Addis Ababa is considered as main route whereas the routes which merge from the main corridor are taken as route out of main corridor.

Therefore an assessment was made on concerned bodies to have the general information towards goods delivery systems and processes currently undertaking through both transportation entities, to do that primary and secondary data were collected through reviewing literatures, distributing questioners and by direct interviews.

Before data collection the following steps were performed.

- Identify the necessary data's.

  Transportation cost, average transportation time & the amount of forwarded freight in the previous years are main types of data which were collected.
- Identify the companies in which the data can be gathered.

  Ethiopian freight transporting companies and Ethiopia Railway Corporation are the companies in which the required data are collected.
- Identify the way & techniques used to collect the required data.

  Interview, literature review and questioners are the techniques which are used to collect the required data's.

Data Collection: Primary & secondary data needed for this study were collected using different data collection techniques which are listed below.

The data collection part of the study is classified in to two categories. The first one is the travel speed and travel time determination whereas the second part of the research is freight transportation cost determination.

Literature Review: Searching previous thesis's, published journals, newspapers, books, etc. on different web sites which are helpful for meeting the secondary objective should be done. Collecting and reviewing document's from responsive companies, like Ethiopian shipping and logistic service enterprise (ESLSE), Ethiopian Railway Corporation (ERC), Ethiopian Revenue and Custom Authority and others. Previous research's which are done on freight transportation of Ethiopia and their results are seen to visualize the gaps that are found in the freight transportation of Ethiopia.

Document analysis: Recorded data are one of the major sources of information about the past. Documents have been analyzed through the study which includes company profiles, reports, company prints and others. Road freight transportation cost and related data are collected from Ethiopian shipping and logistic service, Ealshadai bulk load transport association, Jontrans freight transport association and also from Edl freight transport association by reviewing the cost standard used in the company for different destinations. The total amount of freights which transported to Ethiopia in the past five years is gathered from Ethiopian shipping and logistic service enterprise.

The data for road transport costs were derived from overall average costs of transporting 20 foot and 40 foot of cargo to specified hinterland locations as specified by Ethiopian shipping and logistics service (ESLSE) and from different freight transport companies, like jontran, ealshadai, and edl transport companies for different terrain and environmental condition.

Distance between freight origin and freight destination & the road distance from the dry ports to hinterland of Ethiopia is gathered from Ethiopian Road transport Authority.

Interview: To gather qualitative information about the factors which affect transportation cost, travel time and other interview questions are prepared and asked for four Transport Company's responsive bodies.

Questionnaires: Besides the direct interview carried out with the above listed bodies, a list of questions were prepared in questioner format and distributed to drivers of freight vehicles from different transport associations. The content of the questioner mainly focus to gather information about the travel speed of freight vehicles to different locations of the country. A total of eighty drivers twenty from each mentioned freight transport companies were interviewed through this questioner.

The sample size was determined based on the basic principles of sampling, the level of accuracy planned, type of research design and the scope and limitations of the thesis work.

In principle there are different types of sampling techniques to be used during sample selection processes. These are; simple random, stratified random, cluster, purposive, quota, snowball and volunteer or accidental or convenience.

In the case of transportation purposive sampling techniques was applied intentionally to accommodate all different topography and weather condition of the country.

Note: Even if the aim of the questioner given for the driver is to determine the average speed of freight vehicle to different destination from their origin, the questioner is prepared or asks the time taken to their destination from their origin i.e. Addis Ababa and Djibouti. The content of the questioner are attached as appendix at the back of the thesis.

Data Organization: the data which is gathered using different data collection technique should be organized and classified in to different parts according to their class. The data are classified in to three parts. These are the data which used for synchronization, for cost determination, and for future freight forecasting.

After collecting the data editing is done to detect errors and omissions and to correct these when possible. Moreover, classification of data is done to organize the data using tables, figures, Graphs, charts and others before using for the analysis.

Data Analysis: The volume, size, characteristics and mode of transportation to destination points are necessary parameters of freight traffic analysis. The analysis is done using different techniques and models using software's like: Ms-excel solver, SPSS and other tools. The data are analyzed using descriptive statistics & Geometric Mean Analysis (GMA). These techniques are used to ascertain the temporal and cost differences between the use of rail-road and road freight transport in completing the seaport journey to the dry port and to main cities' in the country. Temporal variation or travel time is calculated using average speed of vehicles. But average speed of freight vehicle is analyzed using the distance and time taken for selected cities of Ethiopia which is collected by the questioner.

To formulate a model to forecast the volume of freight which will be transported to Ethiopia through Djibouti port for the upcoming years, the freight volume which was transported to Ethiopia from Djibouti port for the last five year was used i.e. from 2005 to 2009 EC. In the same way the design specification of the railway line of Addis – Djibouti is used for travel speed and carrying capacity of the railway for the determination of the number of train and cargos.

Furthermore when formulating a model for estimation of road transportation cost the value of weight is designated using simple numbers 1 & 2 (i.e. if weight $W < 300$, $W = 1$ & if weight $W \geq 300$, $W = 2$ for 40" container) this is done because of there is only two types of payment system for freight transportation in all transporting companies due to the same size of the container.

Modelling: To answer freight transportation questions, it comes naturally to look towards the more quantitative tools. Some kind of calculation model of the transport system is necessary to allow for the system to be developed and tested and potentially evaluated. If model is developed time can be compressed and several different scenarios can be tested in a short period of time. Well-developed theories around modelling also allow for the model to include routines to help the researcher design the best transport system.

3.3 Model selection

In this research three models are used, to measure cost, for synchronization of freight vehicles & to forecast freight transport demand.

3.3.1 Costs Measurement models

The transportation cost of multimodal/intermodal transport system depends on the transportation cost of each mode and loading and unloading cost at each node (Thor-Erik, 2001).

There are different models which used to relate transporting cost with travel distance, loaded weight and other factors. Among these Thor-Erik Sandberg Hanssen model and Hummels, 1999 models are the two widely used models to relate transportation cost with its determinants.

Description of Model

I. ***Thor-Erik Sandberg Hanssen model***

$C_t = \alpha_o + \alpha_1 D + \alpha_2 DW + e$ ………………………….. (Thor-Erik Sandberg Hanssen)

Where α_o, α_1, & α_2 are constants & > 0 e, is an error

Costs for the transport firm, "C", depends on the amount transported, "W", and the transport distance, "D". In the equation the influence of "W" and "D" on C are represented by a linear relationships which is a simple cost function with the advantage of simple interpretations.

The total transportation cost of multimodal/intermodal transport system determined by adding total cost spent on each mode and loading and unloading cost at each node (Thor-Erik, 2001).

$C = C_t + C_r + C_l$

Where: C = total transportation cost from origin to destination,

C_r = transportation cost by rail C_t = transportation cost by truck

C_l = total loading and unloading (handling) cost

II. ***Hummel's model***

$$TC_{ijk} = W_{ijk}^{\alpha_1} D_{ij}^{\alpha_2} Q_{ij}^{\alpha_3} Inf_i^{\alpha_4} Inf_j^{\alpha_5} e^{\beta_1 Land_i + \beta_2 Land_{j+} \beta_3 \beta Lang_{ij} + h_k}$$

Where:

TC_{ijk} denotes freight transportation cost, *i* denotes the importer country, *j* denotes the exporter country and *k* denotes a freight type, W_{ijk} denotes the weight, D_{ij} denotes distance, Q_{ij}, is the volume of imports between countries *i* and *j*. Inf_i and Inf_j denote infrastructure of countries *i* and *j*. $Land_i$ and $Land_j$ are dummies that take the value one when the importer or the exporter is a landlocked country, zero otherwise, $Lang_{ij}$ takes the value one when countries i and j speak a common language, zero otherwise. h_k denotes the error term that is assumed to be independently distributed.

The variables Inf_i and Inf_j are first constructed as an index differentiating between importer and exporter country infrastructure as explanatory variables of transport costs. β_1, β_2 & β_3 are constants and shows the effects of the dummy variable on economic relation of the countries.

When comparing the two models to use for the determination of freight transporting cost from Djibouti port to hinterland towns of Ethiopia Thor-Erik Sandberg Hanssen model is selected because the Hummel's model is mainly used for two countries among which one of the country is exporter and the other one is an importer i.e. the countries have trade relation. But the relation between Ethiopia and Djibouti is only for freight transfer using Djibouti land. In addition Thor-Erik Sandberg Hanssen model is simple to relate cost with the available data's, distance and weight. Therefore based on the above reason Thor-Erik Sandberg Hanssen model was used in this research.

The distance, cost and weight of freight to different destinations from mojo dry port is used for the determination of the model.

3.3.2 Synchronization algorithms (Greedy & Heuristic)

III. ***Greedy algorithms:***

The greedy algorithm performs the scheduling of activities by taking travel time, loading and unloading time as synchronization constraints. The algorithm is described as follows:

Step 1: Schedule all activities as soon as possible without considering the fact that loaders are the only resources, and put all loading activities in a list. Go to step 2.

Step 2: Select the earliest loading activity belonging to the list, and if there is any conflict involving the associated loader, correct it by pushing back conflicting activity. Propagate this correction along the route of the associated truck. Finally, remove this loading activity from the list.

Step 3: travel time is determined using the vehicle speed and according distance travel.

Step 4: Select the unloading activity associated with the loading activity at the arrival station. If there is any conflict involving the associated loader, correct it as above. Go to step 5.

Step 5: If the list of loading activities is not empty, return to step 2

IV. ***Heuristic algorithm***

The other model Heuristic algorithm is used for the analysis which is based on the selection of nodes within the network. In each step, the next node is selected, providing that in this node, not all the departure times have yet been determined. According to Heuristic algorithm nodes are classified in to three states.

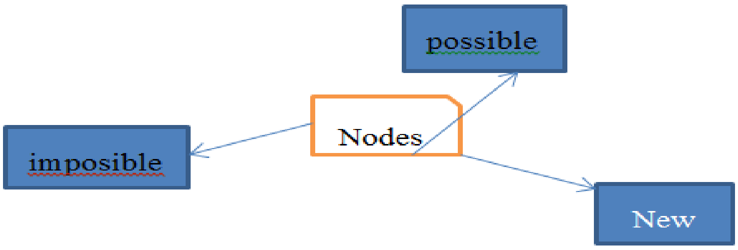

Figure 3-3 Classification of nodes

The main steps of the Heuristic algorithm are shown in section 4.2 of this paper.

The main difference of the two algorithmic methods is heuristic algorithm takes in to account waiting time, headway time and loading and unloading time whereas the greedy algorithm doesn't consider these. And also heuristic algorithm can evaluate more than one routes and nodes at a time where as greedy algorithm considers a single node with many route.

3.3.3 Freight demand forecasting model

Forecasting the volume of freight transportation through the route can be forecasted using different methods like time series method, moving average method, time series logarithmic method and exponential methods.

$D = b + at$ …………………………..time series method.

$D = A\ (1+r)^t$ ………………………... exponential growth rate method

$D = (1/n)\ (D_{t-1}+ D_{t-2}+\ldots\ D_{t-n})$ ……… moving average method

Where: A, a, b & r are constants and t is time in years

Commodity groupings: A requirement for any freight data analysis is to derive a commodity grouping which has some meaning in terms of differing market characteristics or handling characteristics. This is made harder as different sets of input data are invariably presented using different commodity classifications or at different levels of detail. This is a particular problem when looking at historic data – as was required for the freight market forecasting part of the study.

Validation: The final step of the study is model evaluation to determine and show the coordinated rail-road approach is economically selective based on cost and time with that of unimodal freight transportation. The validation of the model can be evaluated by substituting random values of the variable on the model and compare with the actual value.

Chapter 4

Results and Discussion

4.1 Freight transport demand determination through Djibouti port

The transfer of freight from road to rail has long been a government objective especially from the seaport of Djibouti to Ethiopia via Diredawa. And also Freight from dry port to hinterlands of Ethiopia is transported using rail and road transportation service.

Commodity groupings

According to the ESLSE the freight delivered from port of Djibouti to Ethiopia are classified in to three: Containerized freight, Break bulk & Vehicles. This classification of goods is based on the characteristics of the freight. This research also uses this classification of freight as an input because the freight which comes through Djibouti port already lay in these classes.

The base data for the model is the total tonnage of road and sea freight which is moved on the route & split by commodity. In order to develop the model it was necessary to develop a much more comprehensive set of base data. The base data for the model is the data gathered from ESLSE for the year 2012-2016GC

Freight demand forecast (Market projections)

Based up on the freight which reaches to Djibouti port in the previous five years i.e. 2012-2016GC, it is possible to forecast the freight demand for the coming years.

The freight transport demand is forecasted using exponential growth rate method for each group of freight category.

$$D_t = A(1+r)^t$$

Where: D_t = Freight demand at a year t

t = time in year, t=1 at the year 2012GC

r = growth factor

For simplification, the equation is changed to linier format using logarithmic method.

$$LogD_{t} = logA + tlog(1+r)$$

Using SPSS the value of r & A in the above formula are determined for all group of freight category including the total freight.

Table 4-1 values of the constant

S.N	Freight category	Constant log(A)	Growth rate log(1+r)	R^2
1	Total import freight	6.382	0.049	0.84
2	Container	5.031	0.037	0.72
3	Vehicles	4.261	0.017	0.77
4	break bulk	5.686	0.079	0.81
5	Export freight	5.39	0.001	0.52

The freight from 1-4 are freights which is unloaded from ship at port of Djibouti which is subjected to land transport to Ethiopia. But the freight at “5” is freight transported to port of Djibouti from Ethiopia by land transport. The value of the constants (A & r) and the model developed for each freight category is calculated and shown in the following table.

Table 4-2 values of the constant and developed model

S.N	Freight category	Constant (A)	Growth rate(r%)	The developed model
1	Total import freight	2409905	11.94379	$2409905(1+0.12)^t$
2	Container	107398.9	8.893009	$107398(1+0.08)^t$
3	Vehicles	18238.96	3.992017	$18238(1+0.04)^t$
4	break bulk	485288.5	19.94993	$485288(1+0.2)^t$
5	Export freight	245470.9	0.230524	$245470(1+0.02)^t$

The forecasted demand for the next five year is shown in the following table.

Table 4-3 Forecasted demand

S.N	Year (EC)	2017	2018	2019	2020	2021
1	Total Freight demand (tone)	4,756,614	5,327,407	5,966,577	6,682,617	7,483,172
2	Container (TEU)	180,118.8	196,325.3	214,003.1	233,163.1	254,256.3
3	Vehicle (No)	23,072	24,002	24,969	25,960	26,994
4	Break bulk (ton)	1,449,071	1,737,333	2,086,741	2,504,089	3,003,936
5	Export freight	248,882.9	249,447.5	250,012.1	250,625.8	251,165.8

Using the forecasted value of freight & the design standard of railway, the number of train unit and wagon can be determined for each respective year.

According to the design standard of Ethio-Djibouti railway line the total carrying capacity of a freight train is **2250 tons** Payload and the average load carrying capacity of each wagon is 70 tons.

The daily flow or transport of these freights from Djibouti port to Ethiopia is assumed to be the same in a given year even if there is some pick periods in the delivery of freight from abroad to port of Djibouti in the year to keep rail line to have a constant flow throughout the year.

Daily average freight transport

The daily average freight for each year can be settled by dividing the total freight of the year by the total days of the year.

Table 4-4 Daily average forecasted freight

S.N	Year	2017	2018	2019	2020	2021
1	Total Freight demand (tonne)	13031.82	14595.64	16346.79	18308.54	20501.84
2	Container TEU	493.4762	537.8775	586.3099	638.803	696.5926
3	Vehicle (No)	63.21096	65.7589	68.40822	71.12329	73.95616
4	Break bulk (tonne)	3970.058	4759.816	5717.099	6860.518	8229.962
5	Export freight(tonne)	681.871	683.4178	684.9647	686.646	688.1255

The number of train which is necessary for the transportation of expected daily demand of freight transportation in the upcoming year should be resolute as follows.

Number of wagon per train = train capacity/wagon capacity

=2250/70

=32.14 ≈32

32 wagons can be pulled by one train.

The minimum number of trains required to transport the total freight from Djibouti port to Ethiopia can be calculated by dividing total freight by train capacity.

There are freights which have a larger volume than the expected weight of the object and also some types of wagon are suited for specific type of freight. Therefor it is better to determine the number & type of freight vehicles for each category of freight.

Using the same the amount of demand and capacity of train it is possible to determine the number of freight transporting wagons and train for each category of fright.

Table 4-5 No of train &Wagons

Type of freight	Type of vehicle needed	No of vehicle required in the given year (EC)				
		2017	2018	2019	2021	2022
Break bulk	Box cars	57	68	82	98	118
Vehicle (No)	Bi-level Auto carrier	6	7	7	8	8
Container TEU	Flat car	247	269	293	319	348
Total No of wagons		310	344	382	425	474
Total No of trains		10	11	12	13	15

The total number of trains needed in each day of the next five consecutive years was summarized in the table above. To mention in each day of a year 2009 EC, 10 trains and 310 wagons are required to transport the freight from Djibouti port to Ethiopia. The result of the analysis shows almost one additional train is necessary in each consecutive year.

4.2 Synchronization of Rail & Road for Freight Transport

The objective is to minimize waiting time and maximize the number of simultaneous arrival of freight transporting vehicle at the node in the transport network. As mentioned in section 3of this research a node is classified in to three main parts. These are described as follows.

- Possible node: A node is defined as “possible" if the following holds:

  (a) There is at least one freight transport route that passes through the node, and not all the departure times for that route are set;

  (b) It is possible to create more simultaneous arrivals at the node.

- New node: A node is defined as “new” if no arrival times have been set for it.
- Not possible node: A node is “not possible” if all the departures of the routes passing through it are set and no more simultaneous arrivals are possible.

Formulating an algorithm

For the development of the algorithm the following inputs are required.

The given network is presented by a directed graph, **G(A; N),** where

A: is a set of arcs (rail and road) representing the traveling path of the routes,

N: the number of transfer nodes in the network;

T: The planning horizon (the departure times of the freight vehicles i.e. (rail and road) can be set in the interval [0, T] which is a discrete interval);

M: The number of routes in the network;

H_{mink} : The minimum headway between two adjacent departures in route k; ($1 \leq k \leq M$);

H_{maxk}: The maximal headway permitted between two adjacent departures in route k; ($1 \leq k \leq M$)

WT_{mink}: Minimum waiting time at node k.

WT_{maxk}: Maximum tolerable waiting time at node k.

F_k: The number of departures to be scheduled for route k during the interval [0, T] for (1≤k≤M)

T_{kj}: The traveling time from the starting point of route k to node **j** (1≤k≤M, 1≤j≤N) (traveling times are considered deterministic, and can be referred to as the mean traveling times).

X_{ij}^k: Represents the departure time of the **i**th freight road or railway vehicles on route **j** to node **k** (1≤i≤f_j)

R_{ij}^k: Represents the arrival time of the ith freight road or railway vehicles on route j to node k (1≤i≤f_j)

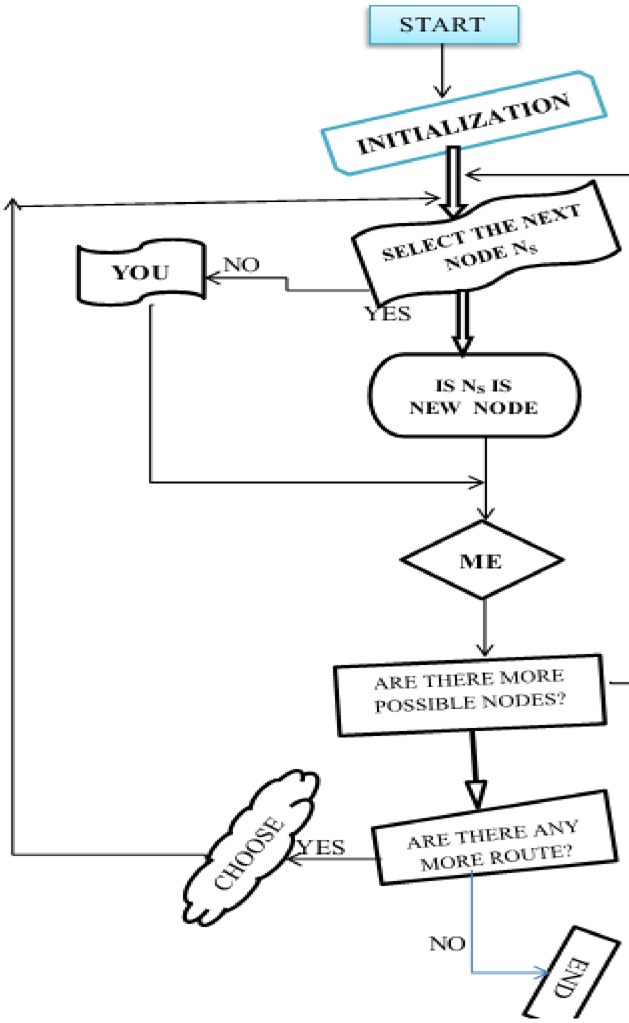

Figure 4-1: Flow Chart of Algorithm

- The following are the assumptions that are taken in this research:

- The first departure in each route k must take place in the interval $[0, H_{maxk}]$;
- Trucks leave the terminal (node) as soon as the loading and unloading of freight is done.
- Traveling times and the waiting times are considered pre-deterministic.
- The waiting time limits for the freight loading and unloading at each node are assumed to be predetermined by the transit planners.
- Bi – Set of nodes contained on route i
- Bi, j– Set of common nodes contained on route i and route j.
- Zijkpq is a binary variable that yields the value 1 if the p^{th} freight road truck or train vehicle on route i meets the q^{th} freight road truck or train vehicle of route j at node k; otherwise, it yields the value 0.

  Let $A= \{1 \leq n \leq N, T_{kn} \geq 0, T_{qn} \geq 0\}$

The problem is impractical unless the following constraints hold, for each route k,

- $H_{maxk} \geq H_{mink}$; (1)
- $T \geq (F_k - 1) H_{mink}$ (2)
- $T \leq (F_k) H_{maxk}$ (3)
- $X_{1k} \leq H_{maxk}$; (4)
- $X_{Fk\,k} \leq T$; $1 \leq k \leq M$ (5)
- $H_{mink} \leq X_{(i+1)k} - X_{ik} \leq H_{maxk}$; $1 \leq k \leq M$; $1 \leq i \leq F_K - 1$ (6)
- $Z_{ijkpq} = 1$ if $WT_{min\,k} \leq (X_{ip} + T_{ik}) - (X_{jq} + T_{jk}) \leq WT_{max\,k}$, $k \in B_{i,j}$
- $Z_{ijkpq} = 0$; otherwise (7)

Constraint (4) ensures that the first departure time of each route will not be beyond maximum headway from the start time horizon and constraint (5) ensures that the last departure is within the planning horizon. Constraint (6) indicates the headway limits. Constraint (7) shows that the decision variable takes a value of 1 if the arrivals at the node are within the waiting limits and value of 0 otherwise.

Algorithm components

The algorithm uses several procedures as described in the following chart.

Step 1: Initialization: check whether the problem is feasible, and create the data structures. Mark all nodes as new;

Step 2: Select a node, $\mathbf{N_S}$, from the possible nodes;

Step 3: If $\mathbf{N_S}$ is new, perform procedure **A**, otherwise perform procedure **B** as shown in chart;

Step 4: If there is any possible node, go to Step 2; if there are any more routes, perform procedure **C** and go to Step 2, otherwise stop.

Step 1 contains a check of whether the problem is feasible (constraints (1)-(3)), and two data structures are built:

a) A structure called route for each route i, which includes H_{mini}; H_{maxi}; $F_{\mathbf{i}}$, the number of nodes the route passes through and the departure times that have already been set;

b) A structure called node for each node n, which includes the number of routes passing through the node; the route with the maximum traveling time to the node, and the number of simultaneous arrivals at the node at each time point in interval $[0; T+\max_{i;j}T_{ij}]$

The node selected "$\mathbf{N_s}$" from possible nodes "N" in Step 2, must satisfy the following:

a) The number of different freight vehicle arrival times at the node is maximal; in such a node, there is a greater probability that another freight vehicle departure can be set so that it will arrive at Ns by any one of the (already set) arrival times;

b) Among the nodes satisfying (a), Ns is that through which a maximal number of routes pass; in such a node, there is a greater potential for simultaneous arrivals;

c) Among the nodes that satisfy (b), N_s minimizes the maximum travel time of all routes from their origin to the node (after the departure times of freight vehicle are set in order to meet at N_s, there is still a potential for simultaneous arrivals at distant nodes).

***Procedure* A**

For a new node N, **procedure A** attempts to set the departure times of freight vehicle that pass through it, such that the freight vehicle will arrive at the node at the earliest time possible, and simultaneous arrivals will continue to be created at the node according to the H_{min}, H_{max} of the routes. The subsequent departures for these routes are fixed after a time "d" from the last departure. The procedure A finds the minimum possible "d" that is given by:

$$\text{For route } i=1, 2, 3 \ \max H_{min_i} \leq d \leq \min H_{max_i}$$

Procedure A perform the following steps

1) At the selected node (N_S)

   For all routes i, passing through it calculate minimum possible **d** satisfying,

   $d=\min_{i=1,2,\ldots M}[\max_{i=1,2,\ldots M} (H_{mini}),\min_{i=1,2,\ldots M} (H_{maxi})]$ for route i passing through N_S.

   Set maxtime = maximum travel time to reach N_S and identify the route associated with maxtime to reach and label it as i*

2) For the route i*, set the first departure (p = 1) as $X_{1i*} = 0$
3) For the other routes i, passing through this node:

   If (maxtime – $WT_{min}N_S$ – T_{iNs} > 0)
   Set X_{i1}= (maxtime – WT min_{NS}- T_{iNS}) and go to "5".
   Otherwise, set w = WT mink
4) If (maxtime + w) ≥ T_{iNS} and if (maxtime + w – T_{Ins}) ≤ H_{maxi}

   Set X_{i1} = (maxtime + w - T_{iNS}) and go to Step 5.
   Else, set w = w +1. If w ≤ WT_{NS} repeat step 4, else exit.
5) For these route i and i*, if the procedure is able to find the value of **d** in Step 1, then the subsequent departures i.e. for p= 1, 2... min (f_i, f_i^*) are assigned after an interval of **d** from the previous departure. That is:

   Set $X_{i(p+1)}$= X_{ip} + d

Set $X_{i*(p+1)} = X_{i*p} + d$

Else go to Step 6.

6) For these routes i and i* compute the arrival times of all the set departures (p =1, 2... min

(f, f*)) to each "possible" and "new" node on the route as:

$T_{ip} = X_{ip} + T_{ik}$ for k =1…N present on i.

$T_{i*p} = X_{i*p} + T_{i*k}$ for k =1… N present on i

7) Label all the other nodes on these routes, as "possible" and label k as "not possible" and exit.

Procedure B.

This method sets the departure times when the selected node is "possible". For a selected "possible" node there will be some routes whose starting times are already set using procedure **A**. The following steps are performed in this procedure:

1) Select node, N_S that is "possible",

Set i* as the route passing through N_S and all the departure times are already set using Procedure **A**. Set arrival times of i* from the origin to N_S as:

$R_{ip}^{Ns} = X_{i*p} + T_{iNS}$, for all p=1....$f_{i*}$

2) For the other route i, passing through N_S, set p as the minimum un-assigned frequency Where p ε (1....f_i).

For each R that is, R_{i*p}^{NS}, R_{i*1}^{NS},R_{i*2}^{NS}, $R_{i*}f^{NS}$ set $w = WT_{NS}$

3) For route i, if $0 \leq (R_{i*}p^{NS} - w - T_i^{NS}) \leq H_{maxi} + X_{i(p-1)}$

For p=1 set $X_{ip} = (R^{NS}_{i*p} - w - T_{iNS})$ and go to step 4

For p > 1,if $(R^{NS}_{i*p} - w - T_{iNS}) - X_{i(p-1)} \geq H_{mini}$, set $X_{ip} = (R^{NS}_{i*p} - w - T_{iNS})$ and go to step 4.

Else if $0 \leq (R_{i*p}^{NS} + w - T_{iNS}) \leq H\ max_{i(p-1)}$

For p = 1, set $X_{ip} = (R_{i*p}^{NS}) + w - T_{iNS})$ and go to Step 4

For $p > 1$, if $(R^{NS}_{i*p} + w - T_{iNS}) \geq H_{mini}$, set $X_{ip} = (R^{NS}_{i*p} + w - T_{iNS})$ and go to Step 4.

Otherwise set $w = w+1$ and, if $w \leq WT\ max_{NS}$ repeat Step 3. Otherwise set $R^{NS}_{i*(p+1)}$ and set $w = WT\ min_{NS}$ and go to Step 3. Else exit.

4) For route i if $p < f_i$ – go to step 2, Otherwise label N_S as “not possible”.

   For routes i passing through N_S and for the departure times that are set in Step 3, compute the arrival time to each “possible” and “new” nodes present on the route as,

   $R^k_{ip} = X_{ip} + T_{ik}$ for all k = 1… N on route i

   Label all the other “new” nodes on these routes, as “possible”.

Procedure C

This procedure checks if there are any un-assigned departures that are not created by the first two procedures.

1) If there is only one unassigned departure on route i, and set p as the minimum un-assigned frequency, where $P \in (1...f_i)$. Set this departure time using the minimum headway from the last departure as

   $X_{ip} = X_{i(p-1)} + H\ min_i$ and exit.
2) If there are more than one unassigned departures on different routes, identify the route i, passing through the maximum number of nodes, break ties arbitrarily and assigns its next departure by using minimum headway from the last departure.

   i.e., $X_{ip} = X_{i(p-1)} + H_{mini}$

All the nodes through which the identified route passes are labeled as “possible” again.

This will allow the algorithm to set additional simultaneous arrivals at “possible” nodes.

In this research which considers transportation of freight from Djibouti port to different parts of Ethiopian cities uses realistic data on number of route, nodes and waiting times.

The study area is divided into several directions of freight transport distribution zonal roots. In zoning there may be more than one route that can use to deliver freight vehicle to a certain cities. In such a case the shortest distance which save both time and cost is selected as the route which join the freight origin to freight destination.

In this research the main freight stations of the railway line from which the transition of freight from railway terminal to different parts of Ethiopia is considered as node. So the stations in the line from Djibouti port to Ethiopia are:

Sebeta, Addis Ababa-Lebu, Addis Ababa-Kality, Bishoftu, Modjo, Adama, Welenchiti, Metehara, Awash, Asebot, Mieso, Mulu, Afdem, Bike, Erer, Dirē Dawa, Shinle, Harewa, Adi Gala, Aysha, Dewele, Ali Sabieh, Djibouti-Nagad, Djibouti-Port.

Among these, the main freight stations which are considered as a node are: DireDawa, Awash, Adama and Mojo & Addis Ababa. Because from these station there are routes which deliver to different towns of Ethiopia.

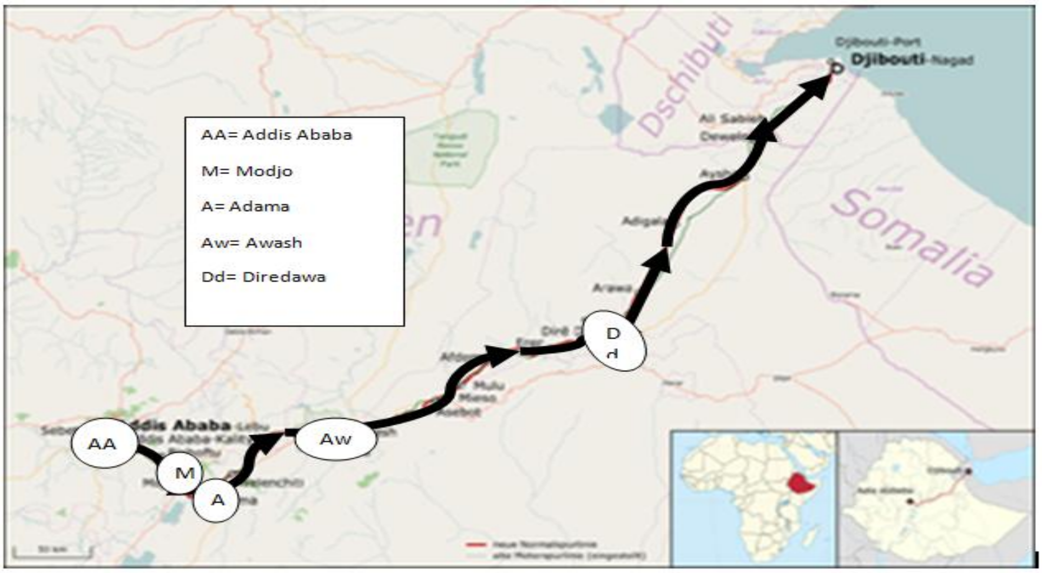

Figure 4-2 Nodes on a railway line from Addis Ababa to Djibouti

From each station (node) there is one or more route which joins to different cities of a country.

Table 4-6 Zonal distribution of freight through Djibouti port

Freight origin	Freight Railway station or Node	Node designation	Freight destination	Route designation
			Jigjiga	1
	Dire Dawa	D	Harar	2
			Kombolcha	3
			Weldiya	4
			Mekele	5
	Awash	W	Axum	6
	Adama	M	Nearby user	
			Dila	7
			Hawasa	8
	Modjo	O	Shashemene	9
			Gonder	10
			Bahirdar	11
			Finoteselam	12
			Debremarkos	13
			Welkite	14
			Nekemti	15
			Jima	16
(Port of Djibouti)	Addis Ababa	A	Assosa	17

Note: There must be some considerations which are taken in mind like there are routes which is used by two freight vehicle with the same origin but with different destination. For example the route from Addis Ababa to Bahrdar is shared by both freight vehicles which travel from Addis Ababa to Gonder and Bahirdar. But the route is treated as two isolate routes.

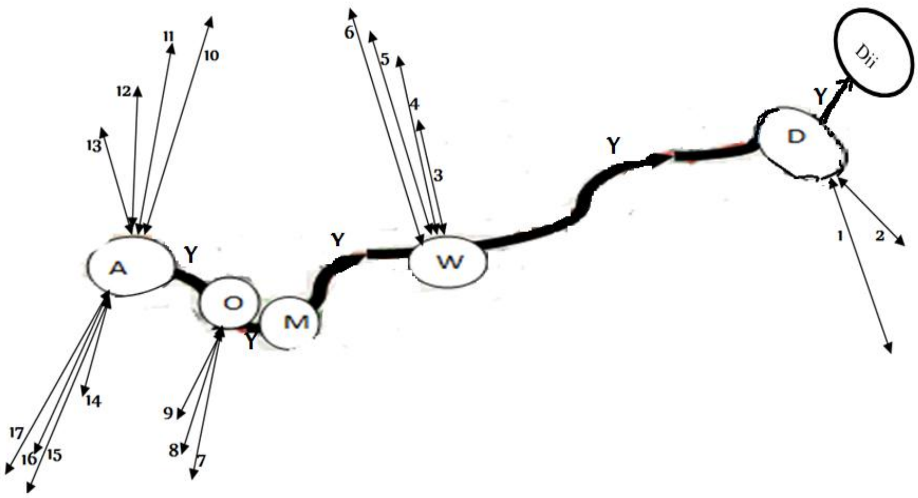

Figure 4-3 Routes designation through the nodes

Inputs for the corridor:

The number of route which scatter from each node D, W, M, O, A, are 3, 5, 1, 4 and 9 respectively. As stated in section 4.1 above, the waiting time and traveling time are considered pre-deterministic.

For the analysis of arrival times the standard waiting times are taken from the interviews of the traffic officers from ESLSE transport company multimodal & unimodal transportation department and for higher manager of the other mentioned transport association. The maximum tolerable waiting time at the arrival and departure station shall not be more than two hours including loading and unloading of cargo. But tolerable waiting time is subjective. Therefore based on the information & based on practical condition of freight transport, the value of max tolerable waiting time is taken as 2 hr.

To determine the travel time it is necessary to have average speed of freight vehicle. The speed gathered from each company’s drivers is grouped and average speed for that company is estimated as shown below.

Table 4-7 Estimated average speed of freight vehicle

Driver from company	Estimated speed on main corridor (km/hr.)	Estimated speed out of main corridor (km/hr.)
ESLSE	33	37
Ealshadai	40	45
Jontrans	35	40

By taking the geometric mean the average speed of freight vehicle is determined both for main corridor and out of main corridor as 36km/hr and 40.33 km/hr respectively.

The minimum and maximum waiting time for each station or node is set to be 30 min and 2h (120min).

The headway limits, H_{mini} and H_{maxi} were set to be 30 minutes and 1.5h (90 min) respectively for each routs i.

Note: The headway time of freight vehicle for each node can vary depending on the amount of freight which delivers to the cities.

The following procedure shows the necessary steps of procedure A.

1) Initializes all nodes as “new”.
2) Identify the selected node Ns (perform the procedure for node) “A”, Ns= A

The travel time from Addis Ababa to Gonder is selected as maximal travel time due to its long distance coverage when compared to other selected towns from Addis Ababa with travel time of 18.6hr.

$$\text{The value of } d = \min\{\max [H_{mini}], \min [H_{maxi}]\}$$
$$= \min\{30,90\}$$
$$d=30min$$

3) As the departure time of all node is assumed to be zero,

Therefor $X_{10,1}^{A}= 0$, $X_{10,2}^{A}=0.5hr$ $X_{10,3}^{A}= 1hr$

By considering the distance and average speed of loaded truck trailer which is 40kph it is possible to fix travel time.

Table 4-8 Travel time from node A to different towns of Ethiopia

FromNode “**A**”	Distance	Travel time (hr)
Gonder	744	18.6
Bahirdar	556	13.9
Finoteselam	387	9.68
Debremarkos	299	7.48
Welkite	158	3.95
Nekemti	328	8.2
Jima	346	8.65
Assosa	675	16.88
Djibouti port (Y)	784	9.8

Node	Town	Distance	Travel time (hr)
	Jigjiga	313	7.83
	Harar	20	0.5
D	Djibouti port (Y)	311	3.88
	Kombolcha	436	10.9
	Weldiya	485	12.13
	Mekele	686	17.15
	Axum	809	20.23
W	Djibouti port (Y)	681	8.51
	Dila	286	7.15
	Hawasa	200	5
	Shashemene	181	4.53
O	Djibouti port (Y)	748	9.35

For other rout starting from node “**A**” maxtime is 18.6 hr.

For route “**11”** first departure, $X_{1,11}^{A} = \text{maxitime} - w - T_{11A}$

$(T_{11,A})=13.9hr$ and $w=0.75hrs$,

Check ($maxtime – WT_{min}N_S – \mathbf{T}_{iNs} > 0$) **=>** 18.6- 0.75-13.9=3.95hr > 0 (ok)

Therefore $X_{11,1}^{A} =3.95hr$

4) The next departure (2nd) for route 11 is $X_{11,2}^{A}$ = 3.95+0.5 =4.45hr

   The third departure (3rd) on route is $X_{11,3}^{A}$ = 3.95+0.5+0.5 = 4.95hr

Repeat this procedure for route Assosa to Addis Ababa (route 17)

3) T_{17A} =16.88hr
4) Check (maxtime – $WT_{min}N_S$ – $\mathbf{T}_{iNs}$ > 0)

   18.6 – 0.75– 16.88= 0.97 > 0   OK

   $\mathbf{X}_{17,1}^{A}$ = 0.97 hr.
5) The second departure for route 17 to node A is $X_{17,2}^{A}$ = 1.47hr.
6) The third departure is $X_{17,3}^{A}$ =1.97hr.

The procedure is repeated for all routes which end at node "A".

The departure time of route Y depend on the speed of the train and the traveling distance of the train. The average traveling speed of the train is 80km/h and the distance to be hauled by the train from Djibouti port to Addis Ababa is 784 km.

Table 4-9 Departure time of the route to node A

Departures	1 Route								Y
	10	11	12	13	14	15	16	17	
1st Departures	0	3.95	8.17	10.37	13.9	9.65	9.2	0.85	8.05
2nd Departures	0.5	4.45	8.67	10.87	14.4	10.15	9.7	1.15	8.55
3rd Departures	1	4.95	9.17	11.37	14.9	10.65	10.2	1.45	9.05

Nodes **O, W & D** are possible nodes, since the departure time of route "Y" is known. But as there is no route which starts from node M and the only route which deliver to node M is route Y for which its departure time is already fixed from procedure A therefore M is "**not possible**" node.

1) Select node "**O**" (station at mojo)
2) Node "**O**" perform procedure **B**
3) In this case route "i" is route "Y" whose departure time is X_{Y1}, X_{Y2}, X_{Y3} are 8.05, 8.55, 9.05 respectively and the arrival time to node "O" R_{Y1}^{O}, R_{Y2}^{O}, R_{Y3}^{O} are 17.85, 18.35, 18.85 respectively.

4) For routes 7, 8, and 9 for which there is no departures assigned yet, so set p=1, for R_{Y1}=17.4, w=0.50hr.

5) Set the departure time for the route

$Xo_7 = R_{Y1}^{O} - w - T_{7,1}^{O}$,

$= 17.4-0.5-7.15=9.75$

The first departure time for route 7 is 9.75hr

The second departure time is 10.25hr

The third departure time is 11.75hr

Following the same procedure departure time for route 8 & 9 to node **"O"** is determined.

The procedure continue to determine the departure time for the other route (route 1-6) to node **W** and **D**

1 Node W & D are possible nodes so proceed to step 2

Step 2: Selected node k*=W

Step 3: As node W is possible procedure **B** is performed

1: Route i is route Y and R_{Y1}, R_{Y2} and R_{Y3} are 16.56, 17.06, and 17.56 respectively.

2. The first departure time from route 3, 4, 5 and 6 are

$X_{3,1} = R_{Y1} - w - T_{3,1}$

16.56-0.5-10.9 = 5.16hr

$X_{4,1} = R_{Y1} - w - T_{4,1}$

16.56-0.5-12.13 = 3.93hr

Check $0 \leq (R_{Y1}^{W} + w - T_{4W}) \leq H_{maxi(p-1)}$ for $X_{5,1}$& $X_{6,1}$

Step 4: $0 \leq (16.56+0.75-17.15) = 0.16$ OK

$X_{5,1} = R_{Y1} - w - T_{5,1}$

16.56+0.75-17.15 = 0.16hr

For route 6 check $0 \leq (R_{Y1}^{W} + w - T_{4W}) \leq Hmax_{i(p-1)}$

$0 \leq (16.56+0.75-20.23) = -2.95$ not ok

Therefore we have to add a discrete value of W = 0.75hr

-2.95+0.75 = -2.2

The first vehicle in route 6 will arrive with the 4^{th} train in route Y with the departure time of 0.69hr.

The 2^{nd} departure for route 3, 4, 5 & 6 are 5.56, 4.43, 0.56 & 1.19 respectively

The 3^{rd} departure for route 3, 4, 5 & 6 are 6.06, 4.93, 1.06 & 1.69 respectively.

There is more possible nodes. So go to step 2

Step 1: The selected node is node **D**

Step 2: As route 1 and 2 are unassigned, node **D** is possible node

1) Route Y is route i with arrival time of R_{Y1}^{D}, R_{Y2}^{D} , R_{Y3}^{D} =12.93, 13.43, 13.93 respectively.

$X_{1,1} = R_{Y1} - w - T_{3,1}$ $X_{2,1} = R_{Y1} - w - T_{4,1}$

$X_{1,1}$ = 12.93-0.75-7.83=4.35 $X_{2,1}$ =12.93-0.75- 0.5=11.68

The 2^{nd} departure for route 1 & 2 are 4.85 & 12.18 respectively

The 3^{rd} departure for route 1 & 2 are 5.35 & 12.68 respectively

Table 4-10 Departure time to node O, W & D

Departures	Route								
	7	8	9	3	4	5	6	1	2
1^{st} Departures	9.75	11.9	12.37	5.16	3.93	0.16	0.69	4.35	11.68
2^{nd} Departures	10.25	12.4	12.87	5.56	4.43	0.56	1.19	4.85	12.18
3^{rd} Departures	11.75	12.9	13.33	6.06	4.93	1.06	1.69	5.35	12.68

Accordingly as the quantity of import and export freight increases the frequency of transportation by rail & road incorporation and the number of departure times of road and railway vehicles with a time difference “d” will increase.

The decision variable Y_{ijkTR} is defined as:

$Y_{ijkTR} = 1$, for all nodes because of $WT_{mink} \leq (X_{ip} + t_{ik}) - (X_{jq} + t_{jk}) \leq WTmaxk$, $k \in Bij$

The following table summarize the departure time for all route which have simultaneous arrivals at the selected nodes.

Table 4-11 Summery of departure time from all nodes

`Node	Route	Departure time		
		1st	2nd	3rd
D	1	4:21	4:51	5:21
	2	11:40	12:11	12:41
W	3	5:10	5:33	6:03
	4	3:55	4:26	4:56
	5	0:10	0:33	1:03
	6	0:41	1:11	1:41
O	7	9:45	10:15	11:45
	8	11:54	12:24	12:54
	9	12:22	12:52	13:20
A	10	0:00	0:30	1:00
	11	3:57	4:27	4:57
	12	8:10	8:42	9:10
	13	10:22	10:52	11:22
	14	13:54	14:24	14:54
	15	9:39	10:09	10:39
	16	9:12	9:42	10:12
	17	0:51	1:09	1:27

The model described can be extended in various ways; for example, defining weights for each node or for a simultaneous arrival between each two freight vehicle routes (describing situations in which there are major nodes or differences in the importance of freight vehicle routes).

There must be some considerations that must be taken in mind like there are routes which is used by two freight vehicle with the same origin but with different destination. For example the route from Addis Ababa to Bahrdar is shared by both routes to Gonder and Bahirdar from Addis Ababa. These routes obviously have a higher weight when compared with other route with a single destination like Diredawa to Harar.

A relatively easy extension of such a problem is to assign weights to each simultaneous arrival (weights for different lines, time periods, direction of travel, etc.). The objective function will be then to maximize the sum of all weights. Another option is to define a “simultaneous arrival” in different ways. For example, a simultaneous arrival can also be defined as an arrival of two freight vehicle within an interval of **30** minutes as done in this paper which is shown in the preceding tables.

This chapter mainly discusses the simultaneous arrival of freight carrying vehicles from different main cities of Ethiopia to the terminals to portion the freight from Djibouti port.

As the final table shows it is possible to have simultaneous arrival of freight vehicle to each node from each hinterland town of the country.

Chapter 5

Analysis of Freight Transportation Cost

5.1 Model development for freight transportation cost

To custom a reliable multimodal system of freight distribution in Ethiopia it is necessary to integrate rail and road to develop a cost effective and timely system to deliver hinterland bound goods. Therefore this section of the thesis analyze the variation in cost and time involved in transporting cargo to different freight destination of Ethiopia by road and rail along Djibouti corridor.

Model development for road transportation cost among Ethiopian cities

The transportation cost for road transport depends on the distance traveled and the weight of the loaded freight. Thor-Erik Sandberg Hanssen develops a relationship between cost, distance and the product of distance and weight.

$$C_t = \alpha_o + \alpha_1 D + \alpha_2 DW + e \qquad \text{where } \alpha_o, \alpha_1, \& \alpha_2 \text{ are constants } \& > 0$$

As it is explained in the methodology of the research the model that is developed in this research is classified in to two parts for cargo of 20 feet and 40 feet.

Using SPSS it is possible to determine the values of the constants and significance of the variables on the determination of cost.

The output of SPSS is the following.

Result for 20” container.

Variables Entered/Removed[a]

Model	Variables Entered	Variables Removed	Method
1	(weight *distance), distance	.	Enter

a. Dependent Variable: cost

b. All requested variables entered.

Model Summary

Model	Change Statistics			
	R	R Square	F Change	Sig. F Change
1	0.987[a]	0.975	139.223	.000

a. Predictors: (Constant), (weight *distance), distance

Coefficients[a]

Model	Unstandardized Coefficients		Standardized Coefficients	T	Sig.	95.0% Confidence Interval for B	
	B	Std. Error	Beta			Lower Bound	Upper Bound
(Constant)	1564.628	839.157		1.865	.105	-419.664	3548.919
1 Distance	19.672	4.953	.491	3.972	.005	7.960	31.384
(weight *distance)	16.916	3.966	.528	4.265	.004	7.538	26.294

a. Dependent Variable: cost

Based on the result of the SPSS it is possible to write a model that relates the variables with cost.

$C_t = \alpha_o + \alpha_1 D + \alpha_2 DW + e$ Where $\alpha_o, \alpha_1, \& \alpha_2 > 0$

The values of the constants are as follows.

$\alpha_o = 1564.63$ $\alpha_1 = 19.672$ $\alpha_2 = 16.916$

$C_t = 1564.63 + 19.67D + 16.92DW$

Cost is measured in birr, distance in kilometer, and weight in quintal.

Note: The value of "W" in this equation takes the value of one if weight is less than 200 quintal and value of two if weight greater than 200 quintal for 20" container.

SPSS result for 40 feet container.

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.995[a]	.990	.986	1272.30865

a. Predictors: (Constant), (weight*distance), distance

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	T	Sig.	95.0% Confidence Interval for B	
		B	Std. Error	Beta			Lower Bound	Upper Bound
	(Constant)	2066.639	868.267		2.380	.063	-165.312	4298.590
1	Distance	30.677	4.603	.633	6.664	.001	18.843	42.510
	Product(DW)	9.786	2.378	.391	4.116	.009	3.674	15.898

a. Dependent Variable: cost

The value of the constant and the coefficient are α_o= 2066.639 α_1= 30.677 α_2 = 9.786
The model that relate the transportation cost of 40” container with the variables ((weight*distance), distance) is the following.

C = 2066.64+30.68D+9.79DW

The value of R^2 is 0.97 & 0.99 for 20feet & 40feet container respectively.

Cost is measured in birr, distance in kilometer, and weight in quintal.

Note: The value of weight in this equation takes the value of one if weight is less than or equal to 300 quintal and the value of two if weight greater than 300 quintal for 40” container.

Railway transport cost

As the data gathered from Ethiopian railway corporation (ERC) the freight transportation cost is 0.057 US$ per tonKm (1.24 Birr/tonKm) with current exchange rate of 23.71birr/ $1USD. This tariff is dedicated at the feasibility steady of Mekele-Weldiya-Asaita and Ethiopia/Sebeta-Djibouti/Nagad Railway line for the year 2016.

This cost is declared in unit of US$/tonkm or by birr/tonkm but it is possible to change it to the unit of US$/(quintal km) to have a similar unit with the road transportation cost.

C_r= 0.124*D_rW

Where:

C_r = transportation cost in birr
D_r = distance transported by rail in km W = weight of freight in quintal

The intermodal transportation cost model for 20feet and 40 feet container shall be written separately based on the road transportation model.

$C_T = (1564.63+19.67D_t+16.92D_tW^{*}) + (0.124*D_rW) + L\ U$ (*)

$C_T = (2066.64+ 30.68D_t+ 9.79D_tW^{**}) + (0.124*D_rW) + L\ U$ (**)

Where (*) for 20feet container (**) for 40feet container

D_t, distance transported by road in km D_r, distance transported by rail in km

C_T, Transportation cost W, weight of freight in quintal

$W^{*} = 1$ if $W \leq 200$ otherwise 2 $W^{**} = 1$ if $W \leq 300$ otherwise 2

5.2 Validation of the model and multimodal transportation in Ethiopia

Costs and Time variation for Freight Transportation among Ethiopian cities

For rail-road transportation analysis the following information are required:

AVT - the average volume of transportations, in quintals;

D_d - the delivery distance from railway terminal to destination city, in km.

D_r - Distance from the delivery terminal to the sea port and vice versa in km

And the total time of transportation, t calculated as

$t = t_r + t_d+t_u$

Where: t_d - time delivery of goods by road to the railway station;

t_r – time of transporting - during carriage by rail;

t_u- loading and unloading time

$t = D_d/V_d + D_r/V_r+t_u$

V_d – speed of road freight transportation vehicles

V_r – speed of rail freight transportation vehicles

In the interaction between rail and road the data required for the analysis are:

1. Average speed on the main road and out of the main road is 40km/h and 36 km/h respectively.
2. Average speed for freight transport by rail - 80 km/h;
3. Average volume of transporting cargo (AVT) – 20 tons &40 tons or 20feet&40feet container respectively;
4. Handling cost at dry port is 2200 and 4000 birr for 20feet&40feet container respectively.

Note: Current handling cost at modjo dry port is used for the thesis.

To show the analysis of the procedure, take one of the cities of Ethiopia, Jima which is 421 km from mojo and 346 km from comet dry port and consider 310 quintal of 40feet container freight volume.

D_t=346km D_r= 759km W > 300 quintal W^{**} =2

$C_{T =}$ (2066.64+ 30.68D_t+ 9.79D_tW^{**}) + (0.124D_rW) + L U

= 52632.56 birr

The total time taken for inland transportation is determined as follow.

$t_{total} = t_t + t_r + t_u$

$= D_t / V_t + D_r / V_r$

= [(346km)/ (40km/hrs)] + [(759km)/(80km/hrs)]

= 18.13 hrs

For unimodal road transportation operating costs is calculated as follow:

Operating cost = (2066.64+ 30.68D_t+ 9.79D_tW^{**})

2066.64+30.68*(909+346) + (909+346)*2*9.79=65142.94 birr

The difference in transporting a single 40feet container from Djibouti port to jima is 12510.38 birr

The average time of delivery for unimodal transporting system is :

$t = D_{road1} / V_1 + D_{road2} / V_2$

Where:

t – Time of transportation

D_{road1} & D_{road2} – distance along the main and out of the main road respectively.

V_1 and V_2 – speed of vehicle along and out of the main road respectively.

With the road mode of transportation option freight can be transported from point of dispatch or origin O to point of destination or consumption D. see figure 5-1

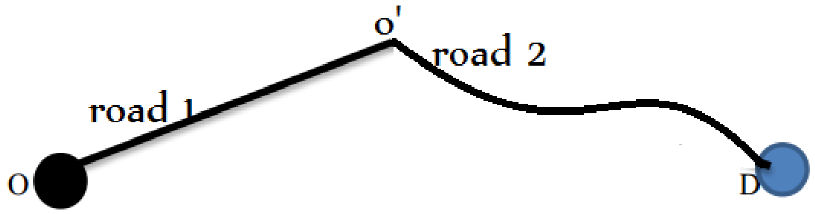

Figure 5-1 The scheme of the road transport relation

Transportation of goods by road, also defined as delivery "from door to door".

Initial data for the analysis of freight transportation by road vehicles are taken from the unimodal transportation carriers of major transport companies. Having these information's it is possible to proceed the analysis as follows.

Note: For this sample analysis the data are taken for road freight transportation from Djibouti port to Jima.

1. Average speed of transportation along the main corridor, with direct delivery of road trucks - 36km/h;
2. Distance of transportation by road (from door to door) - 1255km;
3. Average volume of transportation (AVT) – >300 quintal for 40feet container.
4. Average speed of the truck from the main corridor road line to the selected freight destination – 40km/hr.

Determine the average time of delivery:

$$T = D_{road1} / V_1 + D_{road2} / V_2$$

$$= 909/36+346/40=30.41\text{hrs.}$$

To determine the total cost and time which can be hold back by using multimodal transport system instead of unimodal transportation can be determined using the same procedure for all cities of Ethiopia.

Table 5-1 Unimodal Costs and travel Time from Djibouti Port

From Djibouti port to	Road Distance on main road	Road Distance out of main road	Cost by road	Travel time on main road	Travel time out of main road	Total Travel time
A A	909		47752.98	25.25	0	25.25
Welkite	909	158	55694.06	25.25	3.95	29.2
Jima	909	346	65142.94	25.25	8.65	33.9
Nekemti	909	328	64238.26	25.25	8.2	33.45
D/markos	909	299	62780.72	25.25	7.475	32.73
Bahirdar	909	556	75697.54	25.25	13.9	39.15
Gondar	909	744	85146.42	25.25	18.6	43.85
Mojo	836		44084	23.22	0	23.22
Hawassa	836	200	54136	23.22	5	28.22
Shashmene	836	181	53181.06	23.22	4.525	27.75
Debrezeit	878		46194.92	24.39	0	24.39
Awash	686		36545	19.06	0	19.06
Kombolcha	686	436	58458.36	19.06	10.9	29.96
Weldiya	686	485	60921.1	19.06	12.13	31.18
Mekele	686	686	71023.36	19.06	17.15	36.21
Adigrat	686	793	76401.18	19.06	19.83	38.88
Diredawa	394		21869.08	10.94	0	10.94
Harar	394	20	22874.28	10.94	0.5	11.44
Jigjiga	394	313	37600.46	10.94	7.825	18.77

The construction of railway is in progress and the line from Djibouti port to Ethiopia is already finalized and expects to start service in 2017. As the schedule of ERC the line from awash – weldiya - mekele will be finalized and begun service in 2022.

Table 5-2 Cost and time difference between unimodal & multimodal transportation

Town	Distance (2017GC)		Distance (2022GC)		transport cost and travel time in the year			
					(2017GC)		(2022GC)	
	Rail	Road	Rail	Road	Cost	Time	Cost	Time
A A	784	-	784	-	30136.96	9.8	30136.96	9.8
Welkite	784	158	784	158	40144.68	13.75	40144.68	13.75
Jima	784	346	784	346	49593.56	18.45	49593.56	18.45
Nekemti	784	328	784	328	48688.88	18	48688.88	18
D/markos	784	299	784	299	47231.34	17.275	47231.34	17.275
Bahirdar	784	556	784	556	60148.16	23.7	60148.16	23.7
Gondar	784	744	784	744	69597.04	28.4	69597.04	28.4
Mojo	748	-	748	-	30819.76	9.35	30819.76	9.35
Hawassa	748	200	941	-	40871.76	14.35	38238.68	11.7625
Shashemene	748	181	923	-	39916.82	13.875	37546.76	11.5375
Debrezeyt	764	-	764	-	29368.16	9.55	29368.16	9.55
Awash	681	-	681	-	26177.64	8.5125	26177.64	8.5125
Kombolcha	681	436	1015	-	50157.64	19.4125	41083.24	12.6875
Weldiya	681	485	1056	-	52620.38	20.6375	42659.28	13.2
Mekele	681	686	1324	-	62722.64	25.6625	52961.2	16.55
Adigrat	681	793	1324	125	68100.46	28.3375	59243.7	19.675
Diredawa	311	-	311		11954.84	3.8875	11954.84	3.8875
Harar	311	20	311	20	15026.68	4.3875	15026.68	4.3875
Jigjiga	311	313	311	313	29752.86	11.7125	29752.86	11.7125

Table 5-3 Geometric Mean Analysis of Differential Costs through Djibouti corridor

Town	Cost by road (C_R)	Cost by rail		Cost difference b/n road & rail		$C_x = C_T$ as % of C_R		Log C_X	
		2017GC(C_{T1})	2022GC(C_{T2})	2017GC	2022GC	C_{X1}	C_{X2}	C_{X1}	C_{X2}
A A	47753	30137	30137	17616	17616	176.16	176.16	2.2459	2.2459
Welkite	55694	40145	40145	15549	15549	155.49	155.49	2.1917	2.1917
Jima	65143	49594	49594	15549	15549	155.49	155.49	2.1917	2.1917
Nekemti	64238	48689	48689	15549	15549	155.49	155.49	2.1917	2.1917
D/markos	62781	47231	47231	15549	15549	155.49	155.49	2.1917	2.1917
Bahirdar	75698	60148	60148	15549	15549	155.49	155.49	2.1917	2.1917
Gondar	85146	69597	69597	15549	15549	155.49	155.49	2.1917	2.1917
Mojo	44084	30820	30820	13264	13264	132.64	132.64	2.1227	2.1227
Hawassa	54136	40872	38239	13264	15897	132.64	158.97	2.1227	2.2013
Shashem	53181	39917	37547	13264	15634	132.64	156.34	2.1227	2.1941
De/zeyt	46195	29368	29368	16827	16827	168.27	168.27	2.226	2.226
Awash	36545	26178	26178	10367	10367	103.67	103.67	2.0157	2.0157
Kombolc	58458	50158	41083	8300.7	17375	83.007	173.75	1.9191	2.2399
Weldiya	60921	52620	42659	8300.7	18262	83.007	182.62	1.9191	2.2615
Mekele	71023	62723	52961	8300.7	18062	83.007	180.62	1.9191	2.2568
Adigrat	76401	68100	59244	8300.7	17157	83.007	171.57	1.9191	2.2345
Diredawa	21869	11955	11955	9914.2	9914.2	99.142	99.142	1.9963	1.9963
Harar	22874	15027	15027	7847.6	7847.6	78.476	78.476	1.8947	1.8947
Jigjiga	37600	29753	29753	7847.6	7847.6	78.476	78.476	1.8947	1.8947
						TOTAL		39.468	40.934

The above table shows the differential costs analysis between road and rail from Djibouti seaports to hinterland towns linked by both rail and road transport systems.

Table 5-4 Travel time difference between unimodal and multimodal transport

Town	Unimodal travel time	Multimodal travel time		Unimodal-Multimodal Travel time difference	
		2017	2022	2017	2022
A A	25.25	9.8	9.8	15.45	15.45
Welkite	29.2	13.75	13.75	15.45	15.45
Jima	33.9	18.45	18.45	15.45	15.45
Nekemti	33.45	18	18	15.45	15.45
D/markos	32.73	17.28	17.28	15.46	15.46
Bahirdar	39.15	23.7	23.7	15.45	15.45
Gondar	43.85	28.4	28.4	15.45	15.45
Mojo	23.22	9.35	9.35	13.87	13.87
Hawassa	28.22	14.35	11.76	13.87	16.46
Shasheme	27.75	13.88	11.54	13.88	16.21
De/zeyt	24.39	9.55	9.55	14.84	14.84
Awash	19.06	8.513	8.513	10.55	10.55
Kombolch	29.96	19.41	12.69	10.55	17.27
Weldiya	31.18	20.64	13.2	10.54	17.98
Mekele	36.21	25.66	16.55	10.55	19.66
Adigrat	38.88	28.34	19.68	10.54	19.21
Diredawa	10.94	3.888	3.888	7.053	7.053
Harar	11.44	4.388	4.388	7.053	7.053
Jigjiga	18.77	11.71	11.71	7.058	7.058

Table above depicts the differential temporal analysis between road and rail from Djibouti seaports to hinterland towns linked by both railway and roadway transport systems between the year 2017 and 2022GC.

Table 5.3 above shows a comparison of cost and travel time between the using only road transports to complete the sea leg journey with a proposed rail-road system. For instance, the cost of transporting 40 tons of consignment using road transport from Djibouti seaport to Dire Dawa is birr 21869 with delivery time 10.94hrs whereas rail is expected to cost birr 11955 with delivery time 3.88 hours, which has a difference in transportation cost of 9914birr or 45.33% reduction in cost and a time difference of 7.06hr. For Hawassa with a distance of 1036 kilometers by road, it takes an average time of 28.22 hours and birr 54136 to deliver cargo from Djibouti port but for the rail-road is expected to cost birr 40872 with delivery time 14.35 hours in 2017GC when the construction of Mojo to Moyle line is under construction. But after the construction of mojo-Moyle line which passes through Hawassa is broken up in the schedule time of 2022GC the railway line stretches in some amount when compared to the year 2017GC.

Therefore the transportation cost reduces from 40872 birr to 38239 birr and the transportation time also decreases from 14.35hr to 11.76 hr.

For the long journey from Djibouti port to Mekele the unimodal road transport system takes a cost of 71,023 and a transportation time of 36.21hr. But for multimodal transport i.e. rail transport from Djibouti to awash which cover distance of 681 km and a road transport from Awash to Mekele for a distance of 686 km costs 62723 birr and takes 25.66hr up to the year 2022GC. Afterward the constructions of the line from Awash to Mekele is over and switch for service which reduce the road transport service and shift to rail transportation service to serve in cost of 52961 birr and in delivery time of 16.55 hr. The cost that can be saved if multimodal transport is used are 13472, 13440.4, 14571.2, 11673.6, 13472, 12295, 7268.8 and 7264.8 for Addis Ababa, Welkite, Kombolcha, Weldiya, Mekele, Adigrat, Diredawa and Harar respectively.

Furthermore, the differential costs are subjected to Geometric Mean (GM) test to ascertain the overall average percentage difference in costs saved by moving goods from the seaports using rail-road system rather than the sole reliance on road haulage. According to Schuyler, (2005 GC) and Robinson and Schneider, (2007 GC) when percentage differentials are valuable to a study and/or when costs and temporal requirements are expressed in ratios or percentage of previous measurements, the correct average to use is the geometric mean. Table 5.3 presents the GM analysis of the differential costs freight transportation on the Djibouti corridor. The results presented reveal that the value of the differential by pier-rail-road compared to only pier-road distribution of hinterland bound goods is 19.39%, and 42.56% Eq. (1) through Eq. (4).

$$logGM_1 = \frac{\sum(logC_{X1})}{n} = \frac{39.468}{19} = 2.077 \quad (1)$$

(Antilog 2.077=119.39) (2)

119.39-100 = 19.39%

$$logGM_2 = \frac{\sum(logC_{X2})}{n} = \frac{40.9343}{19} = 2.154 \quad (3)$$

(Antilog 2.154 = 142.56) (4)

142.56-100 = 42.56%

The implication of this result is that 19.39% of the freight costs could be saved if hinter land bound goods is conveyed in a multimodal pattern from Djibouti seaport to the city center of the hinterland locations on this route. And also the proposed line from Awash to Mekele is completed the cost that is saved will increase to 42.56% if the cities that are mentioned in this paper are choose the railway line as freight delivery means. Indeed, economic and reliability considerations dictate that road ought not to be the choice in inter-regional movement of hinterland goods. There is therefore the need to adopt a reliable coordinated rail & road multimodal freight transportation system.

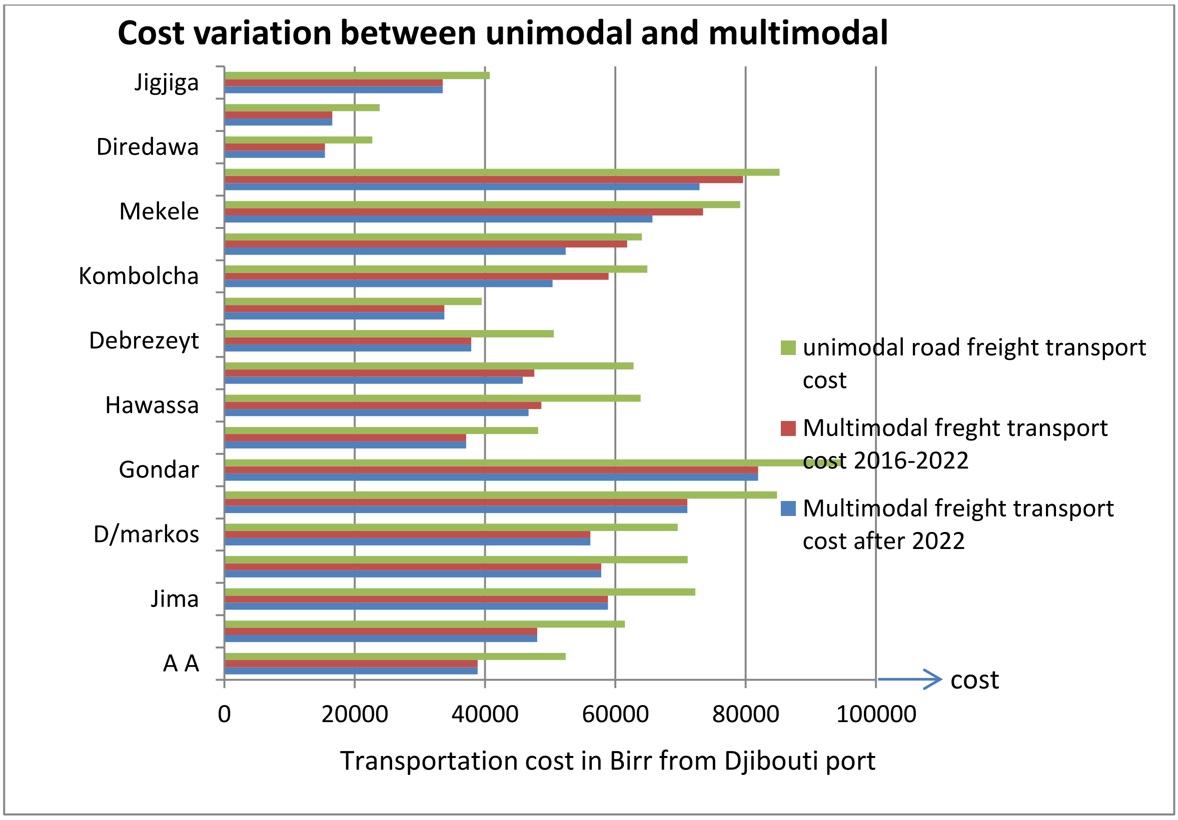

Figure 5-2 Variation of cost between multimodal and unimodal

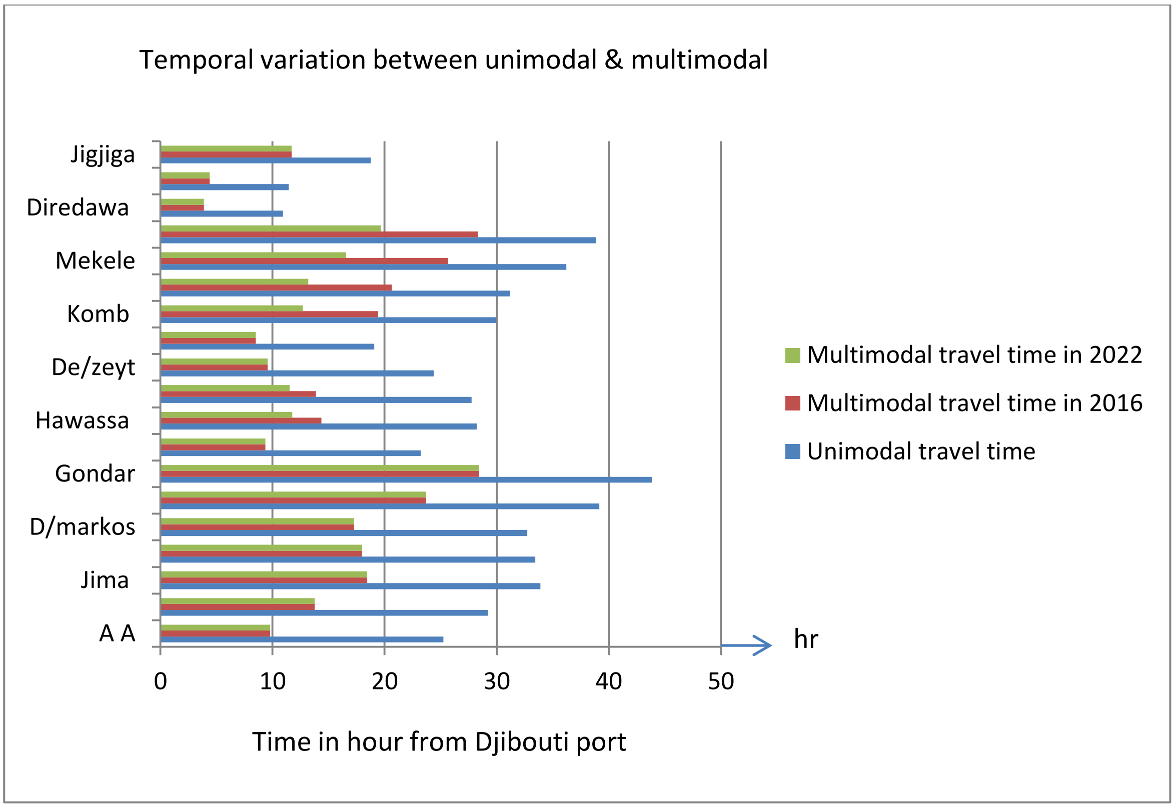

Figure 5-3 Temporal variation of freight delivery

Chapter 6

Conclusion and Recommendation

6.1 Conclusion

This study has shown that the potentials of coordinated rail & road in port-hinterland towns of Ethiopia freight transportation would be beneficial to the economic development of the country. The result of this research show 19% & 42.56% of transportation cost can be saved if multimodal transportation system used instead of the current unimodal transportation system in the years 2017 & 2022GC. It is therefore important that efforts should be geared towards sustaining the emergence of a reliable transportation system that is characterized by timely, safe, efficient and cost-effective method of freight distribution.

A total of 310 wagons and 10 trains in each day of a year 2017GC is required.to transport the total freight using railway line. Containerized freight takes the higher amount of these wagons and trains, 79% of the wagons are subjected to transport containerized freight.

Even if containerized freight has higher volume, the break bulk has a higher growth rate of 19.95% whereas containerized freight has the growth rate of 8.9%.

The freight transportation time from Djibouti port to different towns of Ethiopia minimized and the transportation time can be saved, to mention the transportation time from Djibouti to Addis Ababa and Gondor using Unimodal transport are 25.25hr & 43.5hr respectively. But this time is reduced to 9.8hr & 28.4hr by using multimodal (rail and road) transport system.

This research also demonstrated in clear term that coordinated rail & road transport from Djibouti seaports to the hinterland of Ethiopia would reduce freight transportation cost, the time of delivery and unnecessary operational delays and reduce the pressure on Ethiopian roads.

Synchronization of freight vehicle in dry ports like mojo reduces the waiting time from two days to thirty minutes for loading and unloading.

As shown in the validation part of this paper combined transport, is economically competitive if the transport distance by rail is long enough like Addis Ababa to Djibouti.

6.2 Recommendation

As stated in the feasibility study of Addis Ababa-Djibouti railway line by Ethiopian Railways Corporation, September, 2012 with the concentrated direction of freight transportation, the organization of freight trains mainly comprises non-stop trains to deliver the freight without delay. Pick-up and drop trains shall be organized for local freight transportation along the line. To facilitate and save the time of import and export freight transportation there should be an access of minimum de-marshaling and marshalling time of railway vehicles at selected terminals.

The road and railway vehicles should be loaded and unloaded at the freight transport origin and destination. To implement the assumption and analysis results in the actual freight transportation it is necessary to have well organized loading and unloading machineries and skilled manpower at each selected railway terminals and dry ports. At each selected terminals loading and unloading should be done for each vehicles in parallel with other vehicle which arrive at the same time. Moreover, liaison offices of the concerned companies should be established at the dry ports and railway terminals & in addition to this simplified documentation should be done increasingly by electronic means such as electronic data interchange.

The freight transportation of Ethiopia till now is mainly depends on road but now the government is constructing railway line through the different part of our country. According to this research the railroad freight transportation integrations on Djibouti corridor is cost effective and time saving; moreover, it is environmentally friendly. Local contractors and consultants are better to build their capacity in order to carry out projects in relation to railways. Similarly, government and private metal manufacturing industries should upgrade their technologies to produce necessary parts in the construction of railway lines.

Hence, the following recommendations are given:

- The construction of the railway line should continue throughout our country to facilitate the import and export of the country and save foreign currency from seaport expenses of neighboring countries.
- The forecasted freight should be balanced with the available railway vehicles and road vehicles in each year.
- Since our country is reach in the production of hydroelectric power electric driven railway vehicles should better to be used in the transportation sector.
- Most of the import and export freights better to be done by railway vehicles because of the fastest time and the higher carrying capacity.
- In the future most of the long distance freight transportation will be covered by railway vehicles. Hence, policies better to be set in such a way that the road vehicle should cover under developed door to door local freight transportation of our country.
- The access of highly modernized loading and unloading machineries, well organized warehouse, dry ports, railway terminals and electronically controlled information management system, skilled manpower should be availed by the government, and concerned companies for the success of the country's integrated freight transportation.

A challenge may face the railway to establish operating plans that provide sufficient flexibility to reasonably adjust to short term market fluctuations and unanticipated disruptions within the logistics network at an acceptable level of financial risk. The railway should be ready to compensate for these types of events by continually measuring their performance to plan and assessing and adjusting their operations to maintain service consistency for customers and fluidity within their own networks.

REFERENCE

A. Ceder , B. Golany, & O. Tal. (2000, July 1). Creating bus timetables with maximal synchronization. Transportation Research Part A 35 (2001) .

Andrew , E. U. (2011). The Potentials of Rail-Road Integration for Port-Hinterland.

Andualem, S. G. (2015, April). Retrieved 2016, from The EastAfrican: http://www.theeastafrican.co.ke

Bo-Lennart , N. (2000). Competition and co-operation between railways and trucking in long distance freight transport.

Douglas, L., James, S., & Lisa , E. (1998). Fundamentals of Logistics Management.

Dr Jean-Paul, R. (2009). Forms of modal competion and coplementation. Geograohy of transport system.

H J Stander, & W J Pienaar. (2002). Perspectives on Freight Movement by Road and. 21st Annual South African Transport Conference South Africa,.

Hyman, A. (1998). Multimodal Corridor and Capacity Analysis Manual.

Johan , W., Violeta , R., & Kenth , L. (2004, September). The Dry Port Concept connecting Seaports with their Hinterland by Rail.

Krueger, H. (1999). Parametric Modeling in Rail Capacity Planning:Proceedings of the 1999 Winter Simulation Conference.

Martin , H. (2007). Strategies for Improving the Performance of Intermodal.

Palmer, D. (2008). Strategies for Improving the Performance of multimodalism in freight transport in USA .

Powel, W. (2003). Dynamic models of transportation operations. Handbook on Operations Research and and management science.

Ruijia, S., Zhimin, H., & Yangfan , Z. (2014). Research on Railway Freight MarketShare Based on the Whole Process of Transport. The 9th International Conference on Traffic & Transportation Studies (ICTTS'2014). Beijing.

United Nations Transport Issues. (2003). Transit Transport Issues in Landlocked and Transit Developing countreis.

Vadim , S. (2010). Comparison of Different Transportation Modes for freight transport.

QGI Consulting, (2010) Railway Demand Forecasting and Service Planning Processes

Humels, D. (2001) The Nature and Growth of Vertical Specialisation in World Trade. Journal of International Economics.

Bierman, H., Bonini, C., & Hausman, W. (1991). Quantitative Analysis for Business Decisions. 8th ed. Richard D. Irwin Inc., Homewood, Illinois.

Appendix I

Questioner for respondent drivers of freight vehicle

The aim of the questioner is to determine average speed of freight transporting vehicles in Ethiopia

Please just fill the time taken to drive from the given origin to the specified destination. Please you just fill only for the route you drive.

Note: The time should exclude time for lunch, catnap and sleep

Name of the driver: …………………………………………..

Origin	Drive to (destination)	How many time you drive	Time taken			Average speed
			1st jorney	2nd jorney	3rd jorney	
Modjo	Gondar					
	Mekele					
	Kombolcha					
	Bahirdar					
	Jima					
	Hawasa					
	Nekemt					
	Dilla					
	Adama					
	Diredawa					
	Harar					
	Debrezeit					
Addis Ababa	D/markos					
	Shire					
	Axum					
	Kibremengest					
	Assosa					
	Hosanna					
	Welkite					
	Jima					
	Debrezeit					
	Bahirdar					
Djibouti	Addis Ababa					
	Modjo					
	Diredawa					
	Awash					
Diredawa	Jigjiga					
	Harar					

Appendix II

Interview Question

The aim of the interview is to estimate the waiting time, travel speed, factors affecting the speed and transportation cost.

Company name…………………………………………….

1) Level of the company
a) 1 b) 2 c) 3 d) 4 e) other

2) Total Number of vehicle…………

3) Does your company involve in transportation of freight from Djibouti to Ethiopia and vice versa?
a) Yes b) No

4) For how many days your vehicle stay at Djibouti port before loading
a) < 1 day b) 1-2 c) 2-4 d) 1 week e) > 1 week
f) any other?

5) In average how much time does your vehicles take to travel from Djibouti to Addis Ababa.

6) For how many days your vehicle stay at Modjo dry port before unloading
a) < 1 hr b) 1-2hr c) 2-4 hr d) 1 day e) 2day f) any other?

7) What is the maximum tolerable waiting time at Modjo dry port before loading?
a) 0.5 hr b) 1 hr c) 2hr d) 0.5 day e) 1 day

8) What is your expected maximum waiting time at the dry port when your vehicles integrate with the railway line?
a) 0.5 hr b) 1 hr c) 2hr d) 0.5 day e) 1 day

9) What is the current handling cost of freight at the dry ports or at modjo?
a) By ton? b) TEU c) vehicle

10) What are the major cause of freight transportation delay through Djibouti port
a) Shortage of freight vehicle c) management problem
b) Road congestion problem d)

11) What are the major problem at the transition station or at dry port
a) Shortage of loading and unloading machine.
b) Congestion of loading station
c) Synchronization problem

12) What are the major determinants of freight transportation cost?
a) Distance b) weight c) road condition d) type of goods

Appendix III

Transportation costs used in the analysis which are gathered from different company are listed below.

ESLSE

Origin	Weight of freight	Tariff to AA (birr)	Tariff to Modjo
Djibouti	≤ 250	120	114
	≤ 300	111	104
	≤ 400	105	98

Elshadai Transport Company

Origin	destination	Tariff for 40feet		Tariff for 20feet	
		<300 qu	>300 qu	<200 qu	>200 qu
	Gondar				
	Welkayt	53100	56700	48000	50550
	Bahirdar	28900	30000	24200	25000
	Shashemene		9440	8940	8440.5
Modjo	Kombolcha				
	Addis Ababa	5320		3800	
	Sebeta	7445	7995		

Appendix IV

Freight which deliver to Ethiopia through Djibouti port. This data used to forecast or to estimate the number of train unit.

SN	Service type		Annual operational performance				
		Unit	2004	2005	2006	2007	2008
1	**Shipping service sector**						
1.1	Total import cargo	Ton	3062330	3018969	2767053	3340135	4966265
1.2	Own vessel	Ton	483858	579416	1104813	998597	952628
1.3	Slot carriers	Ton	2578472	2439553	1662240	2341538	4013637
1.4	Containerized	TEU	128692	117238	130638	142724	176749
1.5	Containerized by multimodal	TEU		82067	107968	125581	152509
1.6	Vehicle	No	18389	20165	20839	22207	21384
1.7	Vehicle by multimodal	No			17220	19153	19184
1.8	Steel	Ton	626303	490942	553971	374509	814141
1.9	Break bulk	Ton	493816	869419	759957	1257896	1027431
1.10	Cross trade	Ton	202062	75000	445707	306214	61912
1.11	Export cargo	Ton	492	1082	1351	10706	734
2	**FREIGHT FORWARDING SECTOR**						
2.1	Containerized by inland transport	TEU		67389	88559	120404	175672
2.2	Vehicle by inland transport	No		3389	4225	10636	14776
2.3	Import cargo by unimodal	Ton	2895577	2050801	2271403	2665725	3719205
2.4	Export cargo by unimodal	Ton	250702	268570	217132	230329	274043