ADDIS ABABA UNIVERSITY

ADDIS ABABA INSTITUTE OF TECHNOLOGY

SCHOOL OF MECHANICAL AND INDUSTRIAL ENGINEERING

RAIL-ROAD INTEGRATION FOR FREIGHT TRANSPORTATION ALONG DJIBOUTI CORRIDOR

A Thesis Submitted to the School of Graduate Studies of Addis Ababa University in Partial Fulfillment of the Degree of Master of Science in Rolling Stock Engineering

By

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List of Acronyms

UNCTAD	United Nations Committee on Trade and Development
MTO	Multimodal Transport Operator
ESLSE	Ethiopia Shipping and Logistics Enterprise
ERCA	Ethiopia Revenue Customs Authority
ERC	Ethiopia Railway Corporation
GDP	Gross Domestics Product
GTP	Growth and Transformation Plan
GHG	Green House Gas
EU	European Union

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Many people have generously cooperated and contributed for the success and completion of this thesis. My special thanks, first and foremost, goes to Dr.-Ir. Eshetie Berhan, my thesis supervisor. In his capacity as my advisor, Dr.-Ir. Eshetie Berhan, whose work ethic is worth modeling, closely followed my progress corrected and improved the manuscript with valuable comments. I would not hesitate to state that the merit that is in this paper is on account of the supervision of my advisor. I am deeply grateful for the encouragement and help offered by him.

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I would like to dedicate this thesis to my parents, Koyehu Kebede and Alemitu Chanie, my brother Demeke Koyehu, my wife Genzeb Ayalew and my daughter Bitania and my son Abe. None of this would have been possible without their love and patience. They have always supported, encouraged and believed in me.

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Abstract

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. Multimodal transport between road and rail, also known as combined transport, has received a large interest in recent years as part of a possible solution for a sustainable and efficient transport system. Hence, this study focuses on the model development and analyse the model validation of the potentials of integrated rail-road freight transportation of Ethiopia from Djibouti port to Addis Ababa and other major cities. Much of the primary data is obtained through the administration of a questionnaire specifically designed to gather information on the cost involved, distanced covered, area coverage, amount of tonnage during import and export, problems during loading and unloading and time taken to deliver cargoes to consignees. The respondents that are selected systematically for this study are traffic officers of major transport companies. Secondary data sources were obtained from the interviews of major transport companies operation, technical and marketing managers such as from Trans Ethiopia PLC, Ethiopian Railway Corporation, Ethiopian Shipping Lines and Logistics Enterprise and from Ministry of Transport.

The data set are combined with the model development and validation to create the full model of the transport system used to answer the research questions; and contains the system size, transport demand, infrastructure and geographical data (rail network, road network, terminals, demand points, etc.), equipment (trucks, trains, etc.), costs data, environmental data, time windows, etc. The data are analyzed using Geometric Mean analysis.

The findings of this paper reveal that integrating rail-road for hinterland bound goods would be potentially save 42.67% freight costs and time of transportation than that of using unimodal transportation i.e. road transportation. Furthermore, the emission of greenhouse gases can be minimized with 218.42% when freight transportation is done by road-rail integrations. The implications of these findings are that 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 and less emission.

Chapter 1

1.1 Introduction

Economic transformation, and indeed, the development of any country are hardly possible without an efficient transport system [2]. Among the transport systems Rail-road freight transport acts as a means of reducing the increasing freight traffic in cities and freight gateways (e.g. ports, terminals) more especially as trades are rapidly crossing national and international boundaries. 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 [1]. In Europe for instance, multimodal freight transport has been considered as the most prospective, competitive and environmentally friendly alternative to unimodal road freight transport in medium to long distance corridors[2], with investigations of rail-road multimodal transport gradually emerging as the most innovative area of freight transport research [2]. The major reason for this trend is the desire to minimize freight transport costs and time spent in hauling cargoes to destination points. It is therefore not surprising to observe that in such countries, the major object of contemporary policy measures aimed at redistributing freight volume is in favour of rail-road intermodal system from departure zones to destination points rather than the sole reliance on unimodal systems, particularly road.

Over the years, however, due to oldest and inefficient Ethio-Djibouti railway service very little attention is given to the integration of freight transportation. The primary purpose of this paper is to analyze the new Ethio-Djibouti railway and road freight transportation integrated approach for freight delivery as a veritable means of cargo distribution in completing the journey from the seaports to dry land port and other locations in Ethiopia along Djibouti corridor. This is with a view to assessing the potentials of integrating the different modes as a vital option of solving the inherent constraints facing rail-road freight truck drivers [2]. The road network has the advantage of being able to access almost any location and also of being very flexible, while rail networks have the ability to transport goods long distances at a low cost. A combination of the two networks could, thus, reduce the cost of transport [5]. Rail-Road Integration for Freight Transport in Ethiopia will have greatest advantage in interregional flow of goods and that efficient flow of internationally traded goods require an effective multimodal transport with government assistance. This is because goods should be transported from origin to destination at minimal cost.

1.2 Problem Statement

Similar to other emerging nations the infrastructure in Ethiopia is under developed and also the land locked population is constrained by supply chain bottlenecks at the seaports [3]. High cost of charges due to the impact of illegal brokers who act on the behalf of transporters and importers/exporters, reduced free time for imported cargos and inadequacy of storage facilities are some of factors that exaggerated Ethiopia's total logistic cost for its import and export of commodities, according to the study by UNCTAD.

The country's major freight transport road vehicles in terms of size, age and capacity, are not sufficient to support the growth in the economic activities. With economic growth, the demand for freight transport soared and consequently shortages and congestion problems surfaced due to the inefficiency of screening machineries, failure in the system, lack of skilled manpower to operate the machineries at the Ethiopian Custom and Revenue checking points and also congestion occurs at main traffic dense cities along the main Ethio-Djibouti corridors. Moreover, due to increments of import and export of the country freight transportation by road is becomes time consuming, high transportation cost and difficult to manage it. [7]

There is dalliance of unloading and loading due to lack of well-organized planning of machineries, manpower and also there is poor communication with regard to truck arrival at the customers' warehouses.

On the sides of importers and exporters even if they are complaining the transporters service efficiency they are not paying fee for service of transportation and unable to load and unload the cargoes on time as per their promises.

The increased road transport also raises environmental concerns. Although the development of cleaner and more efficient engines is progressing rapidly, the problem of carbon dioxide (CO2) emissions from fossil fuels remains to be solved. A study published by the IRU17 shows that combined transport causes, on average, 20-50% less CO2 emissions than all-road transport on 19 tested European routes. [5]

In general the constraints associated with freight transportation in Ethiopia could be characterized as follows:

- Under development of logistics management system
- Inadequate fleets of vehicles (means of transport) for goods transport
- The market possibility of the country is hampered by poor logistics system
- Very high traffic accident (the highest in the world) in which contribution of goods transport is significant
- Congestion in cities and at inlets/outlets
- Lack of coordination of goods transport (which resulted in low load rate)
- No or little study has been made related to cargo freight transportation in Ethiopia
- Lack of Organization and management tools that are required to promote multimodal system

1.3 Objective of the Study

The primary purpose of this paper is to model and analyse the validation of the potentials of rail-road integrated approach for freight delivery as a veritable means of freight distribution in completing the sea leg journey from the seaports to hinterland locations in Ethiopia along Djibouti port corridor. This is with a view to assessing the potentials of integrating the different modes as a vital option of solving the inherent constraints facing shippers and haulage operators. In doing so however, this work seeks to determine the costs, temporal, and emission variation involved in freighting goods using combined rail and road in contrast to the present unimodal system of freight distribution. Moreover to assess the current status of freight transportation practice in Ethiopia with the aim of identifying the gaps, potentials and constraints for development of effective and efficient logistics systems.

The specific objectives are

- To study seasonal tonnage of import and export freights
- To determine the costs and temporal variation involved in freighting goods using combined rail and road in contrast to the present unimodal system of freight distribution.
- To forward recommendations based on the analysis made.

- To do transportation scheduling, modeling of the networks and to find means of integration of the different modes of transport especially rail and road freight transportation.

1.4 Scope and Limitation of the Study

According to the future plan of Railway Corporation of Ethiopia the railway network will expand to the other neighboring countries but for this study rail-road integration from the sea port Djibouti to the dry ports and main cities of our country along the corridor of Djibouti port is dealt.

The major limitation that can be encountered in carrying out the rail-road freight transport study is availability and sufficiency of data on volume of freights, transportation tariff, and fleet size. Besides, since the emphasis of the study is on Djibouti corridor, it excludes other corridors freight transportation.

1.5 Significance of the Research

As a research, the primary merits of the study goes to Ethiopia Railway Corporation future research center. This will also develop awareness for the importance of research center in this field since there are a lot studies has to be done in the area, 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 companies future cost effective, time saving and integrated transport service

Chapter 2

Literature Review

Doctoral thesis which is published in 2007 G.C by Jonas Floden 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 analyse the modal split between road transport and intermodal road-rail transport and it meets the requirements of being both practically useful and theoretically satisfactory.

Muh Patrick Tatambunkah in 2007 G.C adopted the principles and characteristics used in passenger trains, airlines and hotel industries into intermodal line train systems to develop a simulation model. Using his developed simulation tool, he examined the performance of an intermodal line cargo train system with respect to the dynamic and constant pricing strategy.

His prime objective was to investigate and answer the questions which pricing strategy leads to the best space utilization and performance of an intermodal line train cargo system? His simulation results show that the dynamic pricing gives the best space utilization and rail freight performance. Dynamic pricing strategy appears good to both the train operators, in term of the revenue generated, and the freight transporters as they achieved reduced transport cost and freights accommodation at train stations different from their closest train stations.

In Sweden on November 2013 Martin Heljedal 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.

Journal of the Eastern Asia Society for Transportation Studies, Vol.5, and October, 2003 by (Harun al-Rasyid S. LUBISL, Bambang Budi PRASETYO, Samuel ELIM, and YOHAN) reported the progress of ongoing research on multi-modal freight transport network modeling. STAN, a regional strategic analysis and planning of freight transportation software, is verified and used to produce an overall estimation of the movements of freight of all products, by all of the modes available.

A Master Thesis by Martin Fuchsberger addressed the problems of generating conflict-free train routings and train schedules in main station areas. Two existing models are presented as work in this field has been done. Then an improved model based on an integer multi-commodity flow formulation incorporating railway topology, passing times, and speed profiles of trains is proposed.

Jian Liu on August, 2003 in his dissertation studied several real-life transportation scheduling problems that are of great importance for railroads and airlines. He presented an integrated model for the locomotive scheduling problem and proposed two approaches to solve the railroad blocking problem. He studied extensions and generalizations of combined through and fleet assignment models. The main focus of his dissertation is to model these problems with realistic constraints and solve the real-life instances of those models with modern optimization techniques. The major solution approaches developed in this dissertation are based on Very Large Scale Neighborhood (VLSN) search, which is a heuristic approach but works very well for real-life instances. The computational tests for those problems are performed on real-life data from major U.S. transportation carriers. The results reveal that the models and solution approaches developed in this dissertation are practically implementable and capable of generating significant economic impact on transportation industries.

Martin Fuchsberger in Switzerland, Zurich in his winter term 2006/2007 thesis study addressed the problems of generating conflict-free train routings and train schedules in main station areas. Two existing models are presented and then an improved model based on an integer multi-commodity flow formulation incorporating railway topology, passing times, and speed profiles of trains is proposed.

2.1 Multimodal Transportation Overview

From the operational stand point, multimodalism is the product of the widespread use of containers for the carriage of cargo and of technological advances that permit their integrated use of various modes of transportation. 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. Containers will ensure the transport of unitized cargo from its origin to its final destination, with efficiency and least possible risk. In the true multimodal movement, the shipper need only deal with one party to arrange for the entire shipment. [8]

The terms ‘Through Transport’, ‘Combined Transport’, Intermodal Transport’ and ‘Multimodal Transport’ are all used in the context of cargo movement, from origin to destination. These four terms have very similar meanings, i.e. the transportation of goods by more than one mode of transport and a through freight rate. However, the United Nations made a distinction between each term and introduced definitions of transportation terminology in their Multimodal Transport Handbook (1995):

• ***Modes of Transport***: The method of transport used for the movement of goods, e.g. by rail, road, sea or air.

• ***Means of Transport***: The vehicle used for transport, e.g. ship, truck, or aircraft.

• ***Types of Means of Transport***: The type of vehicle used in the transport process, e.g. wide-body, tank truck, passenger vessel, etc.

• ***Unimodal Transport***: The transport of freight by one mode of transport only, where each carrier issues his own transport document (B/L3, airway bill, consignment note, etc.).

• ***Combined Transport***: The transportation of goods in one and the same loading unit or vehicle by a combination of road, rail, and inland waterway modes.

• ***Intermodal Transport***: The transportation of goods by several modes of transport where one carrier organizes the whole transport from one point or port of origin via one or more interface points to a final port or point. For Mahoney (1986), “Intermodality” means the movement of freight via two or more dissimilar means of modes of transportation while for Hayuth (1987), “Intermodality” means the movement of cargo from shipper to consignee by at least two different modes of transport under a single rate, through-billing, and through liability. The term "intermodality" has been widely adopted by European Union policy-makers.

Multimodal Transport: Where the carrier organizing the transport, takes responsibility for the entire door-to-door transport and issues a multimodal transport document.

Multimodal transport is therefore a concept (see Figure 2.1) which places the responsibility for transport activities under one operator, who then manages and co-ordinates the total task from the shipper's door to the consignee's door (see figure 2.2), ensuring the continuous movement of the goods along the best route, by the most efficient and, cost-effective means, to meet the shippers requirements of delivery. This means simplified documentation, and increasingly by electronic means such as electronic data interchange.

Origin/Supplier Destination/Customer

Physical Base

Depot	Road/Rail	Terminal	Sea Trunk/Leg	Terminal	Road/Rail	Depot

Commercial System

Cost & Delivery	Pack	Inland Movement	Papers	Port to Port	Papers	Inland Movement	Unpack	Cost &Delivery

Management & Co-ordination

Packing	Container Positioning	Inland Movement	Terminal Operations	Ship Stowage /Route Scheduling

Flow of Information

Booking	Waybill	Invoice	Manifest	Delivery instruction	Release of cargo

Liability Network

Forwarder	Road	Rail	Terminals	Sea	Forwarder

Figure 2.1 Components of a multimodal transport system (Adapted from D'Este)

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.

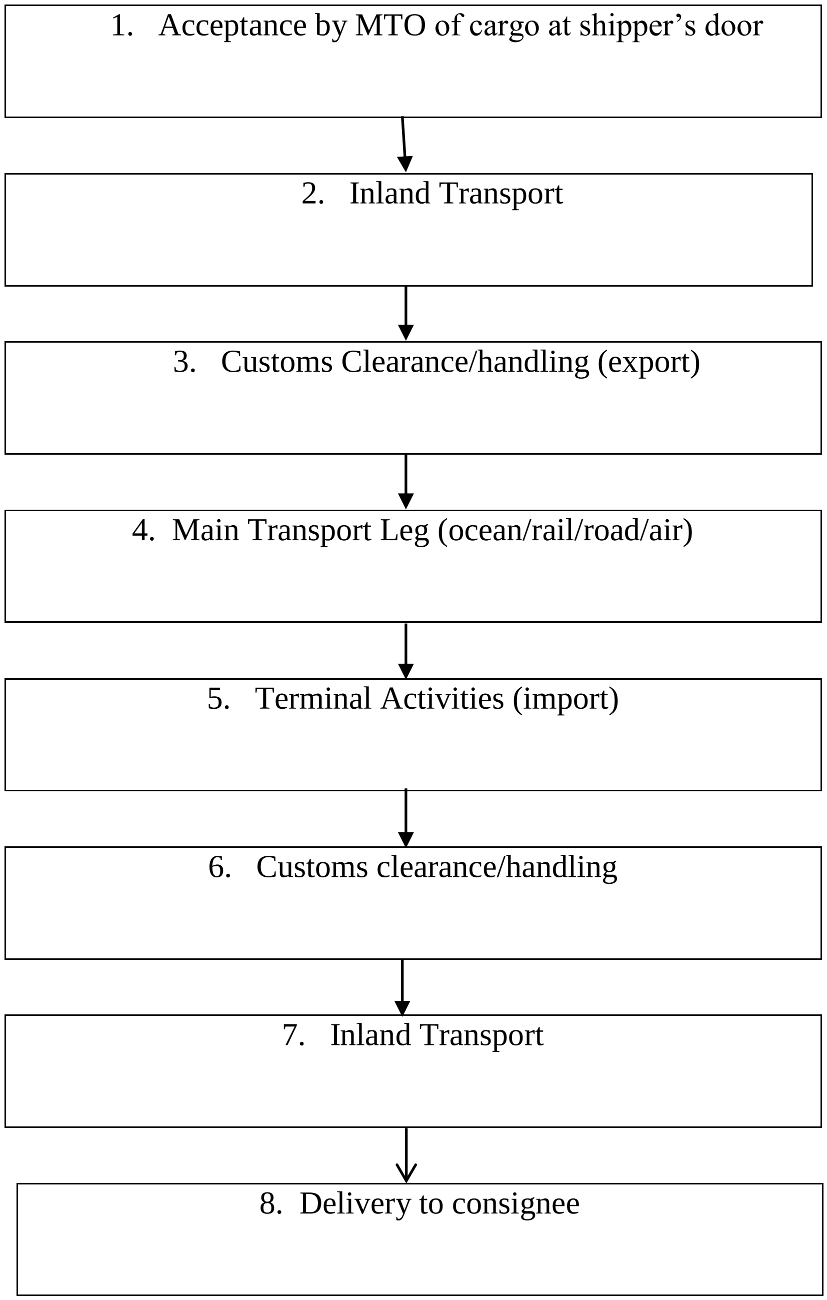


Figure 2.2 Typical steps in the transport chain (Source: 1992 UNCTAD)

The MTO is the only responsible party that is able to co-ordinate all modes of transport and organise multimodal transport. Shippers and consignees are not capable, nor do they have the time to determine the best route or the best price, as they do not have the MTO's expertise in transport management. They also do not have the capability to determine, forecast and even to solve problems that might occur to their cargo during transit (see figure 2.3).

Multimodal Transport

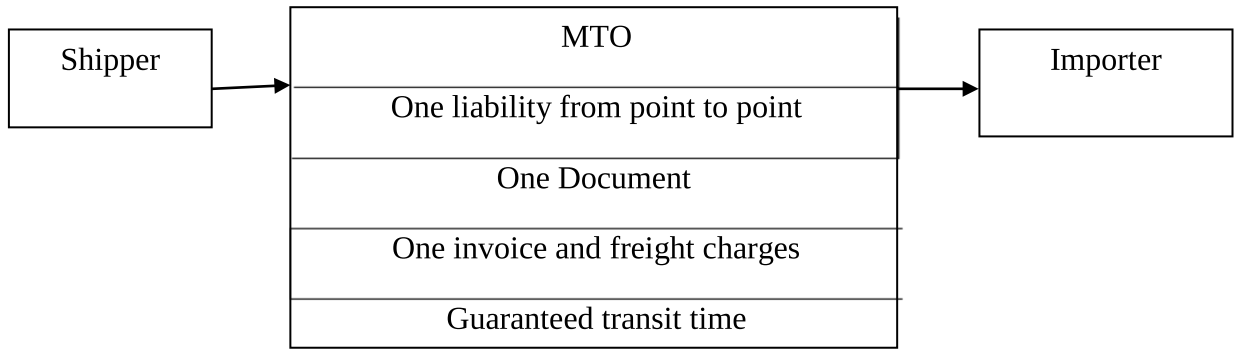


Figure 2.3 Multimodal freight transport (Hayuth, 1987)

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. An optimal transport system could, therefore be planned, developed and operated by properly taking into account the interaction between traffic (demand) and transport (supply) and its intermodal mix based on the inherent advantages and resource costs of different modes of transport.

There are six transport mode performance characteristics living in any transportation selection decision [11]:

1. **Speed**: The ability to transport product from one point in the distribution pipeline to another as quickly as possible is, by far, the fundamental performance characteristic of transportation. Speed provides the marketing utility of time to distribution and ensures place utility. In detail, the speed of any given transport can be defined as the time required moving product from the production source to a terminal, loading the product on to the transportation vehicle, traversing terminal point, and delivering the products to the receiving terminal.

2. Completeness: These performance characteristics refer to the ability of the transport mode to move inventory from one location to another without the use of other modes. This is critical because the less material has to be handled between the point of origin and the point of destination, the lower the transport cost and the shorter the delivery time. For example, if material was shipped by rail and the company did not have a rail siding, a second mode, most likely motor carrier, would have to receive the load from the rail carrier, and then transport it to the company where it would have to be unloaded again for final receipt.

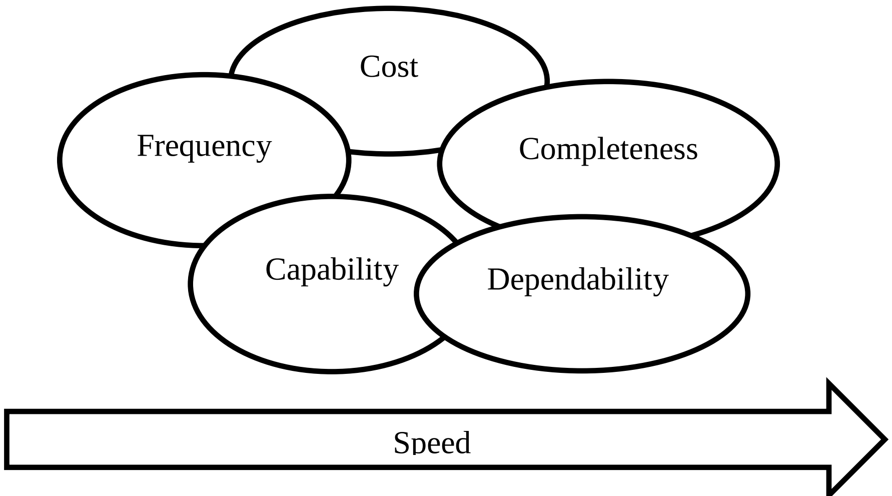


Figure 2.4 Transportation internal characteristics

3**. Dependability**: The degree of transport dependability is measured by the performance of a given mode in meeting anticipated on time of delivery. Dependability is critical in ensuring that planned inventory availability to meet place utility is realized to schedule. Poor dependability adds cost to the enterprise in the form of excess inventories and poor customer service.

4. **Capability**: Capability refers to the ability of a given transport mode to accommodate a specific transport load. The driving factor is the nature of the product. Characteristics such as product type (liquid, solid, bulk, or package), the weight and dimensions, and the load size will have an effect when deciding on the necessary capabilities of material handling equipment and mode of transport. For example, when moving liquids tank cars and pipelines would be the most appropriate methods of transport.

5. **Frequency**: This performance factor is a measure of the frequency a given transport mode can pick up and deliver. Generally, the shorter the transport interval time the greater the flexibility of the mode to respond to channel requirements. More frequent transport also decreases the required modal size and the magnitude of the inventory to be transported.

6**. Cost**: Although market time and place utilized are critical elements of transport mode selection, the costs in transportation. The most obvious costs are the rate paid to the carrier for use of the mode itself. Other indirect costs are labor and material handling to load and unload the carrier, occurrence of spoilage and damage, insurance to protect against possible loss, and in-transit inventory carrying costs paid by the shipper.

2.2.1 Road freight transportation

On long hauls, road freight carriers are able to transport certain primary products of an organic nature such as timber, fish, and agricultural products (for example, live-stock, fresh and frozen meats, fruit, vegetables and dairy products); some semi-finished goods; and most finished goods.

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 [6].

Typical strengths of road transport

Door-to-door service: Road transport is not limited to a fixed route or to fixed terminals. Consignments can be conveyed directly from a shipper to a receiver without the need for specially built terminals.

Accessibility: Road carriers can deliver in every country or economically active region in the world. Deliveries are therefore usually prompt.

Freight protection: As a result of the ability to supply a door-to-door service, little handling and little transshipment take place between origins and destinations.

Speed: This mode maintains short door-to-door transit times, especially over short distances. When delays occur as a result of traffic congestion or other incidents, it is often possible to follow alternative routes.

Capacity: The vehicle carrying capacity, although relatively small compared with other modes of transport, is adaptable and can be readily increased.

High frequency: A high service frequency can be maintained as a result of the small carrying capacity and high speed of road vehicles.

Typical limitations of road transport

Limited carrying capacity: The dimensions and gross mass of road vehicles are limited through legislation.

High environmental impact: Road vehicles create noise and air pollution.

Vulnerability to external factors: Inclement weather conditions and traffic congestion can impact on the reliability and punctuality of road transport operations especially in countries with severe climatic conditions such as heavy fog and snowfalls.

High energy consumption: To convey one unit of freight, road vehicles consume more energy/fuel than other forms of surface transport.

Shared right of way: On public roads, the right of way is shared with other traffic, which increases safety and security risks and the occurrence of unexpected delays. An accident involving a truck with hazardous goods on board may result in a road closure lasting several hours. In addition to high accident risk, road vehicles are vulnerable to theft and hijacking.

2.2.2 Rail freight transportation

In some countries, and especially in Eastern Europe and Asia, rail is the dominant form of transport. In most countries, rail freight services are available between almost every metropolitan area. However, the rail network is never as extensive as the road network. Because rail transport is limited to fixed routes, it lacks the flexibility and accessibility of road freight carriers. Rail transport provides terminal-to-terminal service rather than point- to-point service for clients, unless they have a rail siding at their facility. If a facility is not connected to a rail link, another transport mode has to be used to gain access to the rail service.

Another disadvantage of rail transport is the long transit time. Load consolidation in marshalling yards adds to the slow transport speed. Rail transport also cannot offer such frequent service as road transport. However, since the deregulation of land freight transport, rail transport has improved significantly in these areas. Transport deregulation increases competitive pressure to lower rail rates, resulting in the increasing use of contract rates by rail carriers. Rail carriers, in an effort to increase freight traffic volumes, are entering new markets and are participating increasingly in intermodal transport. Freight trains nowadays also travel on timetable schedules, but departures are less frequent than those for road freight transport. If a client has strict arrival and departure requirements, road transport has the competitive advantage over rail transport.

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.

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, which can reduce air pollution and ease the traffic burden on roads.
- Rail transport generally costs less (relative to weight) than air and road freight transport, especially over long hauls.
- The mode is not as vulnerable to traffic congestion as road transport. Theoretically, trains can be scheduled more reliably than road and sea transport.
- The mode is less affected by inclement weather conditions than other modes.
- Rail wagons cannot be stolen or hijacked as easily as road vehicles.
- High average trip speeds can be achieved by trains over long hauls when shunting and the special composition of train sets are not necessary (e.g. unit trains)
- Private sidings can connect the facilities of clients to the rail network to allow for loading and unloading.
- 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

- Owing to the limitations of a fixed track and specific terminals, rail services often need to be supplemented with additional feeder and distribution services.
- Rail transport has a high freight damage record. Because strong packaging is required to secure the goods, the packaging costs are high.
- Users often still perceive rail services to be of lower quality because of damage to freight and inconsistent service, despite the efforts of rail transport carriers to become more competitive since the economic deregulation of land freight transport.
- Rail transport requires high capital investment.

- ❖ Rail transport is vulnerable to pilferage when rail wagons remain stationary in marshalling yards for long periods.
- ❖ Directional traffic volume imbalances cause a high degree of empty running, so that return freight revenue often does not cover the costs of the return journey.

2.3 The Dry Port Concept

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 standardised units as if directly to a seaport. Apart from the basic service, transshipment, that a conventional inland terminal provides; services like storage, consolidation, depot-storage of empty containers, maintenance and repair for containers, custom clearance, etc. should be available at full-service dry ports.

The quality of access to a dry port and the quality of the road/rail/waterway interface determines the quality of terminal performance therefore it is necessary to have scheduled, reliable, transport by high capacity means to and from the seaport. Thus, dry ports are used much more consciously than inland terminals with the aim to improve the situation caused by increased container flows, focus on security and control by use of information and communication systems. The real difference is that the gates of the port are extended as described by above and that the shipper or forwarder sees the dry port as an adequate interface towards the port and the shipping lines. Hence, the dry port concept goes beyond just using the rail and barge modes for high capacity transportation in the hinterland.

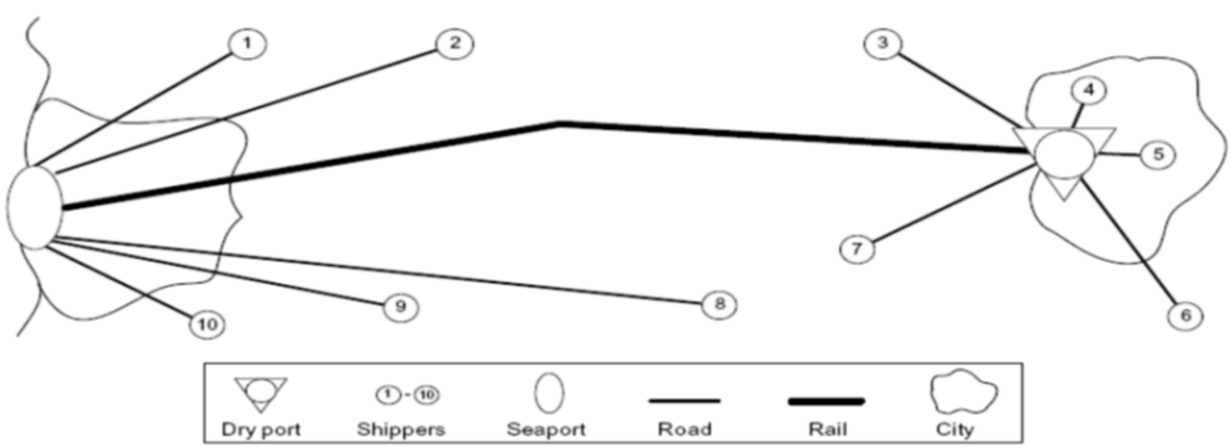


Figure 2.4 A seaport with a dry port (Roso et al., 2009).

The dry ports are mostly located interior from the coast, thus the name dry port, but it does not exclude cities with sea access. Between the seaport and the dry ports, relatively large goods' flows are being concentrated, giving room for other traffic modes than road. For a fully developed dry port concept the seaport or shipping companies control the rail or barge operations, but it does not mean that the terminal itself must be dedicated to serving only one port and it can also be part of a network for continental services.

2.3.1 Advantages of Dry Ports

The advantages are divided over the actors: shippers, rail and road operators, the government (city, province or country), seaport, and the community. The main advantage for the shippers is that a dry port increases the efficiency; therefore, it will reduce the costs of transportation of a shipment [12]. The main way how a dry port reduces the cost is by consolidating the shipments and therefore utilising the economies of scale.

There are gains for the rail and road operators working together with the dry port [13]. Starting with the rail operators, they have access to the economies of scale which reduces the fixed cost per container; moreover, their market share increases. Moving on the road operators, they spend less time on the congested roads and in a seaport terminal. Therefore, the time they use on one shipment decreases; thus, they can handle more shipments in the same time.

Further, the most significant benefits for the government are the ability of the dry port to reduce the road congestion in the area of the seaport [14]. Hence, the truck traffic from and to the seaport will decrease, since the containers/cargo are loaded directly from the ship onto a train for the next step of the transportation. Consequently, a direct positive result is the decrease in pollution.

The first positive input for the seaports is that it enables a seaport to serve a larger hinterland. Hence, a dry port can also be located in landlocked countries [15]. The second benefit is the increased throughput of containers which enables a seaport to serve more ships without physical expansion [16]. Thirdly a dry port can be used, according to Henttu (2011), to balance out the stress (congestion in terminals).

2.3.2 Disadvantages for Dry Ports

The dry port concept does not only have advantages, but it also has few limitations. The first disadvantage is that the complexity of the transport system increases [14]. To give an example, the times that a shipment has to be handled may sometimes increase. Furthermore navigation of the containers becomes more complicated, when more dry ports get involved in the shipment. These limitations may be understood as examples of organisational boundaries.

2.4 Conceptual Model of Freight Transportation System

The general purpose of a freight transportation system is to allow for the availability of goods for production and consumption at various locations, given the availability of natural resources, and needs of suppliers and consumers of goods. Its main function is among others, to facilitate the economy. Within the freight transportation system, a large number of processes can be observed which together enable this necessary function to be fulfilled. These processes themselves consist of many activities that can be observed in the freight transportation system like blending, sorting, storage, packaging and stuffing. [5]

In order to keep the complexity of the conceptual model within manageable limits, the selections can be grouped into three levels of analysis, according to the time frame to which they apply:

1. The locational level describes the land use characteristics, for example: the locations where goods are produced, stored or consumed.
2. The relational level involves the process of spatial distribution of goods between locations of demand and supply.
3. The transport operations level comprises the use of services and facilities for the physical act of transportation.

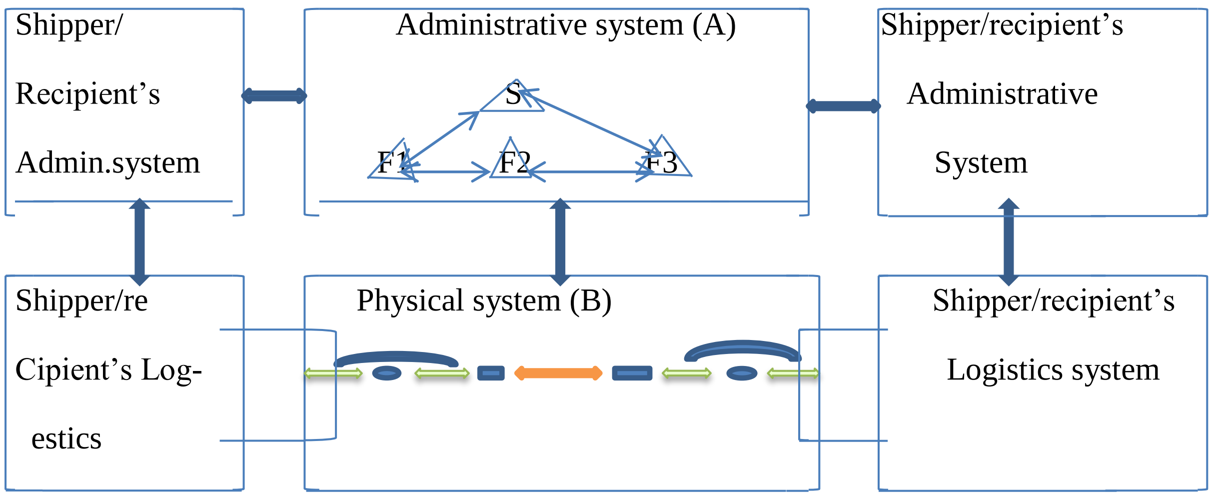
A summary of conceptual models that pertain to the decision maker in a system and their selection problems can be seen in Table 2.1

Table 2.1 Selection Problems in the Three Levels of Analysis (Tavasszy, L. A. 1996)

No.	**Selection Problem**	**Level**	**Process**	**Agent**
1	Locations of production and consumption	Location	Generation (production, consumption)	`Producer, consumer
2	Nature and volume of goods to consume			
3	Nature and capacity of production processes			
4	Location of warehouses			
5	Price of the products			
6	Buyer/supplier relationships	Relations	(multimodal) distribution	Shipper
7	Size and frequency of shipments			
8	Size of inventories			
9	Choice of mode(s)			
10	Vehicle/load unit assignment and scheduling	Operations	(multimodal) transport	Carrier
11	Routes between origins and destinations			

2.4.1 The Jensen model of the combined transport

Previous conceptual models of the transport system include models by Jensen (1990) and Woxenius (1994). Jensen divided the combined transport systems into administrative and physical systems. See Figure 2.6. A complex interdependence between the systems does exist. The physical boundaries are adjustable depending on how well the administrative system performs, and vice versa. A successful administrative system could, for example, create a demand for an extended rail network, new terminals, better rail cars, etc. On the other hand, a change in the physical system, e.g. a reduction in loading capacity, would affect the administrative system. Interdependences within the systems themselves also exist. A better designed timetable could, for example, attract new customers, which would force recourses to be moved to serve these new customers, resulting in a reduction in service and lost customers in other parts of the system.



keys:

Rail transport

Road transport

Rail terminal

Road terminal

Shippers and recipients physical logestics system

Adminstrative system

F1,F2,F3.etc company 1,company 2,company 3,etc

S Co-ordinating unit

Relationship primarily in the form of information

And/or payment flows

System demarcation

Figure 2.6 Jensen's general model of the combined transport system (Jensen, 1990, p. 43)

2.4.2 The Actors in the Combined Transport System

It is clear that the shaping of a combined transport system is a process influenced by many actors. When analysing a system like the combined transport system, it is important to determine which actors are central to the function of the channel. There are several different ways to describe the combined transport system. [5]

The actors can roughly be divided into four groups with regard to a given system.

- ✓ Influencing actors (actors trying to influence the system without any direct power)

  E.g. lobby groups, media or competing transport modes

- ✓ Framework actors (actors setting the framework)

E.g. government or local authorities

- ✓ System actors

  E.g. actors in the transport system such as terminal companies, forwarders, railway companies and road haulers.

- ✓ System output receivers

  E.g. transport customers such as sender or receiver.

In many cases, however, an actor can be involved in several groups depending on the situation, e.g. a forwarder buying a transport service on behalf of a consigner. This is also dependent on the system boundaries of the system chosen to study, for example if the end receiver is included in the system studied or not.

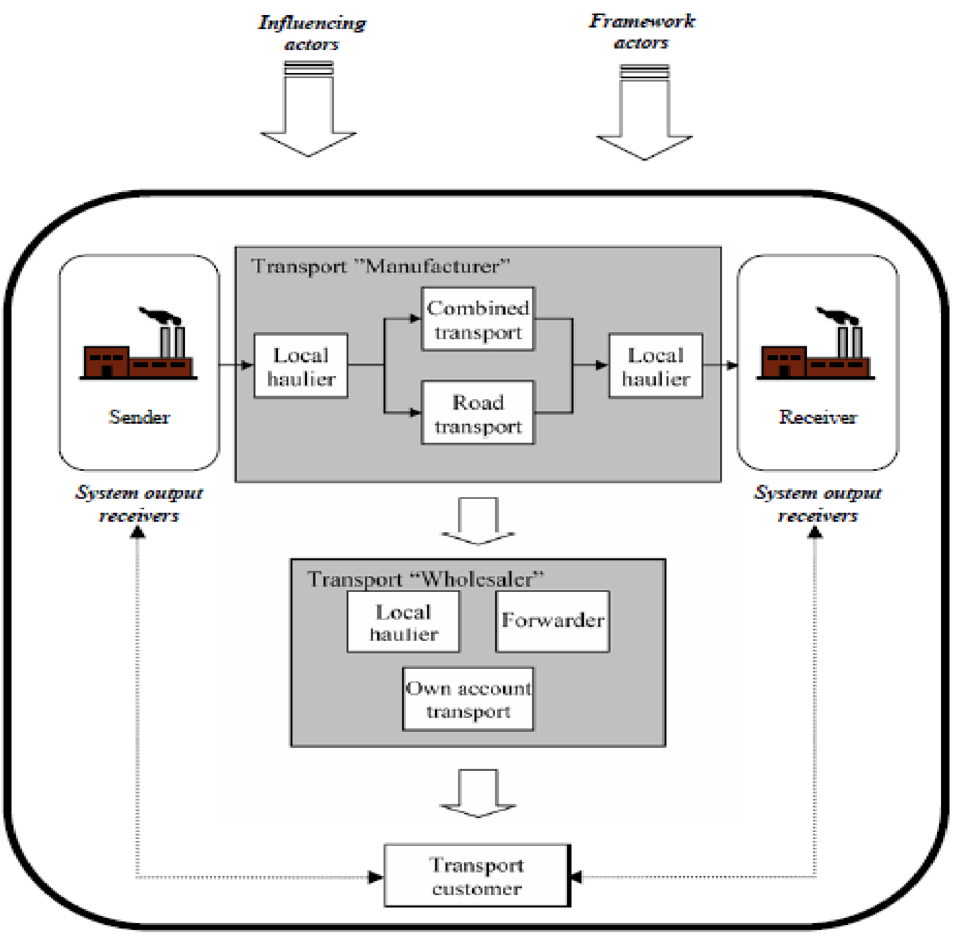


Figure 2.7 a conceptual model combined transportation

Chapter 3

Research Design and Methodology

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. It shows how all of the major parts of the research are done.

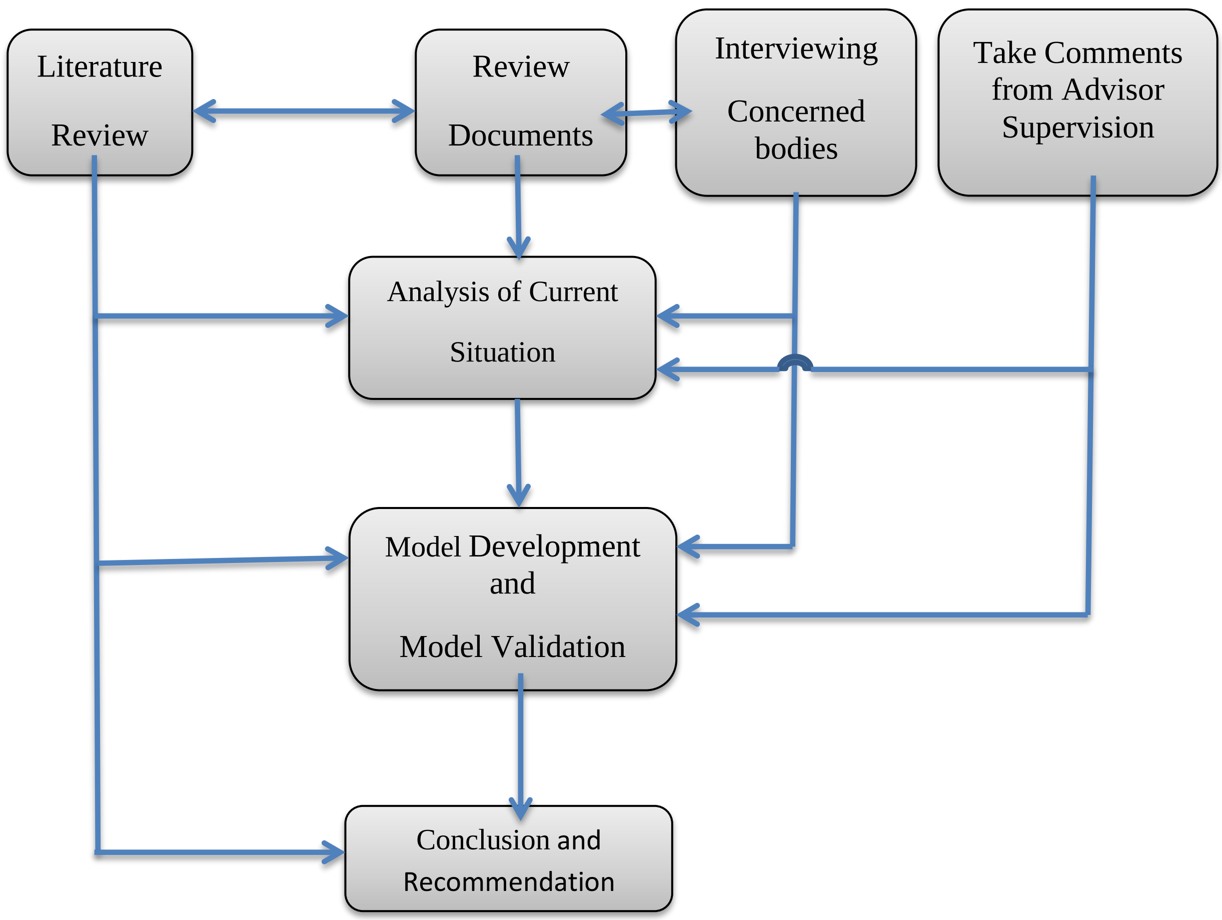


Fig 3.1 Flow chart showing the methods used for the study

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. It provides researchers means of tackling problems. It provides means of locating solution to any defined problem or offset situation. The methodologies used in this thesis are literature review, data collection, data organization, model development of rail-road freight integration, and model validation.

Literature Review: Literature study enables us to identify problems and relationships between problems in our research discipline. A rigorous examination of published journals, books, project works, dissertations and other transport related materials were conducted to have a comprehensive understanding of what others had done in the area, to learn potential rail-road freight transportation. It enables us to gain knowledge on the attempted solutions and possible achieved solutions to problems existing in the research area.

Data Collection: Primary as well as secondary data which are needed for this study is collected using different data collection techniques. These are:

- ✓ From responses to a structured questionnaire administered systematically to traffic officers from major transport company.
- ✓ By interviewing concerned bodies from Ethiopian road authority, shipping lines, ministry of transport and major transport companies.
- ✓ By direct observation and informal discussions
- ✓ By consulting advisors and discussing with friends.
- ✓ Searching for thesis, publishing's journals, newspapers, books, etc. on different web sites which are helpful for meeting the secondary objective and the primary objectives.

Data Organization: Annually, monthly, weekly and daily tonnage of import and export goods, amount of freight distribution along the different regions, types of modes of transport and infrastructure of the country, distance between freight origin and freight destination ,transportation cost ,average transportation time are main parts of the data that are collected. After collecting the data editing is done to detect errors and omissions and to correct these when possible and also coding is done to limit number of categories or classes. Moreover, classification of data is done to organize the data using tables, figures, Graphs, charts and others.

Data Analysis: The volume, size, characteristics and mode of transportation to destination points are necessary parameters of freight traffic analysis. Based the organizing data testing are done; analysis is followed using different techniques and models using software Ms-excel solver and other tools. The data are analyzed using descriptive statistics, Geometric Mean Analysis (GMA) and Student's t-test. These techniques are used to ascertain the temporal and costs differences between the use of rail-road and road freight transport in completing the seaport journey to the dry port and main cities' location in the country.

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. The use of a model gives the researcher the potential to control the design and behaviour of the system. 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. A calculation model is, therefore, best used to answer these questions.

Validation: The final step of the study is model evaluation to determine and show the integrated rail-road approach is economically selective based on cost and time and also it is environmentally friendly than that of unimodal freight transportation.
It can be concluded that the model is well adapted for this problem, and all assumptions made, is also described thoroughly in this thesis which facilitates further uses of the model in other research projects.

Chapter 4

Multimodal Freight Transportation in Ethiopia

The Multi Modal Transport system was set up by an agreement signed between Ethiopia and Djibouti in 2006.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, sea, or road) transportation service operated solely by state owned ESLE. The multimodal arrangement is a scheme whereby the transportation of goods is under a single contract but performed with two or more different means of transportation. The transporter is accountable for the entire journey, including the shipment's delivery at the final destination. The transportation can be carried out by rail, sea, and road.

The new addendum for the Multimodal Transportation Implementation Directive has ordered all private or state containerised import items that use ESLE 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 ESLE. The multimodal service aim is to streamline shipments from Port of Djibouti to avoid warehouse fees in foreign currency. ESLE was formed with the merge of Ethiopian Shipping Lines, Dry Port Services Enterprise, and Maritime and Transit Services to undertake combined service for the sector.

Constructing dry ports is one of the things the government has done to alleviate some of the problems. It has also encouraged the private sector to import modern trucks and introduced the multimodal transportation scheme. A proclamation was also passed addressing the demurrage process. Additionally, private transporters are now required to adhere to associations that now have complete responsibility for transporting freight to and from the country.

4.1 Dry ports in Ethiopia

Exorbitant charges, among other factors, incurred by Ethiopia at the Port of Djibouti, have seen the landlocked eastern African country's economy hit the doldrums, a draft study financed by African Trade Policy Centre. The Economic Commission for Africa has undertaken a feasibility study that could see the construction of more 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. Such ports handle the customs inspections, documentation of cargo and packaging for import and export. The saving, according to the study, could be seven to eight dollars for every container that's transported through Djibouti.

Consequently the Modjo Dry Port, 73Km east of the capital, was built at a cost of 20 million birr on a 63 hectar plot and started operations back in 2009. An additional 617 million birr was spent to expand its capacity. Another dry port, in Semera, 580Km north of Addis Ababa, also started operations at the same time, although it is not used quite as regularly. Use of the Modjo Dry Port increased in February 2012, when the multi-modal transport system, whereby the ESLSE handles the transport of goods from port of origin to an inland destination port, was launched.

The port has 40ft containers, too, but they are statistically recorded as two 20ft containers. The ESLSE set up satellites at 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, to ease the congestion at Modjo.

Out of these, Addis Ababa, Dire Dawa and Kombolcha are now being recommended by the Maritime Affairs Authority to become full-scale dry ports. The Maritime Affairs Authority has also recommended Mekelle, according to research & planning expert at the Authority, but the Ministry of Transport already approved a dry port for the town in December 2012. Four of the 12 suggested sites are located in Amhara region, followed by two in Oromia. A single site was identified in Somalia, Gambella and Southern regions, each. (Source: fortune February 2012).

Ostensibly, the ports are to create logistic chains to ports in Somaliland, Djibouti, Kenya, Sudan and South Sudan. This strategic drive also aims to take advantage of the growing international and regional trade including the country's burgeoning economic relation with its trading partners in the region. The nascent ESLSE is intended to provide not only gubernatorial functions within the maritime and logistics industries, but also to provide commercial multi-modal logistic services.

Table 4.1 Dry port service capacity from 2000-2006 E.C (ESLSE Port and terminal Department)

S.N	TERMINAL	2002 E.C		2003 E.C		2004 E.C		2005E.C		2006E.C	
		H/r	Qty in TEU	Hector	Qty in TEU	H/r	Qty in TEU	H/r	Qty in TEU	H/r	Qty in TEU
1	Modjo	2	1152	4	2688	4	2688	9	6605	17	12238
2	Commet	0	0	0	0	3	2500	3	2500	3	2500
3	Gelani	0	0	0	0	0	0	0	0	4	2352
4	Kombolcha	0	0	0	0	0	0	3	1152	3	1152
5	Mekele	0	0	0	0	0	0	1	510	1	510
6	Dire Dawa	0	0	0	0	0	0	1	288	1	288
7	Semera	0	0	2	980	2	980	2	980	2	980
Total		2	1152	6	3668	9	6168	19	12035	32	20020
Annual percentage Development				267	218	58	68	119	95	67	67

4.2 Warehouses

One of the major obstacles for efficient freight transport and logistics system of the country in rural, regional and international freight movement and distribution system is lack of storage facilities, adequate loading and unloading equipment and efficient management of the system. At present, there is a total of about 0.8million metric ton capacity warehouses all over the country. Most of these are owned by public institutions such as Coffee Marketing, Ethiopian Grain Trade Enterprise, and World Food Program etc. Most warehouses particularly the private ones are not designed to handle heavy truck trailers and semi-trailers. Adequate doors and turning areas are not provided. In short, there is no standard set for commercial warehouse building. There is a serious lack of cargo handling equipment all over the country which normally is part of warehousing businesses. Cranes, forklifts and other equipment are rented as and when cargo is already waiting to be loaded and unloaded at the warehouses.

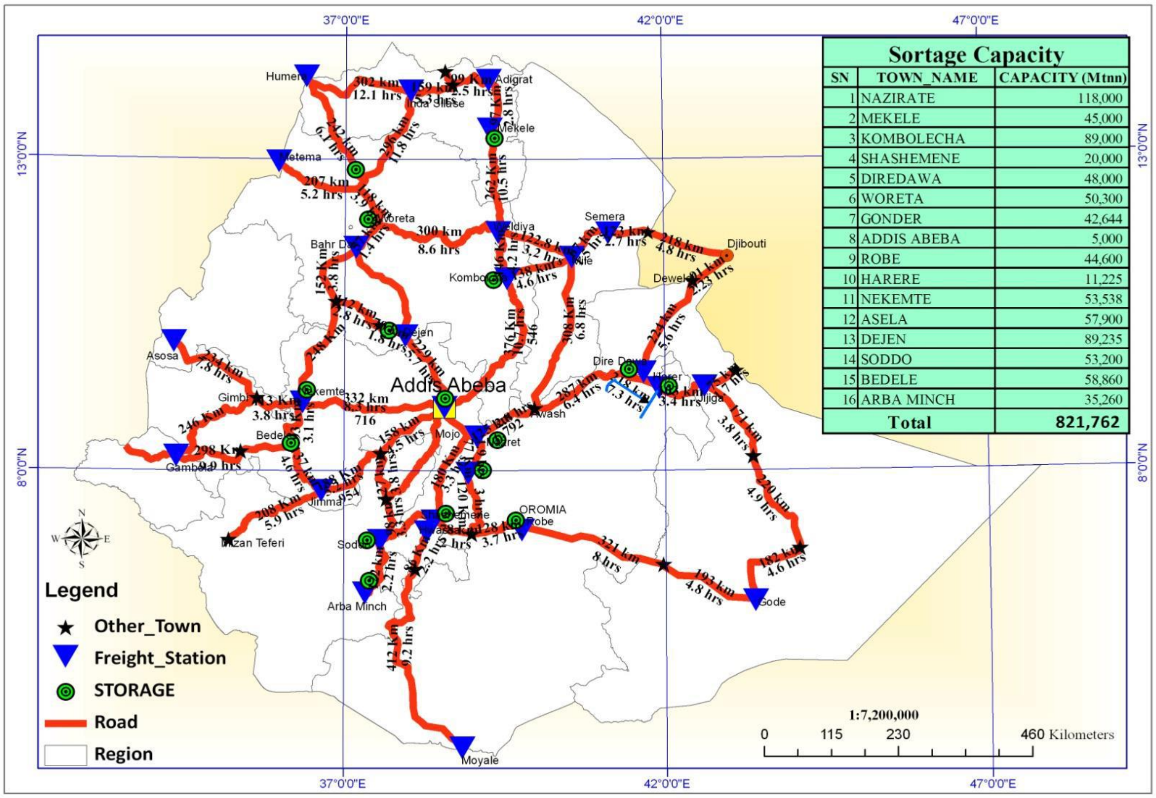


Fig.4.1 Regional Network, distance and trip time (Afro Consult & Trading PLC, 2010)

4.3 Road Cargo Transportation in Ethiopia

4.3.1 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. In particular, the government noted that, the development of road transport creates a network over a wide array of infrastructural facilities so as to improve the accessibility and mobility of agricultural and industrial products. As a result, the road transport in Ethiopia has been the dominant mode of transport. During the fiscal year 2012/13, the total stock of road network reached 85,966 km of which 25,756 km Federal, 32,582 km rural road and 27,628 are woreda road. The Federal road includes 11,301km (43.9 percent) asphalt and 14,455km (56.1 percent) gravel road, showed annual expansion of 14.4 percent and reduction of 1.5 percent, respectively.

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 36.3

percent compared to 9,086 Km recorded in 2011/12. The community road, which was replaced as woreda road in 2010/11 have been included under the total road network, which grow remarkably in 2012/13 to 27,628 km from 6,983 km registered last year the same period. This huge increment is due to the government's plan to connect each kebele to the main road in line with the woreda road program during the growth and transformation period.

Table 4.2: Road Densities (Ethiopian Road Authority)

Year	Road Density /1000 person	Road density /1000 sq. km
2000/01	0.50	29.9
2001/2	0.50	30.3
2002/3	0.49	30.8
2003/4	0.51	33.2
2004/5	0.50	33.7
2005/6	0.53	35.9
2006/7	0.55	38.6
2007/8	0.56	40.3
2008/9	0.57	42.6
2009/10	0.60	44.4
2010/11	0.65	48.3
2011/12	0.75	57.3
2012/13	1.00	78.2

The proper level of road network is assessed by road density, which is measured by road length per 1,000 persons or by road length per 1,000 km2. In the five year GTP period, the plan is to increase the road density from 44.5Km to 123.7 km per 1,000 persons and from 0.64 Km to 1.54 km per 1000 km2. At the end of 2012/13, the road density per 1,000 square Km showed improvement to 78.2 km from 57.3 km a year ago; though GTP target is 89.3 for the year 2012/13.The road density per 1,000 populations in 2012/13 was 1 km and up by 33.3 percent from 0.75 Km in the preceding fiscal year (Table 4.2).

4.3.2 The Addis Ababa-Djibouti Road

There are two principal road routes connecting Djibouti and Addis Ababa. One of them passes through Nazreth and Awash and the other passes through Kombolcha. These two routes join near mille and the section from Mille to Djibouti is common to both routes.

The Djibouti- Awash Addis Ababa route has a distinct advantage over Djibouti- Kombolcha Addis Ababa due to differences in terrain. The corridor analysis in this study however, refers to the Addis Ababa- 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 more difficult to achieve and the average load factor of trucks is low, about 60%.

The average standard time which is set by major transport companies that should be covered by the drivers from Djibouti to Addis Ababa is about 22 hours.

4.3.3 Road Freight Transport Vehicles

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. In Order to cater for the demand emanating from, export, import, domestic cargo movement availability of vehicles with lower age spectrum higher carrying capacity and formidable fleet size are presupposed.

Road freight transport has a detrimental role in affecting positively or otherwise sectors that require efficient input-output movements and accessing consumption centers, which other modes are not in a position to cater for in terms of cost and coverage. Indications to the regeneration of the service at large and future requirement for more investment therefore envisage for the study of the current situation of vehicle stock, vehicle age and capacity in the country .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.

Level 2 is for trucks from the age of 10.1-20 years and is classified in two grades with a loading capacity similar to level one, but the association that is included under this category must have at least 100 trucks, and at least three offices including the head office and a branch at the port.

Level 3 associations are made up of trucks that have a manufacturing date of over 20 years and they have two offices and 75 trucks in each association, and level 4 is classified for only companies that have over 50 trucks. The other level included in this system is level 5 or a specialized category, which is used for transporting machines, construction materials, or very large cargo.

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. For example business people who have ten trucks, a majority of which are between the ages of 10.1-20 years and few new brands will be included in the association organized on level 2, while the business person who has a majority of brand new trucks and few older trucks would be a member of level 1.

Table 4.3 Cross country fleet population in Ethiopia (Ethiopian road transport authority)

Serial No.	Levels	Numbers of Associations	Number of trucks
1	Level 1	28	4696
2	Level 2	22	2349
3	Level 3	27	2317
4	Level 4	15	802
Total		92	10164

4.3.4 Road Transport Costs (Tariff)

Road transport Costs are represented by vehicle operating costs and the cost of time. Road transport Costs include also Costs of road maintenance, which is paid mostly by fuel taxes for road fund. Transport operators recover their transport costs applying road transport tariffs, which allow them to gain a reasonable profit from the services given. 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 (which favour the use of large trucks) backhaul possibilities (which depend strongly on the demand pattern) empty running and idle time due to seasonal variation in demand, restriction in working hours, road conditions (such as mountainous terrain, deteriorated pavement and traffic congestion) standard of trucks in terms of design and condition (which affects speed availability and consumption rates for fuel, spares and other inputs, quality of services offered (specialized freight services may involve higher costs) input or factor prices of labor, vehicles, spares and fuel, quality of management. (RTA, 2002:23)

Among the factors that affect the availability of the transport service, the transport tariff is obviously a fundamental one. It is the price that transport agencies receive for the costs they incur and users pay for the services they get. As such, whether or not such a price is capable of allowing transport service providers to stay in the sector of inducing additional investors for entry, and of enabling user to get an efficient and competitive service is a crucial question.

4.4 Rail Cargo Transportation in Ethiopia

The past couple of years saw Ethiopia registering accelerated economic growth of double digit. The growing economy demanded the expansion for various utilities and infrastructural facilities in various sectors, among which transportation is one. In line with this there is a strong need for having better transport access to the various corners of the country in order to exploit the underutilized potentials of the country. [9]

However, as some studies indicate 70 percent use of transportation in the country is traditional non-motorized, while modern motorized transport constitutes only a small percent. Apart from that, the increasing foreign trade necessitates the country to spend a large amount of money for transportation. In some documents, it is stated that Ethiopia spends about 18 percent of its imported value and 8 percent of its export earnings on transportation that in turn will affect the country's competitiveness in the international market.

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 1000kms and can be economically sustaining without government subsidy.

In recent studies, it is showed that railways cover their operating cost and achieve normal return on capital under competitive price. In terms of energy, railway carries 80T/Km per liter compared to 24T/Km by trucks and electrification of railways advances its advantage making it six times cheaper than diesel train. Cognizant of these facts and advantages, many agree that it is a right time for the government to consider railway as an alternative way of transportation. The construction of railway requires a large amount of Money. The estimated cost for the construction of one kilometer railway in Ethiopia is expected to be three million USD. The construction cost for a new railway line investment on railway project can be divided as locally implemented costs which are about 45 percent of the total cost with 30 per cent of it for civil work and 15 percent for earth work. The other 55 percent that is foreign implemented costs; with 25 percent of it for track and rail works, 10 percent for electrification, 15 percent for signaling and communication, and the remaining 5 percent for others.

Despite the high expenses and difficult tasks that may be faced ahead during construction, the building of these railways has an immediate impact on the reduction of the transport related bottlenecks to the economy. That is achieved through the reduction of high transportation cost strengthening competitions in the international market, not to mention its contribution to the local market at Woreda level.

Ethiopia already has a 781-kms meter gauge diesel railway that stretches from Addis Ababa to Djibouti and served almost 100 years. During its time it has served as a major means of passenger and freight transport to the eastern part of the country and contributed to the establishment and expansion of major economically active urban centres along its line like Adama and Dire Dawa. Nevertheless, as time passed by its capacity deteriorated and currently it is out of service. Though, the government was trying to rehabilitate this railway and frequently signed an agreement with few companies, it did fail due to many reasons.

No doubt, the current railway construction plan of the government is of paramount significance in supporting the economic development of the country. Nevertheless, the owner of railway project in the country, Ethiopian Rail Way Corporation is also looking forward to bridging gaps existing in skilled man power by establishing a Railway Institute. In order to build the future skilled human capacity of the Corporation, curriculum has been developed in the academic institutions and is designed to be implemented with intensive training. Local contractors and consultants are also expected 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 parts in puts necessary in the construction of railway lines.

Ethiopia National National Railway Network

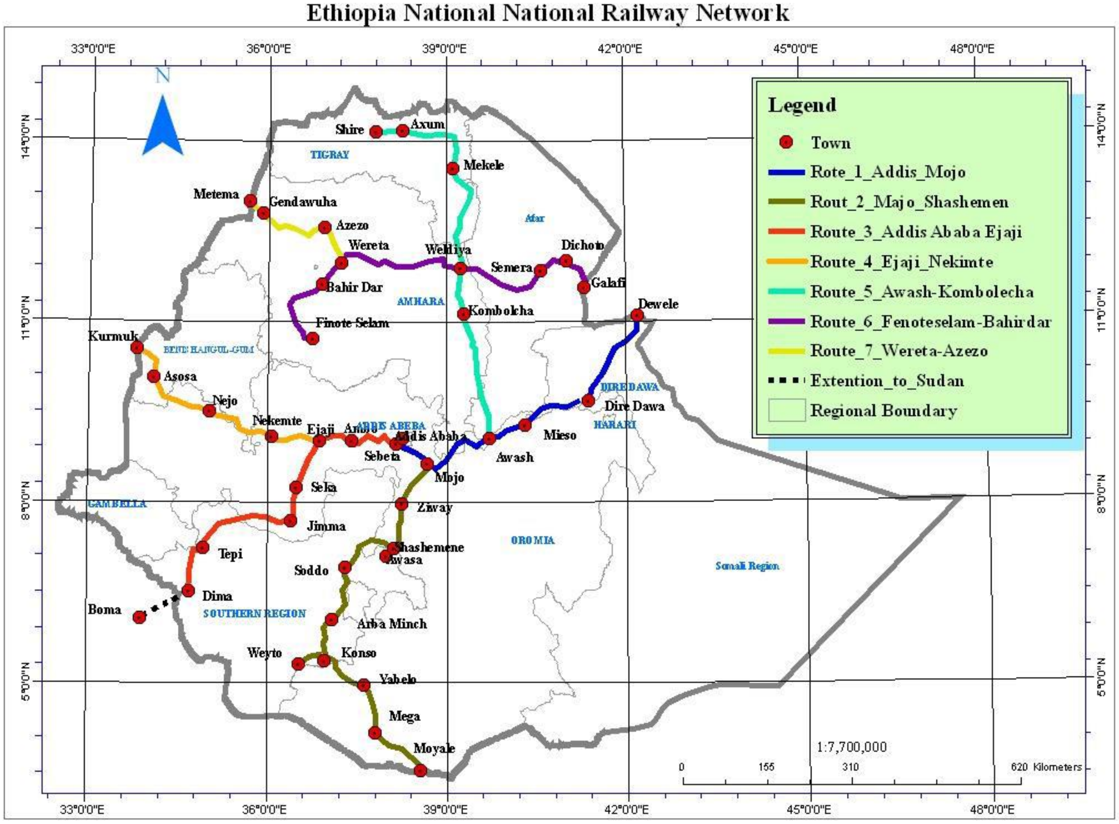


Figure 4.2 Ethiopian National Railway Network (ERC, 2010 G.C)

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 4.4 Ethiopian railway roots data (ERC, 2010 G.C)

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	4744

In order to make the implementation process manageable, the NRNE projects have been phased into two parts as follows.

PHASE I

1. Addis Ababa - Djibouti Railway Project
2. Mekele - Welidya/Hara Gebeya - Semera-Tadjourah Port Railway Project
3. Addis Ababa - Ijaji-Jimma - Dima Including Jimma - Bedele Railway Project
4. Awash - Kombolcha - Hara Gebeya Railway Project
5. Mojo - Shashemene - Arbaminich - Weyto Railway Project

PHASE II

1. Jimma-Guraferda-Dima directed to Boma
2. Ijaji-Nekemet-Assosa-Kumuruk
3. Mekele-Shire
4. Fenoteselam-Bahirdar-Wereta-Weldia
5. Wereta Azazo-Metema
6. Adama-Indeto-Gassera-Ginir

4.5 Freight Transport Demand and Supply

4.5.1 Freight Transportation Demand

Transport demand is the expression of the transport needs even if these needs are satisfied fully, partially or not at all. It is expressed in volume of freight or mass or ton per unit of time and space. The demand is generated by the economy, which is composed of industries which generates movements of freight. For freight transportation the demand is the function of the nature and importance of economic activities (GDP, Commercial surface, number of tons) and of modal preference.

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 produce except coffee for domestic market
- ✓ Industrial products for domestic consumption all over the country.

Table 4.5: Volume of Major Exports (Ethiopian Revenue and Customs Authority)

(In millions of K.G.)

Particulars	2010/11	2011/12	2012/13	Percentage Change	
	A	B	C	C/A*100-100	C/B*100-100
Coffee	196.1	169.4	198.7	1.3	17.3
Oilseeds	254.2	367.4	280.2	10.2	-23.8
Leather and Leather products	5.2	4.4	4.6	-11.0	3.6
Pulses	224.5	226.2	356.1	38.6	57.4
Meat & Meat Products	16.9	17.7	15.4	-8.5	-12.6
Fruits & Vegetables	91.6	123.5	134.6	47.0	9.0
Live-animals	112.8	144.9	100.7	-10.7	-30.5
Chat	41.0	41.1	47.1	14.8	14.6
Gold	0.0112	0.0122	0.0123	10.23	0.99
Flower	41.6	46.8	42.3	1.8	-9.6

4.5.2 Transport Demand Forecasting

Theoretically transport traffic could be generated and forecasted at a macroeconomic level, at conventional sequential model or direct demand model which estimates in a single step the flow from a particular origin to destination. Since in 1950G.C, the more widely used transport forecasting model than any other is the four-step or sequential process consisting of the following sub models:

- ✓ Trip generation sub model: trip production and attraction based on population and socio economic activities
- ✓ Trip distribution sub model: based on mainly “gravity” type models
- ✓ Modal split sub model: based on comparative costs and efficiency often using diverse logit model
- ✓ Traffic assignment sub model: based on minimum cost path models

The trip generation, trip distribution and modal split models, taken together, form transport demand functions; the inputs to these models are various socioeconomic variables and network service measures and the output consists of the number of trips desiring to travel from each origin to each destination by various modes. The traffic assignment model which is implemented as the path choice sub model provides the transport supply function.

The most appropriate approach for estimating the future volume of freight traffic for Ethiopian Railway Corporation along the Addis-Djibouti corridor consists of the following five steps.

- ✓ Consideration of the total size and growth rate of the GDP and economic activities
- ✓ Estimation and projection (forecasting) of total volume of Ethiopian foreign trade traffic
- ✓ Traffic assignment among the ports serving Ethiopia
- ✓ Determination of traffic passing through the port of Djibouti to different hinterlands
- ✓ Estimation of rail versus road share or modal split of transit traffic to central regions

The Frameworks for Traffic Forecasting are

A. The national economy: The level and growth of the national economy determines the size of trade and transport demand. The history and current situation of the corridor clearly ascertains that the Ethiopian economy is the main traffic potential of the corridor particularly the new railway and the Port of Djibouti.

B. Ethiopia's Foreign Trade Sector

For the new railway line the largest potential for traffic is the international import trade relative to export and domestic traffic. Freight transport is based on the development of GDP and Import/Export Traffic.

The new GTP is based on the performance of the economy during last consecutive years of double digit growth rates and envisages a further rapid growth across sectors to attain the level of Middle Income Countries (MIC's) by 2020. This requires huge transport capacity in the country and particularly in the import/export corridor.

Table 4.6 Thirty year projection of the Ethiopian Foreign Trade Traffic (000 MT) (Final Report Transport Planning for BFS of Addis Ababa-Djibouti Railway)

Year	Total Forecast Traffic						Railway Traffic		
	Export			Import			Export	Import	Total
	12%	14%	16%	10%	12%	14%			
2009	910	910	910	8,133	8,133	8,133			
2015	1,796	1,997	2,217	14,408	16,053	17,852	799	6,421	7,220
2020	3,165	3,846	4,647	23,204	28,291	34,372	1,538	11,316	12,855
2025	5,098	6,678	8,966	34,095	45,563	60,575	2,711	18,225	20,936
2030	8,210	11,945	17,263	50,097	73,380	106,754	4,778	29,352	34,130
2035	12,064	19,237	30,424	73,608	118,179	188,137	7,695	47,271	54,966
2040	17,726	30,981	53,618	108,155	19,0328	331,562	12,393	76,131	88,524

Table 4.7 Forecast Annual Container Traffic for Railways (Final Report Transport Planning for BFS of Addis Ababa-Djibouti Railway)

Type	2015			2020			2030		
	Import	Export	Empty	Import	Export	Empty	Import	Export	Empty
TEU (60%)	148	23	125	168	42	126	371	109	262
FEU (40%)	39	9	30	45	17	28	99	43	55
Total	187	32	155	213	59	154	470	152	318

4.5.3 Traffic Assignment to Different Ports and Modes

Port Assignment

The distribution pattern of import to and export from each of the specified hinterlands are now frequently routed through Addis Ababa which puts them in a category of overlapping hinterlands. This is mainly determined by the organization of freight shipment, location of foreign trade business and the established pattern of import distribution and export collection within the country.

Basically the port assignment is a function of available port capacity for Ethiopian foreign trade, relative costs of port charges and hinterland transport cost. The present and planned share of different ports is mainly based on the above factors, and the Final Report Transport Planning for BFS of Addis Ababa-Djibouti Railway estimates the following distribution:

1st level distribution of foreign trade (import) to three key sea ports will be as follows:

Sea Port	Present (2010-2015)	After 5 years (2015)
• Djibouti port	93%	75%
• Berbera port	5%	15%
• Port Sudan	2%	10%

2nd level assignment of foreign trade traffic concerns the distribution of Djibouti port traffic:

Hinterlands		
• Northern Ethiopia	10%	15%
• Eastern Ethiopia	10%	10%
• Central Ethiopia	80%	75%

Traffic Split

At present, there is a direct, though very unequal, competition between the more efficient trucking and the poor capacity CDE. Proper modal split analysis involves the assessment of the capacity, cost and performance of existing and proposed alternative transport system along the corridor. In spite of increased role of non-price factors in the modern transport marketing process, price still remains a critical element.

Freight transport market is essentially a service market that is particularly sensitive to changes in price charged by different carriers. The price is determined by the underlying cost structure of different modes. The cost is not limited to moving products but also of other aspects of freight distribution and logistics system including cargo handling, inventory and safety.

Modal split between road and rail is 75:25. However, for other considerations the actual railways traffic share used for Djibouti oriented traffic to the central Ethiopia is as follows:

	Present (2010)	**After 5 years (2015)**
• Road transport (%)	95	40
• Railways transport (%)	5	60

4.6 The New Addis Ababa –Djibouti Railway Line

Although there could be many possible routes for railway development in Ethiopia, the new Addis - Djibouti line serves the principal traffic corridor of the country and it is the best and most urgent projects on many grounds:-

- ✓ The route has a very suitable distance for railway (mode) project of 781Km
- ✓ There is already more than adequate traffic of over 9Mn MT a year and growing fast
- ✓ The corridor terrain is acceptable with 70:25:5 for plain, rolling & mountains topography respectively with good materials and traversing 20 woreda and railway developed towns
- ✓ The route has the shortest distance from the seaport to Addis Ababa and the Central regions with big traffic generating hinterland of the country
- ✓ The corridor is strategic route serving both domestic and particularly foreign trade traffic.

The project is also in-line with the World Bank's new "clean, safe and affordable" transport policy which favors the development of such railway project. Thus although both road and railways are necessary and could be complementary, for the expected traffic size and distance involved and the technical advantages, the new railway is very much favored to be the principal mode of transport for foreseeable future particularly for the Addis-Djibouti corridor.

The Addis-Djibouti railway will enable Ethiopia easy access to the port of Djibouti providing both passenger and freight service transporting 3,500 tons of goods at a time. The project owner, ERC and the contractor, China Civil Engineering Construction Corporation expect the project to be completed by October 2015.

The Addis-Djibouti Railway stretches a total length of 756km, out of which some 100km will be built within Djibouti. The first section of the project stretching 317km from Sebetta to Mieso is also under construction by the China Railway Engineering Corporation, the same company undertaking the Addis Light Rail Project.

When completed the Addis-Djibouti electrified railway, a priority project within the GTP, is expected to reduce the travel time from Addis Ababa to Djibouti by half to less than ten hours with a designated speed of 120km/hour. The railway will have 17 major stations and passes through major cities including Bishoftu, Adama, Metehara and Dire Dawa.

4.6.1 Stations along the Railway Line

a. Distribution principle of stations

- ✓ The setting up of stations along the line should satisfy the traveling needs of residents in cities along the line and the economic development in regions of the Project to the largest extent.
- ✓ The setting up of stations should in compliance with the target speed value of the line. Bypassing station (intermediary station) and station sidings should be set based on transportation organization and topographic and landform conditions along the line.
- ✓ The setting up of stations should take interfaces with other means of transportation into consideration for passengers' convenience in transferring and freight transportation to enhance the competitiveness of railway in comprehensive transportation system.

b. Overview of station distribution

The length of the whole international railway line from Sebeta to Nagad is 743.245km. The section from Sebeta to Adama (included) is double track railway, with a length of 113.836km, 7 stations, and an average distance between two stations 16.26km. The section from Adama (excluded) to Mieso (included) is single track railway, with a length of 213.418km, 12 stations, and an average distance between two stations 17.78km. The section from Mieso (excluded) to Dewele (included) is single track railway, with a length of 334.014km, 21 stations, and an average distance between two stations 15.91km. The section from Dewele (excluded) to Naga (included) in single track railway, with a length of 81.977km, 5 stations, and an average distance between two stations 16.4km.

Labu Station is set as passenger station to meet the passenger transportation demand in the capital. Indode Station is set as the technical station for freight trains, taking charge of the arrival-departure operation of cargoes in the capital and de-marshaling of freight trains to facilitate the technical operation of freight transportation. In initial stage, the following stations will have passenger transport operations: Sebeta, Labu, Bishoftu, Mojo, Adama, Awash, Mieso, Dire Dawa, Dewele, Alisabieh, Holhol, and Nagad. (The other stations can choose to start freight transportation as appropriate based on the increase of transportation demand after the railway is put into operation.) In initial stage, the following stations will not have freight operation tentatively: Feto, Metehara, Awash, Sirba Kunkur, and Bike. (The five stations can choose to start freight transportation as appropriate based on the increase of transportation demand after the railway is put into operation.)

4.6.2 The pairs of freight trains and required passing capacities of the line

The freight transportation is mainly bulk cargo traveling in the direction of the Port, while other local transportation is little. With the concentrated direction of freight transportation, the organization of freight trains on the line mainly comprises non-stop trains. Pick-up and drop trains shall be organized to digest local freight transportation along the line.

Freight trains shall adopt electric-power dual-locomotive traction, with a traction mass of 3500t.

a. Type of traction

The installed power capacity will be increased to 2.54 million kW in 2012 and to 7.75kW in 2015. Considering the fact that now Ethiopia has a low level of industrial electric power consumption and much power are transmitted to other countries, and the power generated can satisfy the demand of traction power supply, electric power traction will be adopted for the whole line.

b. Type of locomotive

Based on the feasibility study of Ethiopia/Sebeta-Djibouti/Nagad Railway DC locomotives (SS9, SS4) or AC locomotives (HXD3C, HXD3B) will be used for the line.SS9 is suggested to be used as passenger locomotive and SS4 is used for freight locomotive.

c. Transportation price rate

Due to the lacking of market investigation for freight price of Ethiopian roads and railways, the evaluation follows the condition of Ethiopian Railway cooperation and the local fact, the financial evaluation is calculated at basic freight price of 0.046 USD/ton-km and basic passenger price of 0.023 USD /ton-km.

Table 4.8: Pairs of Passenger and Freight Trains and Required Passing Capacity in Each Stage Unit: pair/day (Ethiopia/Sebeta-Djibouti/Nagad Railway Feasibility Study)

Year	Section	Design Passing Capacity (pair/day)	Passenger Train (pair/day)	Freight train (pair/day)	Pick-up and Drop Train (pair/day)	Subtotal	Required Passing Capacity
Initial Stage	Sebeta -Adama	40	5	5	1	11	17
	Adama- • ` Awash	12	2	5	1	20	11
	Awash-Dire Dawa	11	2	5	1	19	11
	Dire Dawa -Nagad	12	1	5	1	19	10
Short Term Stage	Sebeta-Adama	40	6	7	1	54	21
	Adama-Awash	18	2	8	1	27	15
	Awash-Dire Dawa	16	2	9	1	28	16
	Dire Dawa -Negad	15	1	9	1	26	15
Long Term Stage	Sebeta-Adama	50	10	16	1	77	38
	Adama-Awash	28	3	17	1	49	27
	Awash-Dire Dawa	29	3	19	1	52	30
	Dire Dawa -Negad	28	2	19	1	50	28

Chapter 5

Model Development on Rail-Road Freight Transport Integration

5.1 Inputs Required

The followings are the inputs required for the problem described in this research.

1. Details of existing road and rail networks like origin-destination of various routes, A and the transfer nodes, N present on these routes and the given network is presented by a directed graph, G (A, N).
2. Period during which the departure times of railway and road freight transportation vehicles can be set. This is called planning horizon represented by [0, T].
3. Number of road and rail vehicle routes in the network, M.
4. Maximum and minimum headway (time between each successive departures) for each route i, ($1 \leq i \leq M$) represented by [$H\ min_i$, $H\ max_i$].
5. Minimum required frequency, f_i (number of freight transportation rail and road vehicles to be scheduled for a particular time period) on each route.
6. Traveling time, t_{ik} from starting point of route i ($1 \leq i \leq M$) to node k ($1 \leq k \leq N$).
7. Permissible waiting time limit for freight delivering and receiving, loading and unloading to transfer at each node k, ($1 \leq k \leq N$) is [$WT\ min_k$, $WT\ max_k$]

5.2 Assumptions

The followings are the assumptions made for the problem presented in this research.

1. The planning horizon in which the departure times are set is a discrete interval and also large enough so that all the departures can be set.
2. For each route i, $H\ max_i \geq H\ min_i$
3. Traveling times and the waiting times are considered deterministic.
4. The waiting time limits for the freight loading and unloading at each node are assumed to be predetermined by the transit planners.
5. The first departure of each route i must take place in the interval [0, $H\ max_i$]
6. The travel on all routes is in one particular direction.
7. The trucks leave the terminal (node) as soon as the loading and unloading of freight is done.

5.3 Methodology

The methodology that is implemented in this research is to create synchronized timetables. This includes formulating the problem as a Mixed Integer programming problem and an algorithm to solve this problem.

The followings are the notations used in defining the problem and are used in the entire research.

N – Total number of nodes k present in the network.

M – Total number of road and rail freight transportation routes present in the network.

T – Planning horizon during which the departure times are constructed.

$H\ min_i$ – Minimum required headway for route i.

$H\ max_i$ – Maximum required headway for route i.

t_{ik} – Travel time from the starting point (origin) on route i to node k.

$WT\ min_k$ – Minimum allowed waiting time at node k.

$WT\ max_k$ – Maximum allowed waiting time at node k.

X_{ip} – Departure time of p^{th} freight road trucks and railway vehicles on route i.

T^k_{ip} – Arrival time of p^{th} freight transportation road trucks and railway vehicles on route i at node k.

B_i – Set of nodes contained on route i.

$B_{i,j}$ – Set of common nodes contained on route i and route j.

f_i – Frequency (number of freight trucks and railway vehicles departing in a given time period) on each route.

5.4 Formulating the Model

The decision variable $\mathbf{Y_{ijkTR}}$ is defined as,

$\mathbf{Y_{ijkTR} = 1}$, if the arrivals of T^{th} road Trucks on route i and R^{th} railway vehicle on route j at node k are separated by a time that is within the required waiting time limit.

$\mathbf{Y_{ijkTR} = 0}$, otherwise.

The arrival time of road trucks and railway vehicles at a node is calculated by adding the departure time and the time taken to travel to that of node, i.e., $\mathbf{T^k_{ip} = X_{ip} + t_{ik}}$

The objective function of the model presented is to maximize the number of simultaneous arrivals.

$$Max \sum_{i}^{M-1} \sum_{j=i+1}^{M} \sum_{k \in B i,j} \sum_{T=1}^{fi} \sum_{R=1}^{fj} \{YijkTR\}$$

The constraints are given by the following equations

$X_{i1} \leq H\ max_i$; $1 \leq i \leq M$ (1)

$X_{if} \leq T$; $1 \leq i \leq M$ (2)

$H\ min_i \leq X_{i(p+1)} - X_{ip} \leq H\ max_i$; $1 \leq i \leq M$; $1 \leq P \leq f_i - 1$ (3)

$Y_{ijkTR} = 1$ if $WT\ min_k \leq (X_{iT} + t_{ik}) - (X_{jR} + t_{jk}) \leq WT\ max_k$, $k \in B_{ij}$ (4)

$Y_{ijkTR} = 0$;

If $/X_{iT} + t_{ik} - X_{jR} + t_{jk}/ < WT\ min_k$ or $/X_{iV} + t_{ik} - X_{jR} + t_{jk}/ > WT\ max_k$ (5)

Constraint (1) ensures that the first departure time of each route will not be beyond maximum headway from the start of time horizon and constraint (2) ensures that the last departure is within the planning horizon. Constraint (3) indicates the headway limits. Constraint (4) shows that the decision variable takes a value of 1 if the arrivals at the node are within the waiting limits and constraint (5) ensures that $\mathbf{Y_{ijkTR}}$ takes the value 0 otherwise.

5.5 Heuristic Approach

This section will present the algorithm developed to solve our problem of setting departure times. The basic outline of the algorithm is based on the algorithm developed by Ceder et al. (2001). The incorporated change in the definition of simultaneous arrival is applied in the different procedures used to set the departure times. The flow chart of the algorithm is shown in Figure 5.1. The algorithm is based on the selection of nodes. There are three possible states for a node. A node can be ‘new’, ‘possible’ or ‘not possible’.

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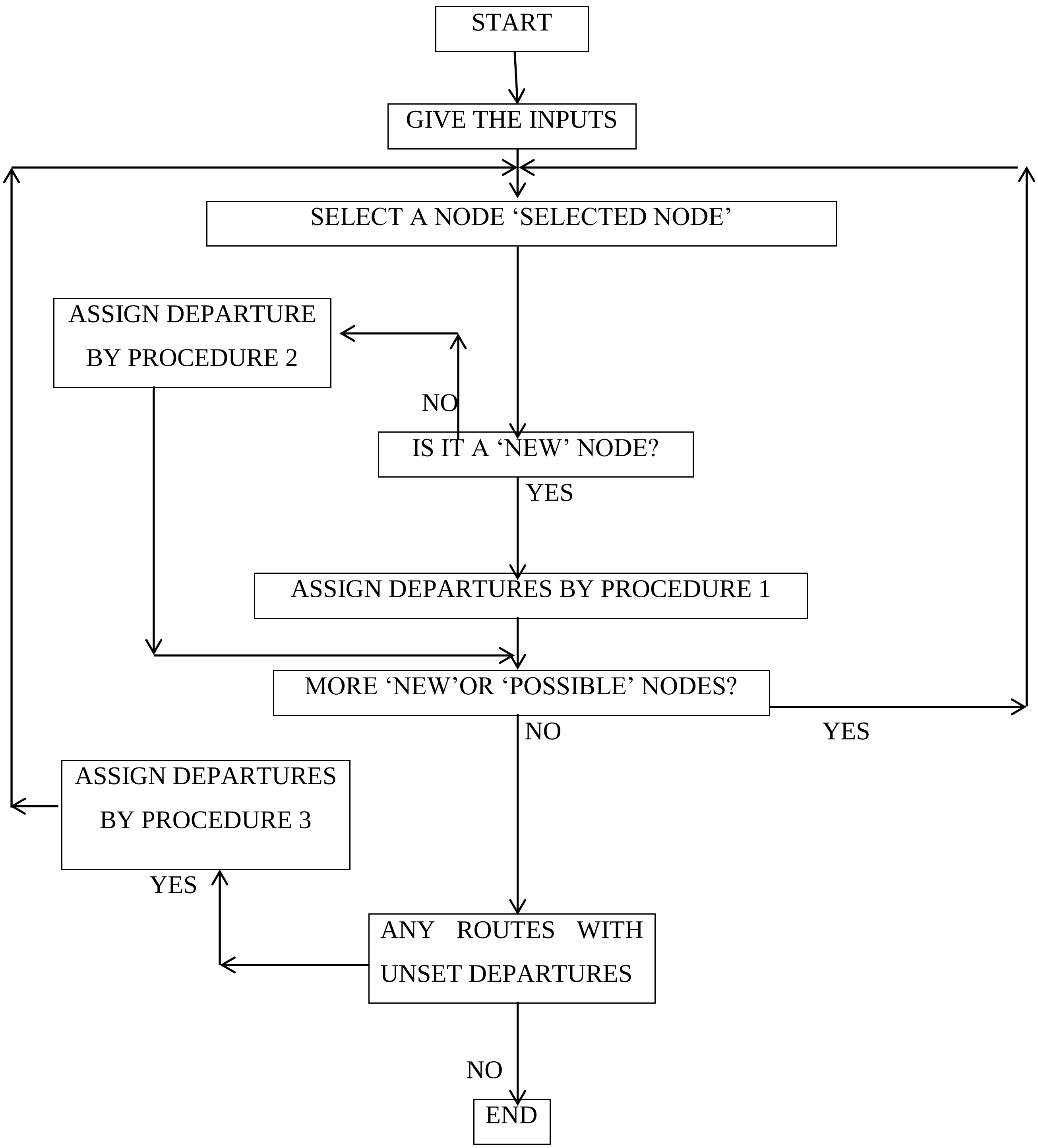

Figure 5.1: Flow Chart of Algorithm

1. A node is 'new' if none of the departure times of routes passing through the node are set.
2. A node is defined as 'possible' if:
   - ✓ There is at least one route passing through it and not all the departure times for that route are set.
   - ✓ There is a possibility to create more synchronized arrivals at the node.
3. A node is 'not possible' if all the departures of the routes passing through it are set and no more simultaneous arrivals are possible

The flow chart of the algorithm is presented in Figure 5.1. Details about input values, node selection processes and procedures are discussed in the following sub-sections. The followings are the steps in the algorithm:

1. Take the input values and initialize all the nodes as 'new';
2. Identify the node 'SELECTED NODE' by the following Node Selection Procedure in section 5.5.1;
3. If 'SELECTED NODE' is new perform PROCEDURE 1, otherwise perform PROCEDURE 2;
4. Are there any 'new' or 'possible' nodes? If yes, go to Step 2. Otherwise continue;
5. Are there any routes with unassigned departures? If yes, perform PROCEDURE 3, otherwise stop.
6. Are there any possible nodes? If yes, go to Step 2. Otherwise stop.

5.5.1 Node Selection Procedure

In each iterative step of the algorithm, a node is selected from among all the 'new' and 'possible' nodes. There are three steps for selecting a node. They are:

1. Among the 'new' and 'possible' nodes find the node that has maximum number of already set arrival times. If no arrival times are set or if ties exist go to Step 2. If only one 'new' or 'possible' node is identified, label this node as 'SELECTED NODE' (k*) and exit.
2. Identify the node with the maximum number of routes passing through it. If ties exist go to Step 3. If only one node is identified, label this node as 'SELECTED NODE' (k*) and exit.

3. Calculate the maximum travel time from the origin of each route to these nodes. Select the node with the minimum value and label it as 'SELECTED NODE' (k*). If a tie exists break it arbitrarily.

PROCEDURE 1

This procedure assigns departure times for routes meeting at the 'SELECTED NODE' if it is 'new'. Suppose that two routes meet at the node, then this procedure assigns the departure time of the route that takes maximum time to arrive to that node. It assigns a departure time of 0 (i.e., the starting time of the planning horizon) to the 1st freight truck on this route that takes maximum travel time. For the other route it assigns the departure time such that the arrival times of these two routes at the selected node is within the specified waiting time limits.

The procedure first checks if it is possible to have the minimum allowed waiting time and if it is possible, departure times are assigned accordingly. If it is not satisfied it increases the time by one (discrete time) and verifies for the next possible waiting time from the limit and so on till the maximum limit is reached. The subsequent departures for these routes are fixed after a time d from the last departure. The procedure finds the minimum possible d that is given by:

d = • $\min_{i=1,2,\ldots M}$ [$\max_{i=1,2,\ldots M}$ (H $\min_i$), $\min_{i=1,2,\ldots M}$ (H $\max_i$)] $\vee$ i, passing through the selected node.

This procedure performs the following steps:

Step 1: At the SELECTED NODE (k *),

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 $\min_i$), $\min_{i=1,2,\ldots M}$ (H $\max_i$)] $\vee$ i passing through k * .

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

Step 2: For the route i*, set the first departure (p = 1) as $X_{i*1} = 0$

Step 3: For the other routes i, passing through this node:

If (maxtime – WT $\min_{k*}$ - t_{ik*} > 0)

Set X_{i1} = (maxtime – WT $\min_{k*}$ - t_{ik*}) and go to Step 5.

Otherwise, set w = WT $\min_{k*}$

Step 4: If (maxtime + w) ≥ t_{ik*} and if (maxtime + w – t_{ik*}) ≤ H $\max_i$

Set X_{i1} = (maxtime + w - t_{ik*}) and go to Step 5.

Else, set w = w +1. If w ≤ WT $\max_{k*}$ repeat step 4, else exit.

Step 5: For these routes i and i*, if the procedure is able to find the value of d in Step 1, then the subsequent departures i.e. ∨ p= 2... min (f_i, f_i*) are assigned after an interval of d from the previous departure. That is:

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

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

Else go to Step 6.

Step 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:

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

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

Step 7: Label all the other nodes on these routes, as 'possible' and label k as 'not possible' and exit.

PROCEDURE 2

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 1. Hence the departure times of the routes that are not set are assigned to have a simultaneous arrival with the set arrivals at the node. If no more assignments are possible the node is marked as 'not possible'. The following steps are performed by this procedure:

Step 1: At the SELECTED NODE, k * that is 'possible',

Set i* as the route passing through k * and all the departure times are already set using PROCEDURE 1. Set arrival times of i* from the origin k * to as:

$\mathbf{T_{ip}^{k*} = X_{i*p} + t_{ik*}}$, $\forall$ p=1....f_{i*}

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

For each T that is, T_{i*p}^{k*}, $Ti_{*1}^{\ k*}$,T_{i*2}^{k*}, $T_{i*f}^{\ k*}$ set w = WT_{k*}

Step 3: For route i, if $0 \leq (T_{i*p}^{k*} - w - t_{ik*}) \leq H\ max_i + X_{i\,(p-1)}$

For p=1, set $X_{ip} = (T^{k*}_{i*p} - w - t_{i*k})$ and go to step 4

For p > 1, if $(T^{k}_{i*p} - w - t_{ik*}) - X_{t\,(p-1)} \geq H\ min_i$, set $X_{ip} = (T^{k*}_{i*p} - w - t_{ik*})$ and go to step 4.

Else if $0 \leq (T_{i*p}^{k*} + w - t_{ik*}) \leq H\ max_{i(p-1)}$

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

For p > 1, if $(T^{k*}_{i*p} + w - t_{ik*}) \geq H\ min_i$, set $X_{ip} = (T^{k*}_{i*p} + w - t_{i*k})$ and go to Step 4.

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

Step 4: For route i if $p < f_i$ – go to Step 2, Otherwise label k* as 'not possible'.

Step 5: For routes i passing through k* 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,

$$\mathbf{T^{k}_{ip} = X_{ip} + t_{ik}}\ \forall\ k = 1 \ldots N \text{ on route i.}$$

Step 6: Label all the other 'new' nodes on these routes, as 'possible'.

PROCEDURE 3

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 unassigned frequency, where P ϵ (1... fi). Set this departure time using the minimum headway from the last departure as

$$\mathbf{X_{ip} = X_{i\,(p-1)} + H\ min_i} \text{ and exit.}$$

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., $\mathbf{X_{ip} = X_{i\,(p-1)} + H\ min_i}$

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

This will allow the algorithm can to set additional simultaneous arrivals at 'possible' nodes.

5.5.2 Application and Discussion of Heuristic Approach

The heuristic approach is applied to real-life rail-road integration that incorporates realistic data on number of routes, nodes and waiting times. The study area is divided into several direction freight transport distributional zonal roots. The root zoning system is considered the transportation distance and time in such a way that the shortest path which can save time and cost of freight transportation and can minimize congestion along the main import and export line.

Table 5.1 zonal group of freight transportation from Djibouti port complex

Seaport	Railway Terminal (Node)	Route Representation	Freight Destination
Djibouti port	Dire Dawa (2)	I	Harar
		II	Jigjiga
	Awash (3)	III	Kombolcha
		IV	Welideya
		V	Mekele
		VI	Adigrat
	Adama		To industry zones near the town
	Modjo (4)	VII	Hawasa
		VIII	Dilla
		IX	Yirgachefi
	Addis Ababa (5)	XI	Debremarkose
		XII	Bahidar
		XV	Wereta
		XVI	Gondor
		X	Jimma
		IIX	Nekemiti
		XIII	Asossa

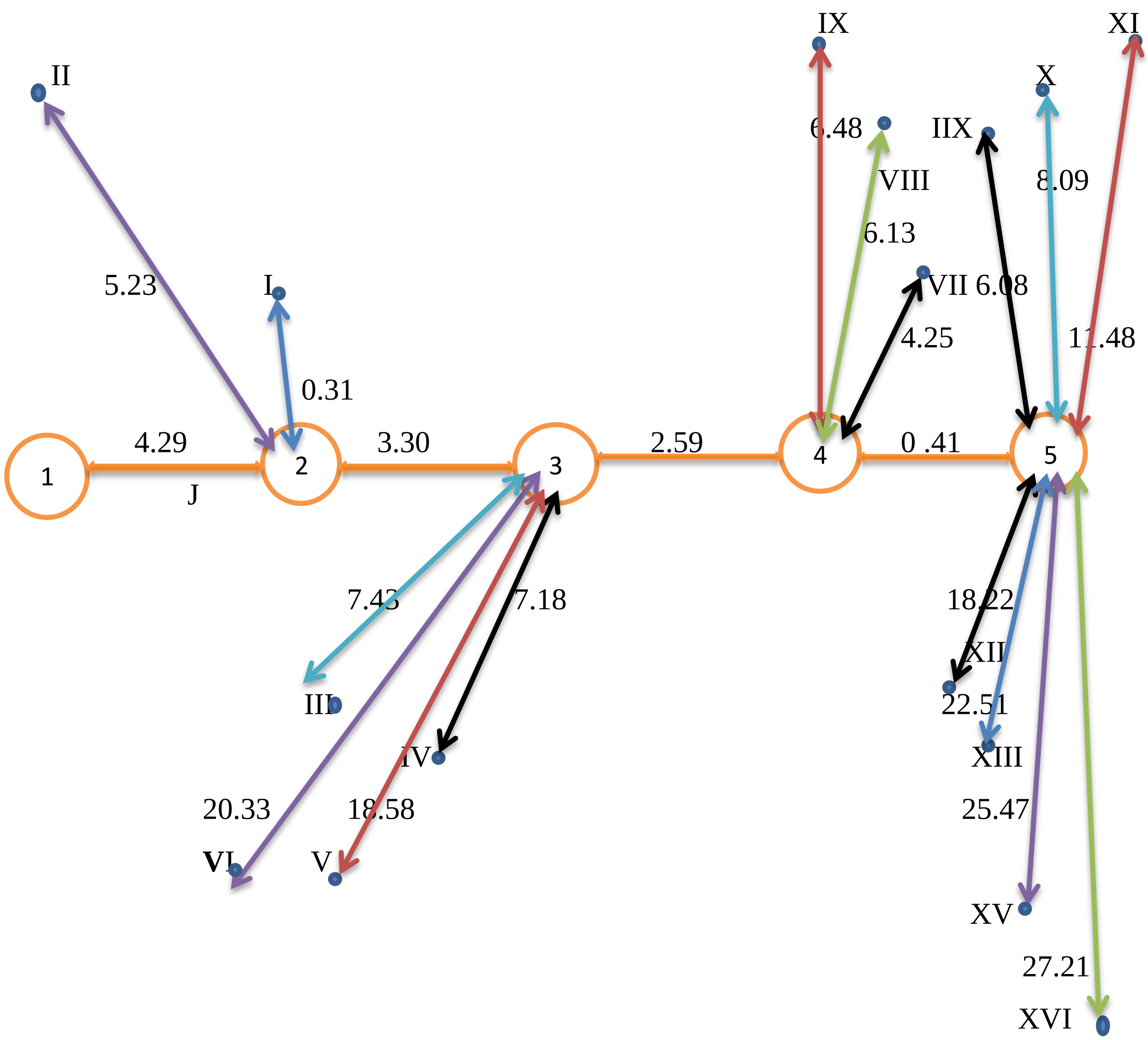

Figure 5.2: Real life rail road integration along Djibouti corridor

Table 5.2: Inputs for Nodes in the corridor

Nodes, k	Number of roots	Minimum waiting time, WT min_k	Maximum waiting time, WT max_k
Dire Dawa (2)	3	30 minutes	90 minutes
Awash (3)	5	30 minutes	90 minutes
Modjo (4)	4	30 minutes	90 minutes
Addis Ababa (5)	8	30 minutes	90 minutes

The headway limits, H min_i and H max_i were set to be 20 minutes and 100 minutes respectively for each root i. The planning horizon is [0,300] minutes and frequency of each route f = 3.

Step 1: Initializes all nodes as 'new'.

Step 2: Identify the node 'SELECTED NODE' k*

1. Number of departure times (=0) for all nodes.
2. Number of crossing routes for node 2,3,4,5 are 3,5,4,8 respectively. Hence the selected node is node 5.

Step 3: perform PROCEDURE 1 at node 5 on roots IIX, X, XI, XII, XIII, XV, XVI, and J.

1. The value of d = min {max [H min_i], min [H max_i]}

   = min {20, 100}

   = 20minutes=0.20hrs

   And the route I set XVI maxitime = 27.21hrs

3. The first departure of route (XVI) is zero.

2. Set w=0.30hrs, X_{XVI1} = 0.20, X_{XVI2} = 0.40

4. For w=0.30hrs the conditions are satisfied and

   For route XV first departure, X_{XV1} = maxitime - w-t_{XVI}

   = 27.21-0.30-25.47

   = 1.04hrs

   The second departure, X_{XV2} = 1.24hrs

   The third departure, X_{XV3} = 1.44hrs

With the same procedure the departures of other routes at node 5 are

Departures	Routes					
	IIX	X	XI	XII	XIII	J
First round	20.43	19.42	15.03	8.23	4.00	15.12
Second round	21.03	20.02	15.23	8.43	4.20	15.32
Third round	21.23	20.22	15.43	9.03	4.40	15.52

Step 4: Lebel nodes 2, 3, 4 'possible' Node 5 as 'not possible' go to step 2

Step 2: Identify the node 'SELECTED NODE' k*

1. Arrival time is three for both nodes 2,3and 4.

2. Number of routes passing through 2,3and 4 nodes are 3,5and 4 respectively, hence node k* = 3.

Step 3: As node 3 is possible PROCEDURE 2 is performed

1. Route i is route J and T_{J1}, T_{J2}, T_{J3} are 23.11, 23.31, and 23.51 respectively.
2. For routes III, IV, V, and VI no departures have been assigned, so set p=1, for T_{J1}=23.11, w=0.30hr.
3. The first departure of the time on the route III, IV, V, and VI

$X_{III1} = T_{J1}+w-t_{III}$ =15.58hrs

With the same procedure X_{IV1}, X_{V1}, and X_{VI1} are 16.23hrs, 4.43hrs, and 3.11hrs respectively.

4. The second and third departure is unassigned go to step 2, p = 2, 3

Departures	Routes			
	III	IV	V	VI
Second round	16.18	16.43	5.03	3.31
Third round	16.38	17.03	5.23	3.51

Step 4: More possible nodes go to step 2

Lebel node 2 and 4 ‘possible’ and node 4 and 5 are ‘not possible’

Step 2: Identify the node ‘SELECTED NODE’ k*

1 .Arrive time is three for both 2 and 4

2 .Number of roots passing through 2 and 4 are 3 and 4 respectively, hence node k*=4

Step 3: As node 4 is possible PROCEDURE 2 is performed

1. Route I is route J and T_{J1}, T_{J2} and T_{J3} are 25.10, 25.30, and 25.50 respectively.
2. The first departure time on the route VII, VIII, and IX

$X_{VII1} = T_{J1} + w - t_{VII1}$ $\quad$ $X_{IX1} = T_{J1} + w - t_{IX}$

$= 25.10+0.30-4.25$ $\quad$ $= 25.10 + 0.30 – 6.47$

$= 21.15$hrs $\quad$ $= 18.53$hrs

$X_{VIII1} = T_{J1} + w – t_{VIII1}$

$= 25.10 + 0.30 – 6.13 = 19.27$hrs

Similarly the departure times X_{VII2} ,X_{VII3} ,X_{VIII2} ,X_{VIII3} ,X_{IX2} ,and X_{IX3} are 21.35 ,22.05 ,19.47 ,20.07 , 19.13 ,19.33 hours respectively.

Step 4: More possible nodes go to step 2

Lebel node 2 ‘possible’ and the others are ‘not possible’

Step 2: Identify the node ‘SELECTED NODE’ k* = 2

Step 3: As node 2 is ‘possible’ PROCEDURE 2 is performed

1. Route i is route J and T_J, T_{J2} and T_{J3} are 21.45, 22.05, and 22.25 respectively.
2. The first departure time on the route I and III

$X_{I1} = T_{J1} + w - t_{I1}$

$= 19.41 + 0.30 - 0.31$

$= 19.40$hrs

$X_{II1} = T_{J1} + w - t_{II1}$

$= 19.41 + 0.30 - 5.23$

$= 15.08$hrs

Similarly the departure times X_{I2}, X_{I3}, X_{II2}, and X_{II3} are 20.00, 20.20, 15.28, and 15.48 hours respectively.

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

The decision variable Y_{ijkTR} is defined as,

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

The final timetable 5.3 shows the simultaneous arrivals at the given selected nodes. For the analysis of arrival times the standard waiting times are taken from the interviews of the traffic officers of major transport companies who are working at the port Djibouti. 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 parallels which are arrived at the same time.

As stated in the feasibility study of Ethio-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. Pick-up and drop trains shall be organized to digest local freight transportation along the line.

Table 5.3 Final Timetables of Simultaneous Arrivals at node 2, 3, 4, 5

Node	Route	Arrival time in hours for		
		(p=1)	(p=2)	(p=3)
2	J	19.41	20.01	20.21
	I	20.11	20.31	20.51
	II	20.11	20.31	20.51
3	J	23.11	23.31	23.51
	III	23.41	24.01	24.21
	IV	23.41	24.01	24.01
	V	23.41	24.01	24.21
	VI	23.41	24.01	24.21
4	J	25.10	25.30	25.50
	VII	25.40	26.00	26.20
	VIII	25.40	26.00	26.20
	IX	25.40	26.00	26.20
5	IIX	26.51	27.11	27.31
	X	26.51	27.11	27.31
	XI	26.51	27.11	27.31
	XII	26.51	27.11	27.31
	XIII	26.51	27.11	27.31
	XV	26.51	27.11	27.31
	XVI	27.21	27.41	28.01
	J	26.51	27.11	27.31

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. 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.

Chapter 6

Validations on Integrated Railroad Freight Transportation

To fashion 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. This section therefore considers the variation in cost and time involved in transporting cargo and emission analysis to the different selected sample freight transportation destination of Ethiopia by road and rail along Djibouti corridor.

6.1 The Costs and Time Dimensions of Hinterland Freight Transportation

For this analysis the cost and time taken are derived by determining the overall average costs and time of transporting for 40 tonnes of cargo to specified hinterland locations as the data samples are collected from Ethiopian shipping line and logistics service (ESLSE), from different transportation companies, from Ethiopian Road Transport Authority and from Ethiopian Railway Corporation. For the purpose of this study, basic railway freight transportation price of 0.046 USD/ton.km has been used. This railway freight transportation price is forecasted by New Standard Gauge Railway Ethiopia/Sebeta-Djibouti/Nagad Railway Feasibility Study.

Monetary expression of operating costs used during transportation need to be calculated as follows: [11]

For rail-road transportation the following calculation has to be implemented:

$$\textbf{Operating cost} = AVT * (TC_d * D_d + TC * D_t) \quad (6.1)$$

Where:

AVT - the average volume of transportations, tons;

$TC_{delivery}$ – cost of transportation in birr/ton.km by road to the main railway terminals and vice versa.

TC - the cost of cargo transportation by railway vehicle, birr / ton. km;

$D_{delivery}$ - the delivery distance to main railway terminal or dry port by road vehicles, km.

$D_{transportation}$- Freight transportation distance from the delivery terminal to the sea port and vice versa in km.

And the total time of transportation, t calculated as

$$t = t_{delivery} + t_{transporting} \quad (6.2)$$

Where: $t_{delivery}$ - time delivery of goods by road to the railway station;

$t_{transporting}$ - during carriage by rail;

$t = D_{delivery}/V_{delivery} + D_{railway} / V_{transportation}$

$V_{delivery}$ – speed of road freight transportation vehicles

$V_{railway}$ – speed of rail freight transportation vehicles

According to the rail-road alternative, freight is delivered by road vehicle to the railway station O' from departure point O, and from O' freight transportation is done by rail to the destination D. See Figure 6.1

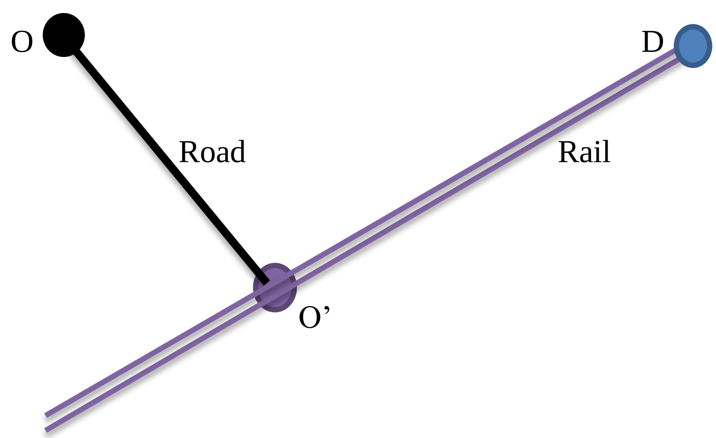

Figure 6.1 the scheme of freight transportation by rail-road option

In this option considering the interaction between rail and road the data for analysis of the transporting goods are:

1. Average speed of transporting by road from place of unloading to railway station or from railway station to destination of distributional centre is 60 km/h since there is a decrease of congestion out of the main corridor the vehicle speed will be increase;
2. Average speed for transport by rail - 80 km / h;
3. Transportation distance by road to the station and from the station to the distribution centre - 218 km;
4. Distance of transportation by rail - 748 km;
5. Base costs by road - 1.16 birrs / tonne.km;
6. Base costs of railway transportation - 0.9292 birr /ton.km
7. Average volume of transporting cargo (AVT) - 40 tons;

Current operating costs are calculated using the following formula:

Operating costs of railroad = AVT * (Base cost $_{delivery}$ * D $_{delivery}$ + base cost $_{transportation}$ * D $_{transportation}$) (6.3)

Where:

Base cost $_{delivery}$, base cost $_{transportation}$ - base cost of birr/ton.km in the delivery of goods by road to the station of departure and accordingly the cost of carriage by rail;

D $_{delivery}$, D $_{transportation}$ - distance of transportation by road and relatively distance of transportation by rail.

Operating cost of railroad = 40 * (1.16 * 218 + 0.9292* 748)

= 37,917 birr

Next to calculate the total time taken for transportation as

$$t_{total} = t_{delivery} + t_{ransportation} \quad (6.4)$$

$$= D_{delivery} / V_{delivery} + D_{transportation} / V_{transportation}$$

$$= [(218km)/ (60km/hrs)] + [(748km) (80km/hrs)]$$

$$= 13.01 \text{ hrs}$$

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

For road transportation operating costs calculated as follow:

Operating costs = TC * D * AVT (6.5)

Where:

AVT - The average volume of transportations, tons;

TC - Cost of transportation birr/ ton.km and it includes costs of fuel, repair, depreciation, driver salary, etc.

D - Distance of transportation, km.

Determine the average time of delivery:

$$t = Droad1 /V1 +Droad2 /V2 \quad (6.6)$$

Where:

T- time of transportation

D_{road1} – distance along the main road

D_{road2} – distance out of the main road

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 6.2.

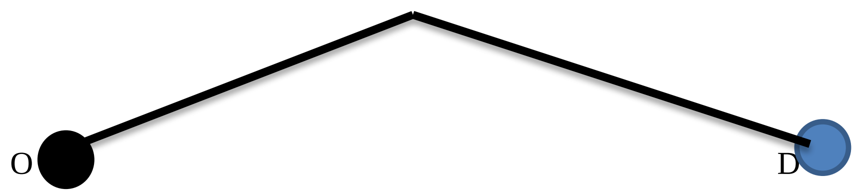

Figure 6.2 the scheme of the transport relations by road option of transportation.

Transportation of goods by road, also defined as delivery "from door to door”. In this case along the research corridor there is high congestion so that the average speed of the vehicle will be decrease.

Initial data for the analysis of freight transportation by road vehicles are taken from the unimodal transportation carriers of major transport companies and from Ethiopian road transport authority:

1. Average speed of transportation along the main corridor, with direct delivery of road trucks - 41.3 km / h;
2. Distance of transportation by road (from door to door) - 1109 km;
3. Base costs per ton.km -1.16 birr / ton.km;
4. Average volume of transportation (AVT) - 40 tons;
5. Average speed of the truck from the main corridor road line to the selected freight destination – 60km/hr.

Current operating costs are calculated using the following formula:

Operating costs = TC * D * AVT

=1109*1.16*40

= 51,458 birr

Determine the average time of delivery:

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

$$= 836/41.3+231/60=24.09hrs.$$

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

With the same procedure of analysis as above the cost and time of freight transportation along the Djibouti corridor from sea port to the dry ports and to the different destinations of main cities of our country for the comparison of integrated rail-road and with unimodal, road is shown below on the table 6.1.

Table 6.1 The Costs and Time Needed to Deliver Goods (40 tonnes) From Djibouti Port Complex to Hinterland Towns in Ethiopia

Towns	Distance by road (km)	Distance by railroad (km)	Cost by road (birr)	Cost by railroad (birr)	Cost/ton .Km by road	Duration of delivery by road (hrs)	Duration of Delivery by railroad (hrs)
Diredawa	394	311	20646	11559	1.31	10.01	4.28
Harar	414	311+20	21694	12607	1.31	10.33	5.01
Jigjiga	707	311+313	37047	17480	1.31	15.22	9.51
Adama	827	667	38373	24791	1.16	20.17	8.34
Modjo	836	748	38790	27802	1.16	20.39	9.35
Bishofitu	878	764	40739	28396	1.15	21.41	9.55
Hawassa	1109	748+231	51458	37917	1.16	24.09	13.01
Dilla	1195	748+368	55448	41675	1.16	27.17	14.00
Yirgachefi	1225	748+389	56840	43206	1.16	27.27	16.23
A.A	909	781	41087	29028	1.13	22.00	10.16
Jimma	1272	781+346	63600	46428	1.25	26.55	16.23
Nekemiti	1253	781+340	66157	46980	1.32	28.24	15.23
Assosa	1584	781+682	83635	65038	1.32	33.42	22.03
D.Markos	1208	781+315	65232	46038	1.35	28.37	16.28
Bahirdar	1472	781+566	79488	59592	1.35	36.20	32.39
Wereta	1533	781+624	82782	62724	1.35	38.00	33.06
Gondor	1647	781+744	88938	69204	1.35	41.00	37.36
Awash	681	543	31598	20182	1.16	17.01	7.09
Kombolch	1127	543+446	57702	43017	1.28	25.04	14.52
Welideya	1112	543+431	60048	43456	1.35	23.24	14.27
Mekele	1374	543+693	75295	58159	1.37	35.14	26.02
Adigrat	1479	543+798	81049	63913	1.37	38.34	28.42

Table 6.2 depicts the differential costs and temporal analysis by road and rail from Djibouti seaports to hinterland towns linked by both transport systems. The use of only road transport to complete the sea leg journey is compared with a proposed rail-road system. For instance, the cost of moving 40 tonnes of consignment by road from seaport to Dire Dawa is birr 20,646.00 with

Table 6.2 Geometric Means Analysis of Differential Costs on the Djibouti Corridor

From Sea port to	Cost by Road (P_i)	Cost by Railroad (P_j)	Difference in cost (birr)	Difference in time (hrs)	Px = P_j as % of Pi	Log x
Dire Dawa	20646	11559	9087	3.3	178.6	2.2526
Harar	21694	12607	9087	3.3	172.1	2.2357
Jigjiga	37047	17480	19567	3.3	211.9	2.3262
Adama	38373	24791	13582	7.53	154.8	2.1897
Modjo	38790	27802	10982	7.49	139.5	2.1446
Bishofitu	40739	28396	12343	9.18	143.5	2.1568
Hawassa	51458	37917	13541	11.08	135.7	2.1326
Dilla	55448	41675	13773	7.49	133.0	2.1240
Yirgachefi	56840	43206	13634	5.57	131.6	2.1191
Addis Ababa	41087	29028	12059	11.44	141.5	2.1509
Jimma	63600	46428	17172	11.54	137.0	2.1367
Nekemiti	66157	46980	19177	11.44	140.8	2.1487
Assosa	83635	65038	18597	10.54	128.6	2.1092
Debremarkose	65232	46038	19194	5.34	141.7	2.1513
Bahirdar	79488	59592	19896	4.44	133.4	2.1251
Wereta	82782	62724	20058	4.54	132.0	2.1205
Gondor	88938	69204	19734	3.24	128.5	2.1090
Awash	31598	20182	11416	8.52	156.6	2.1947
Kombolcha	57702	43017	12685	10.12	129.5	2.1122
Welideya	60048	43456	16592	10.57	138.2	2.1404
Mekele	75295	58159	17136	9.12	129.4	2.1121
Adigrat	81049	63913	17132	9.52	126.8	2.1032
Total						47.3953

delivery time 7.58hrs whereas rail is expected to cost birr 11559.00 with delivery time 4.28 hours. For Hawassa with a distance of 1109 kilometers by road, it takes an average time of 22.27 hours and birr 51,458.00 to deliver cargo from Djibouti port but for the rail-road is expected to cost birr 37,917.00 with delivery time 13.01 hours. Thus, an enormous differential cost in excess of birr 9,087.00 and birr 13,541.00 could be saved for Dire Dawa and Hawassa respectively when used integrated rail-road freight transportation. As regards the temporal variation in delivery time, 7.53, 11.54, 10.12, 5.34, 9.12, and 9.52 hours could be saved when rail will be adopted in transporting goods from Djibouti port to Adama, Jimma, Kombolcha, Debre Markose, Mekele, and Adigrat 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. This average is used in special cases, one of the most important being the overall average percentage of change. According to Schuyler, (2005) and Robinson and Schneider, (2007) 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 6.2 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 44.67 %, Eq. (1) and Eq. (2).

The implication of this result is that 42.67 % of the freight costs could be saved if hinterland bound goods is conveyed in a multimodal pattern from Djibouti seaport to the city centre of the hinterland locations on this route.

$$Log\ G.M = \frac{\sum(log x)}{n} = 47.3953/22 = 2.1543 \quad (1)$$

(Antilog of 2.1543 = 142.67)

$$142.67\text{-}100 = 42.67\% \quad (2)$$

Indeed, economic and reliability considerations dictate that road ought not to be the choice in interregional movement of hinterland goods. There is therefore the need to adopt a reliable integerated rail-road multimodal freight transportation system.

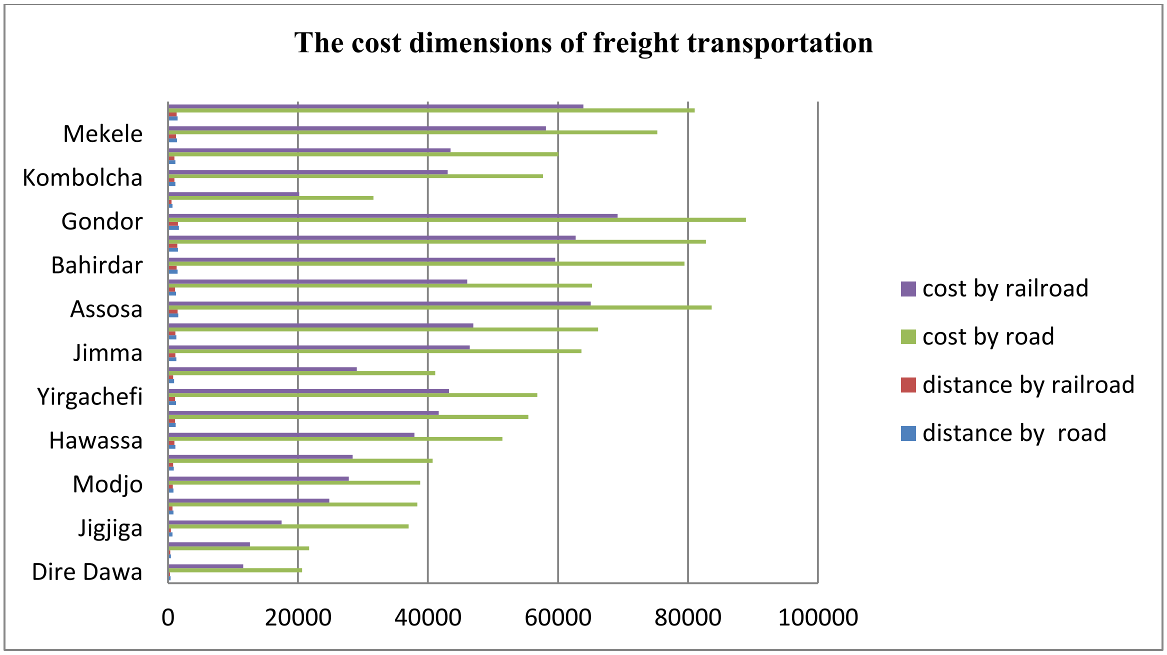

Figure 6.3 Cost Dimensions of Freight transportation

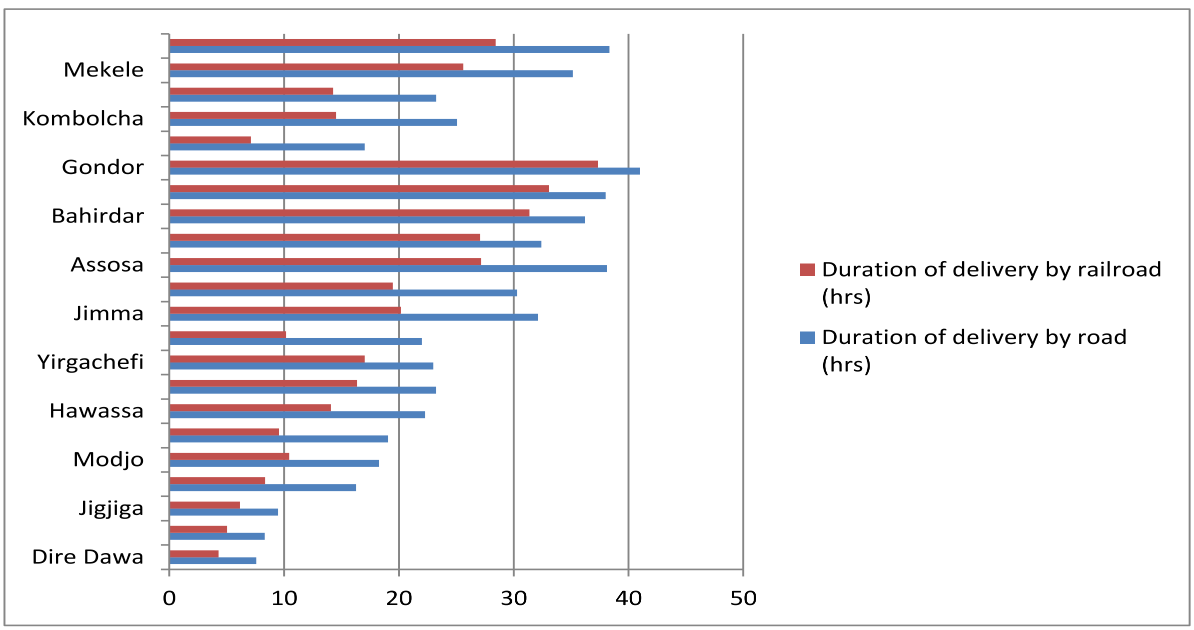

Figure 6.4 Duration of delivery by road and railroad

6.2 Analysis on Emission of Road and Railroad Freight Transportation

The analysis of CO_2 and SO_2 emission from fuel consumed can be carried out by multiplying the fuel consumption per distance unit by the total travel distance and the appropriate fuel specific emission factor as shown in the Equation below.

$$\mathbf{E_{ij} = FC_j * VKM_j * FSEF_i}$$

Where: E_{ij} = total emission of pollutant i for vehicle type j

FC_j = the fuel consumption by vehicle type j in tonnes of fuel per v-km

VKM_j = the vehicle-km for vehicle type j

$FSEF_i$ = the fuel specific emission factor, in kilotonne pollutant per tonne fuel

The total amount of emissions of each pollutant is obtained by simply adding up the emissions by vehicle type:

$$\mathbf{E_i = \sum_j E_{ij}}$$

Where: E_i = total emission of pollutant

For converting the fuel consumption from units of volume into units of mass the density factor 0.845 kg/litre for fuel (Volvo Truck Corporation, personal communication, March 2005) is applied.

Foe this study even if the fuel consumption during driving in our country depends on the skill of the driver, the technical condition of the vehicle, and the geographical variation of the road is taken 45litre/100km which is taken by interviewing the Engineers from Equatorial Business Group PLC which is a VOLVO dealer company.

Table 6.5: Input and output variables for estimating emissions from road freight transport, using a fuel-based approach

Input variables	Emission factor SO_2: 0.8 (t SO_2/ kt fuel) (AEA Technology, 1998)
	Emission factor CO_2: 3,142 (t CO_2/kt fuel) (AEA Technology, 1998)
Output variables	Total emissions of SO_2 in kt
	Total emissions of CO_2 in kt

For the given data below road transport Emission of CO_2 and SO_2 calculated as follow:

For this analysis the data that are taken for road freight transportation from Djibouti port to Hawassa.

Road distance from Djibouti port to Hawassa=1109km

Fuel consumption ton per km mileage $= 0.845*10^{-3}$ton/litre*0.45litre/km

$= 0.38025*10^{-3}$ton/km

Emission factor SO_2 = 0.8 (t SO2/ kt fuel)

= 0.0008 (ktSO_2/kt fuel)

Emission factor CO_2 = 3,142 (t CO2/kt fuel)

= 3.142(kt CO2/kt fuel)

Hence total emission of pollutant i for vehicle type j for road freight transportation is

$$E_{ij} = FC_j * VKM_j * FSEF_i$$

$$= [0.38025*10^{-3}\text{ton/km}*1109\text{km}*0.0008\text{ktSO}_2\text{/kt fuel}] + [0.38025*10^{-3}\text{ton/km}*1109\text{km}*3.142\text{ktCO}_2\text{/kt fuel}]$$

$$= [0.38025\text{ton/km}*1.109\text{km}*0.0008\text{SO}_2]+[0.38025\text{ton/km}*1.109\text{km}*3.142\text{CO}_2]$$

$$=3.374*10^{-4}\text{ton SO}_2 + 1.325 \text{ ton CO}_2$$

To find the emission of rail-road freight transportation from Djibouti port to Hawassa city we should use only the road distance from Modjo dry port to Hawassa city=231km by neglecting 748km from the sea port to Modjo since freight transportation by railway vehicle uses zero emission hydroelectric power.

$$E_{ij} = FC_j*VKM_j*FSEF_i$$

$$= [0.38025*10^{-3}\text{ton/km}*231\text{km}*0.0008\text{ktSO}_2\text{/kt fuel}] + [0.38025*10^{-3}\text{ton/km}*231\text{km}*3.142\text{ktCO2/kt fuel}]$$

$$= [0.38025\text{ton/km}*0.231\text{km}*0.0008\text{SO}_2] + [0.38025\text{ton/km}*0.231\text{km}*3.142\text{CO}_2]$$

$$= 7.027*10^{-5} \text{ ton SO}_2 + 0.276 \text{ ton CO}_2$$

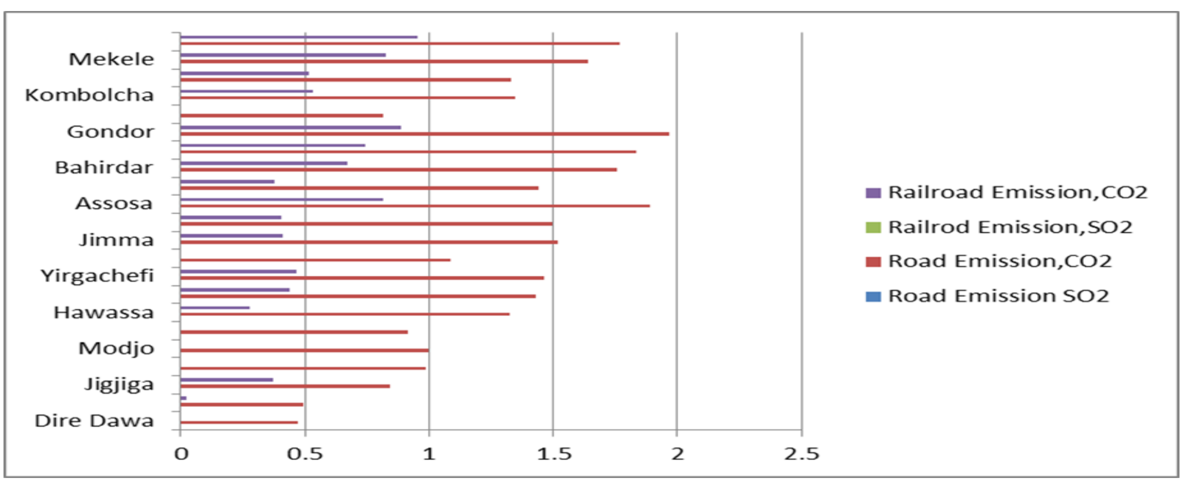

Figure 6.5 Emission of road and railroad freight transportation

Table 6.6 Road and railroad emission of freight transportation

Towns	Distance by road	Distance by railroad		Road Emission (in ton)		Rail-road Emission (in ton)	
		rail	road	SO_2	CO_2	SO_2	CO_2
Dire Dawa	394	311	-	$1.119*10^{-4}$	0.471	-	-
Harar	414	311	20	$1.259*10^{-4}$	0.495	$0.060*10^{-4}$	0.024
Jigjiga	707	311	313	$2.150*10^{-4}$	0.845	$0.952*10^{-4}$	0.374
Adama	827	667	-	$2.516*10^{-4}$	0.988	-	-
Modjo	836	748	-	$2.516*10^{-4}$	0.999	-	-
Bishofitu	878	764	-	$2.324*10^{-4}$	0.913	-	-
Hawassa	1109	748	231	$3.374*10^{-4}$	1.325	$7.027*10^{-4}$	0.276
Dilla	1195	748	368	$3.635*10^{-4}$	1.428	$1.119*10^{-4}$	0.440
Yirgachefi	1225	748	389	$3.726*10^{-4}$	1.464	$1.183*10^{-4}$	0.467
A.A	909	781	-	$2.765*10^{-4}$	1.086	-	-
Jimma	1272	781	346	$3.869*10^{-4}$	1.520	$1.053*10^{-4}$	0.413
Nekemiti	1253	781	340	$3.812*10^{-4}$	1.497	$1.034*10^{-4}$	0.406
Assosa	1584	781	682	$4.819*10^{-4}$	1.892	$2.075*10^{-4}$	0.815
D.Markos	1208	781	315	$3.675*10^{-4}$	1.443	$0.958*10^{-4}$	0.376
Bahirdar	1472	781	566	$4.478*10^{-4}$	1.759	$1.722*10^{-4}$	0.672
Wereta	1533	781	624	$4.660*10^{-4}$	1.832	$1.898*10^{-4}$	0.746
Gondor	1647	781	744	$5.010*10^{-4}$	1.968	$2.263*10^{-4}$	0.889
Awash	681	543	-	$1.920*10^{-4}$	0.814	-	-
Kombolcha	1127	543	446	$3.428*10^{-4}$	1.346	$1.357*10^{-4}$	0.534
Welideya	1112	543	431	$3.383*10^{-4}$	1.329	$1.311*10^{-4}$	0.515
Mekele	1374	543	693	$4,180*10^{-4}$	1.642	$2.108*10^{-4}$	0.828
Adigrat	1479	543	798	$4.499*10^{-4}$	1.767	$2.428*10^{-4}$	0.953

As shown in the figure 6.5 above freight transportation by road has significant emission than that of railroad freight transportation. Emission of freight transportation by rail is zero emission because of the power source for running the railway vehicle is hydroelectricity.

Table 6.7 Geometric Analysis of freight transportation emission

Towns	Road Emission (E_i) in ton	Rail-road Emission (E_j) in ton	Difference in Emission in ton	E_x=E_j as % of E_i	Log E_x
Dire Dawa	$4708.496*10^{-4}$	-	$4708.496*10^{-4}$	-	-
Harar	$4951.259*10^{-4}$	$240.06*10^{-4}$	$4711.199*10^{-4}$	2062.68	3.314
Jigjiga	$8452.15*10^{-4}$	$3740.952*10^{-4}$	$4711.199*10^{-4}$	225.936	2.353
Adama	$9883.061*10^{-4}$	-	$9883.061*10^{-4}$	-	-
Modjo	$9990.588*10^{-4}$	-	$9990.588*10^{-4}$	-	-
Bishofitu	$9130.180*10^{-4}$	-	$9130.180*10^{-4}$	-	-
Hawassa	$13253.374*10^{-4}$	$2767.027*10^{-4}$	$10486.347*10^{-4}$	478.975	2.680
Dilla	$14283.635*10^{-4}$	$4401.119*10^{-4}$	$9882.534*10^{-4}$	324.546	2.511
Yirgachefi	$14643.726*10^{-4}$	$4671.183*10^{-4}$	$9972.543*10^{-4}$	313.491	2.496
A.A	$10863.002*10^{-4}$	-	$10863.002*10^{-4}$	-	-
Jimma	$15203.869*10^{-4}$	$4131.053*10^{-4}$	$11072.816*10^{-4}$	368.039	2.566
Nekemiti	$14973.812*10^{-4}$	$4061.034*10^{-4}$	$10912.778*10^{-4}$	368.719	2.567
Assosa	$18924.819*10^{-4}$	$8152..075*10^{-4}$	$10772.744*10^{-4}$	232.147	2.366
D.Markos	$14443.675*10^{-4}$	$3760.958*10^{-4}$	$10672.717*10^{-4}$	383.777	2.584
Bahirdar	$17593.478*10^{-4}$	$6721.722*10^{-4}$	$10872.756*10^{-4}$	261.756	2.418
Wereta	$18324.660*10^{-4}$	$7461.898*10^{-4}$	$10862.762*10^{-4}$	245.576	2.390
Gondor	$19685.01*10^{-4}$	$8892.263*10^{-4}$	$10792.747*10^{-4}$	221.372	2.345
Awash	$8138.137*10^{-4}$	-	$8138.137*10^{-4}$		-
Kombolcha	$13463.428*10^{-4}$	$5341.357*10^{-4}$	$8122.071*10^{-4}$	256.06	2.408
Welideya	$13293.383*10^{-4}$	$5151.311*10^{-4}$	$8142.072*10^{-4}$	258.058	2.412
Mekele	$16424.180*10^{-4}$	$8282.108*10^{-4}$	$8142.072*10^{-4}$	198.309	2.297
Adigrat	$17674.499*10^{-4}$	$9532.428*10^{-4}$	8142.428*10-4	185.414	2.268

Furthermore, the differential emissions are subjected to Geometric Mean (GM) test to ascertain the overall average percentage difference in emission reduction by moving goods from the seaports using rail-road system rather than the sole reliance on road haulage. This average is used in special cases, one of the most important being the overall average percentage of change.

$$\text{Log G.M} = (\sum (\log Ex))/n = 40.047/16 = 2.503 \quad (3)$$

$$(\text{Antilog of } 2.503 = 318.42) \quad (4)$$

$$318.42 - 100 = 218.42\%$$

The implication of this result is 218.42 % of emission could be reduced if hinterland bound goods is conveyed in the railroad integrated pattern from Djibouti seaport to the different destinations of the hinterland locations on this route and vice versa.

Chapter 7

Conclusion and Recommendation

7.1 Conclusion

This study has shown that the potentials of integrating rail-road in port-hinterland freight transportation would be beneficial to the economic development of the country. 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. This paper has demonstrated in clear terms that integrating rail-road transport from Djibouti seaports to the hinterland of Ethiopia would reduce freight cost, the time of delivery and unnecessary operational delays, accidents and loss of cargo in transit, and by extension, reduce the pressure on Ethiopian roads. For Ethiopia to be able to achieve this, multimodal transport as a concept must be adapted into our national transportation system by incorporating it in our national transport policy. The infusion of this transport technique into our transportation system can only be effective if the country adopts the implementation of modern best practices in transportation such as deregulation and concession. The reason is that if Ethiopia continues to regulate her modal infrastructures and restrict herself to conventional services, the country runs the risks of losing out in distribution trade that is increasingly becoming globalized.

As shown in the validation of the integration both businesses economic costs and environmental effects can be lowered by using more combined or integrated transport. It can also be seen that combined transport, almost always, is economically competitive if the transport distance by rail is long enough.

Thus, the main challenge for combined transport is not cost, but achieving competitive pick-up and delivery times compared with all-road transport. There are two main strategies for achieving this: creating a speed advantage for combined transport or influencing the attitude of the transport customer to allow later deliveries and/or earlier pick-up. Strategies take time to implement, but, already now, it is possible to start influencing the transport customer, since each individual transport customer will contribute towards reaching the potential.

A possible way of convincing the transport customer is to use the cost reduction gained by using combined transport to reduce the price of transport. At the same time, technical development in the rail sector indicates that the speed of combined transport will increase. Also, a more market oriented rail transport sector with the, potential, entry of new actors, is likely to put pressure on the combined transport actors to streamline their operations. The transport sector is, therefore, likely to move towards the use of more combined transport, however, actions are necessary to ensure this development. In particular, the attitude of the transport customer is a key factor in increasing the share of combined transport.

The potential gain for society from using more combined transport is also substantial. In particular, the environmental impact of transport can be reduced by an increase of combined transport. Specifically, reduced CO_2 emissions are a major concern for society today, considering the climate change and greenhouse effect. It is important for the society to retain its high interest in multimodal transport to support and facilitate a modal shift to achieve a sustainable society. Also, the rail industry must continue to use electric power from renewable energy sources to maintain its environmental advantage.

7.2 Recommendation

The freight transportation of Ethiopia until 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. Hence, the following recommendations are given:

1. 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 nehibouring countries.
2. Since our country is reach in the production of hydroelectric power electric driven railway vehicles should better to be used in the transportation sector.
3. Most of the import and export freights better to be done by railway vehicles because of the fastest time and carrying capacity.
4. In the future most the long distance of 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.
5. The access of highly modernized loading and unloading machineries, well organised 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.

7.3 Future Research Areas

This study is done at the time of the new Ethio-Djibouti railway transportation is not starting and all the necessary related data for freight transportation by railway vehicles are taken from the feasibility study of New Standard Gauge Railway Ethiopia/Sebeta-Djibouti/Nagad Railway by ERC in September, 2012. Hence, further study should be done in the future using actual railway operational data to be more confidential in the potentials of rail-road freight transportation integrations.

The integration of rail freight transportation from Djibouti port to Addis Ababa with that of road transportation from hinterland location to the railway terminals along the Djibouti corridor is the main study area of this research. However, at the completion of other railway construction projects which are planned by Ethiopian Railway Corporation the role of road freight transportation will be decreased, hence, further studies better to be done in the integration of rail-road multimodal freight transportation to have more reliable, timely and cost-effective freight transportation of the country.

In this research integration of rail-road passenger transportation is not included. Hence studies should be done on this area. Moreover, latest software like STAN, C$^{++,}$ and other software are better to be used in the integrations of rail and road modes of transportation.

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