UNIVERSITY OF NAIROBI
DEPARTMENT OF CIVIL & CONSTRUCTION ENGINEERING

FREIGHT RATE DETERMINANTS ALONG THE NORTHERN CORRIDOR ROAD

BY

OYIER SAMWEL ZEPHANIAH

(F56/ 9045/2005)

A Research Thesis submitted to
the Department of Civil and Construction Engineering
in Partial fulfilment of the Requirements for the Degree of

Master of Science in Civil Engineering

August, 2009

Declaration

This thesis is my original work and to the best of my knowledge has not been submitted in part or whole for a degree in any other university for any award.

Signed.................................... Date 11/08/09

Oyier Samwel Zephaniah (F56/ 9045/2005)

This research thesis is submitted in partial fulfilment of the requirements for the award of Master of Science in Civil Engineering at the University of Nairobi.

Supervisor's Declaration

This thesis has been submitted with my approval as supervisor.

Signed.................................... Date 11/08/'09

Professor Oyuko.O. Mbeche,

Department of Civil & Construction Engineering,

University of Nairobi

Dedication

to

My father, mother and late grand father

Acknowledgements

I would like to extend my sincere thanks to my supervisor Prof Oyuko O. Mbeche, the team leader of the Northern Corridor Monitoring and Evaluation project, for initiating my interest in this research topic and monitoring its progress keenly. Special thanks go to Eng. Tom Opiyo the former team leader of the Northern Corridor Monitoring and Evaluation project for his invaluable guidance throughout the process of developing and writing of this thesis. I am also indebted to the Dean of the Department of Civil Engineering, Prof. Patts M.A Odira who has been my guardian and role model, as well as the main force behind my academic and intellectual development.

My appreciation goes to the World Bank, Ministry of Roads & Public Works and University of Nairobi Enterprises and Services (UNES) Limited whose financial support under the Monitoring and Evaluation of the Northern Corridor project enabled me to conduct this research study. In addition, I would also like to thank Godfrey Onyango (NCTTCA), Eunice Mwonyalo (KTA), Rodrigo Achondo (World Bank), members of the Kenya Transport Association, Mcjuma Adongo and Judith Kibuye (Public Relations office, UoN) for availing important resources and data during fieldwork and interviews. Without their efforts this thesis would not have been realized. To my colleagues Peter Kojwang, Susan Awuor, Faith Mwangi and Mahinda, thank you so much for your kindness and support during my study.

I am also indebted to Sam Aguyo and Udo Mbeche who proof read and edited the manuscript before the final submission.

Finally, my heartfelt appreciation goes to my parents, family members, Uncle Kabunge and Beryl for their love, care and support.

Abstract

This study is the first comprehensive and empirical effort to measure and quantify the determinants of freight rates and transport costs in Kenya. Accordingly, a model has yet to be developed which represents in detail the relation of freight rates against factors influencing transportation costs. Ordinarily, transport costs between a specific origin and destination has mostly been determined through guesswork, and is based on the expenses incurred by transporters in fuel, spare parts and maintenance labour charges. For instance, the establishment of freight rates between any origin and destination is largely dependent on direct inquiries from transportation companies. Hence its reliability cannot be ascertained. This situation is further worsened by the lengthy process involved, and rates obtained which do not accurately represent what majority of transportation companies would charge. As a result, the freight customers are often exploited and inappropriate policies adopted by the country's transport sector.

In a free market, perfect competition is assumed whereby prices depend on demand and supply. Besides competition in the market, other factors that influence freight rates include vehicle operating costs (VOCs), travel time between the origin and destination, freight tonnage, absence or presence of return cargo and truck category used for the transport. This research seeks to establish the relationship between factors influencing freight rates along the transport corridor, using the Northern Corridor road in Kenya as a case study.

The Northern Corridor road network extends from the Kenyan seaport of Mombasa, on the Indian Ocean, and offers a passageway to the landlocked countries of Uganda, Rwanda, Southern Sudan, and Eastern Democratic Republic of Congo respectively. For the purposes of this thesis, a survey was conducted to establish the number of transporters and various categories of motor vehicles using the aforementioned transport corridor. Likewise, key informant interviews were carried out to determine the vehicle operating costs (VOCs), and data analyzed using Statistical Package for Social Sciences (SPSS), and Excel. In addition, the use of Global Positioning System (GPS)

equipment was employed in order to establish travel time data, which was later analyzed by Ozi explorer. Based on the investigated parameters, two freight transport cost prediction models were developed to simulate the relationship between transport costs and VOCs, while taking into consideration other factors influencing the freight rates. The parameters adopted to develop the Freight Transport Cost Prediction Model (FTCPM) were an inexpensive means of data collection.

The first model is a multiple linear regression equation which estimates the freight rate charged by transporters. The model can be used to estimate the freight transport rates (US$/ton-km) where input variables are known. The second model is an exponential equation which shows the sensitivity of freight rates to VOCs, which is applied in predicting freight rates. Findings revealed that transport rates increase alongside the vehicle operating costs within a specific range. Furthermore, the degree of influence of each factor varies depending on the truck category, that is, whether classified as a light/medium or heavy truck. The transport rates vary substantially with vehicle operating costs, distance and tonnage in the case of heavy trucks. While for light/medium trucks, freight rates depend mostly on distance, tonnage and whether there is a return cargo or not. It was also established that heavy trucks had high vehicle operating costs, while light trucks had low vehicle operating costs. In both cases the tyre and fuel consumption was more than 50 percent of the operating costs. Conversely, findings revealed that light trucks had the highest freight transport rates per ton-km, while heavy trucks had the lowest freight rates per ton-km.

This research study recommends that sections of the Northern Corridor road which experienced a repeated change of horizontal alignment be realigned to shorten the distance covered, and lower vehicle operating cost. In addition, the maximum allowable cargo weight limit should be strictly enforced at weigh bridges to prevent high vehicle operating costs.

Key Words: Transport Cost, Freight Rates, Vehicle Operating Costs, Trucks, Regression.

Freight Rates Determinants
along the Northern Corridor Road

Table of Contents

List of Tables

List of Figures

Acronyms

AADT	: Annual Average Daily Traffic
ADT	: Average Daily Traffic
COMESA	: Common Market of Eastern and Southern Africa
DRC	: Democratic Republic of Congo
FTCPM	: Freight Transport Cost Prediction Model
GDP	: Gross Domestic product
GoK	: Government of Kenya
GPS	: Global Positioning System
GVW	: Gross Vehicle Weight
HDM	: Highway Development and Management
HGV	: Heavy Goods Vehicles
IRI	: International Roughness Index
JIT	: Just In Time
KENATCO	: Kenya National Transporters' Company
KRC	: Kenya Railways Company
LGV	: Light Goods Vehicles
MAPL	: Maximum Allowable Pay Load
MGV	: Medium Goods Vehicles
MoRPW	: Ministry of Roads and Public Works
NC	: Northern Corridor
NCTA	: Northern Corridor Transit Agreement
NCTTCA	: Northern Corridor Transit Transport Coordination Authority
NMT	: Non Motorized Traffic
O-D	: Origin-Destination
PCSE	: Passenger Car Space Equivalent
RED	: Road Economic Decision
RUC	: Road User Costs
RUCKS	: Road User Cost Knowledge System

1. INTRODUCTION

1.1 Transport and Economy

Transport is defined as the movement of people and goods between destinations. The transportation system helps overcome the effects of distance. Efficient freight transport brings the benefit of a widened market area for trade while also enabling Just-in-Time [1](JIT) production techniques. Total cost of freight transport and logistics is significant and has a direct bearing on the efficiency and growth of an economy. Trade in any country directly depends on the efficiency of freight transportation carried out by air, water, rail or road. Each of these modes of transportation offers certain advantages and disadvantages in terms of cost, speed, reliability, and security services, depending on their specific transport needs. Accordingly, the cost of road freight transport is determined by a number of factors including vehicle operating costs, which depends on road characteristics. Edward (2003), in a discussion paper at Harvard Institute of Economic Research revealed that the theoretical aspects of trade and economics are based on transportation costs.

Over the years, demand for road freight transport in Kenya has grown rapidly as reflected by the growth of heavy trucks, which have increased at a rate of 3 percent per annum (MoRPW, 2003). As a result, it is important that a sound infrastructure which minimizes transport costs caters for the increased demand for freight transport (Colin, 2001).

If industries continue to move in the direction of Just-In-Time production and distribution, the economic consequences of disruptions in the transportation system become more acute. Disruptions in freight transport can be caused by a variety of factors including escalated transport costs among others (Caldwell et al, 2000).

[1] Is an approach to operations planning control based on the idea that goods and services should be produced only when they are needed and neither too early (so that inventory build up) nor too late (so that customers have to wait)

1.2 Description of Study Area

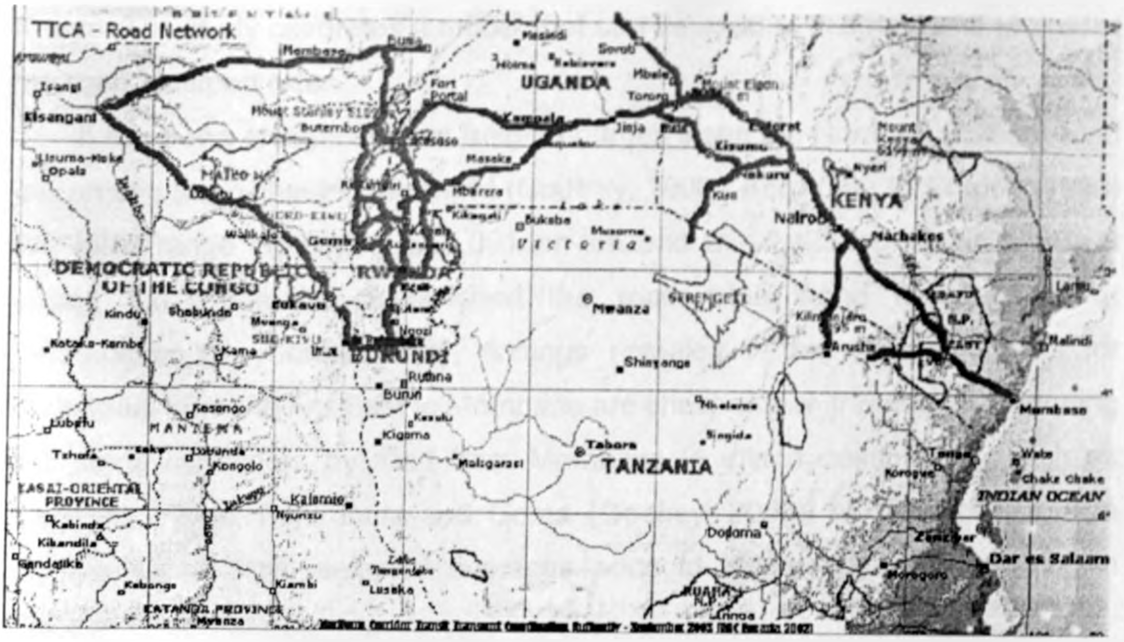
The Northern Corridor (NC) road extends from the Kenyan seaport of Mombasa, passing through the mainland towns of Nairobi, and Eldoret, exiting in Uganda at the Malaba border post. It is the main highway to Uganda, Rwanda, Southern Sudan, and Eastern Democratic Republic of Congo (DRC). The corridor route network also serves Northern Tanzania, Southern Sudan and Ethiopia (TTCA, 2004). The approximate distance from Mombasa to Malaba is 960km, while that from Mombasa to Busia is about 1010km. Over the years, statistics reveal that traffic along the Northern Corridor road has grown at a steady rate of 7.2 percent per annum (TTCA, 2004). The road infrastructure is characterised by a flexible pavement with an asphaltic concrete surface. Varied is the geometry of the main road route network, which has two-lane two-way carriageways in most of the road cross-sections and dual carriageways within the urban centres which include Mombasa, Nairobi, Nakuru and Eldoret

An alternative transport link is the Central Corridor road which originates from the sea port of Dar es salaam in Tanzania to Rwanda, Burundi and Southern Uganda. Compared to the Central Corridor network which covers Tanzania and parts of Rwanda, the Northern Corridor road which is shorter in distance, is busier in the East Africa Region. Therefore, its rehabilitation and maintenance would spur economic growth and sustainable development in the Region (TTCA, 2004).

1.2.1 The Northern Corridor Road Network

The main road network shown in plate 1.1 below depicts the Kenyan component of the corridor. It is the main distribution link from the port of Mombasa to A1 road, which connects to Southern Sudan through Lodwar. Additionally, the importance of the Northern Corridor road network is reinforced by the fact that it branches to Tanzanian through Voi, which is situated close to the port of Dar es Salaam. Further North, the road serves Southern Sudan, as well as Uganda, DRC, Rwanda and Burundi to the West.

Plate 1.1: Northern Corridor Routes



Source: TTCA Secretariat, 2004

1.3 Problem Statement

Currently, no model has been developed which relates freight rates to factors influencing transport cost in Kenya. An investigation is yet to be carried out to ascertain the degree of influence of such factors. Consequently, the transport cost between a given origin and destination is mostly approximated. For example, most transport companies quote their transport costs based on what they incur in fuel, spare parts and maintenance labour charges. In addition, any estimation of the transport cost between any origin and destination is based on direct inquiries from transport companies. The process of obtaining this kind of information takes a long time, in addition to the high probability of errors and unreliability. This may lead to high freight rates whose charges are incurred by customers, since the data used by the transporters is unfounded.

Yet to be established is whether the transport rates along the Northern Corridor road are affected by vehicle operating costs transporters' profit margins, and demand for transport, insurance costs, or distances covered on the road. In a free market where there is perfect competition, prices are determined by forces of demand and supply. Against this backdrop, this research was undertaken to investigate the factors affecting freight rates along the Northern Corridor road in Kenya. The study calibrates a model that can be used to estimate and to predict the road transport rates.

It has been recognized that freight charges along the Northern Corridor road are among the highest in the world (Godfrey, 2006). According to Gordon (1996) the rates range between US$0.081/ton-km and US$0.123/ton-km. In a recent paper, the researcher established the road rates along the Corridor at US$0.04/ton-km. Consequently, findings revealed that shipment costs for containers from the Far East to Mombasa are cheaper than those for transporting the same containers by road from Mombasa to inland destinations, such as Kampala, Kigali, Bujumbura and Goma (Godfrey, 2006). A comparison of the shipping costs from selected overseas ports to Mombasa is summarized in Tables 1.1 below:

Table 1-1: Shipment Cost to Port of Mombasa

Origin/Destination	Shipment Cost (US$) per 20ft container	Average Shipment cost (US$) per 20ft container
Hong Kong – Mombasa	950 – 1800	1300
Shanghai – Mombasa	1120 – 2040	1500
Yokohama – Mombasa	1250 – 1800	1550

Source: NCTTCA Survey, 2006

As suggested by the NCTTCA survey (2006), the average shipment costs is measured per 20ft container, whilst import and export cargo is measured per 20ft and 40ft container for freight transport costs along the Northern Corridor road (See Table 1.2). Findings revealed that the road transport costs from Mombasa to Kampala range between US$2700 and US$3300 which are higher than the sea transport costs to the seaport of Mombasa.

Table 1-2: Freight Transport Costs along NC Road

Origin/Destination	Imports (US$)		Exports(US$)	
	20ft	40ft	20ft	40ft
Kampala-Mombasa	1800	3000	1200	2000
Kigali – Mombasa	2450	3700	1950	3900
Bujumbura-Mombasa	3500	4500	2100	3800
Goma – Mombasa	3500	7000	2000	4000

Source: NCTTCA Survey, 2006

The rising transport costs are a major problem to manufacturing and distribution companies, attributing to the collapse of several companies in Kenya's transport sector. In the absence of transporters, storage costs for goods have simultaneously increased due to the delay in ferrying them to the local market, as well as neighbouring countries of Uganda and Rwanda (TTCA, 2004). The situation is further worsened by poor road infrastructure, and resulting low levels of African trade (World Bank, 1999).

In addition to the high road transport costs, trucks along the Northern Corridor road are also delayed at weighbridges namely Mariakani, Mlolongo and Gilgil, where trucks spend an average of 6.5, 7.5 and 11.5 hours respectively. Moreover, time ranging from 5 to 10 hours is spent at the Kenya/Uganda border posts at Malaba and Busia due to the lengthy clearing procedures. Besides, there are a total of 21 police road blocks along the Northern Corridor road in Kenya which are haphazardly positioned. Consultations with the corridor transport crews revealed that the delay by the police range between 20-30 minutes at each road block.

1.4 Research Questions

The major research questions in this study were:

1. What are the major freight rates determinants along the NC road?
2. How do vehicle operating costs affect freight rates along the NC road?
3. What are the vehicle operating costs (VOCs) for goods vehicles along the NC road for various truck models?
4. What are the freight rates for various categories of trucks and models of goods vehicles along the NC road?

1.5 Objectives

The main objective of this thesis was:

"To develop a model for determining freight transport rates along the Northern Corridor road in Kenya"

The Specific objectives were:

- To determine vehicle operating costs for goods vehicles plying the NC road.
- To determine freight transport rates along tne NC road.
- To identify the main factors (determinants) affecting freight transport costs by comparing the freight rates to vehicle operating costs, travel time, backhauls, distance, tonnage, and truck type.
- To develop a model for estimating freight transport rates based on the freight rates determinants.

1.6 Scope of the Study

The research undertaken was on costs of freight transport along the Northern Corridor road. Vehicle categories studied comprise of light, medium and heavy trucks, the details of which covered several vehicle travel origins and destinations along the Corridor road in Kenya, and to or from Kampala, Kasese and Entebbe in Uganda. The major transport parameters studied include:

1. Vehicle operating costs for the goods vehicles;
2. Freight transport costs;
3. Travel time for the goods vehicles; and
4. Cargo tonnage transported.

1.7 Limitations of the Study

Inasmuch as vehicle operating cost (VOCs) is a key parameter studied in this research, no information was obtained for the cost of administration and management overheads. Hence, the VOCs calculated in this report were slightly lower than the actual costs incurred by transporters. However, it was assumed that the components such as fuel, lubricants, tyre, maintenance, depreciation, return on capital, crew, insurance, passenger time value and cargo time value were indicative of the total VOCs. Further, the study was limited by the fact that some transport companies were guarded and declined to give details of their transport operating costs, hence approximate values were given. Similarly, it was not easy to establish the actual freight weights carried by the trucks, though as observed some of the trucks were overloaded, and still managed to pass through the load check points at the weighbridges.

1.8 Justification of the Study

The Kenyan economy and those of the surrounding landlocked countries in Eastern Africa depend on the efficiency of the Northern Corridor road. Efficient transport systems spur economic growth by facilitating rapid movement of goods. Hence the need to establish factors that affect transport costs. Landlocked countries experience high transport costs, a phenomenon experienced globally (Cadwell *et al*, 2000). This can be substantially reduced by improving the quality of infrastructure, particularly those of transit countries (World Bank, 1999). In East Africa, halving transport costs would increase the volume of trade by a factor of five (Manufacturers & Distributors, 2006). However, an issue of concern is the lack of a framework that represents the freight costing and control tools, making the economies of the region less competitive in the global market.

2. LITERATURE REVIEW

2.1 Historical Perspective of the Northern Corridor

Transport corridors are defined as one or more routes that connect economic centres within and across countries. Trade corridors can also be universally classified as economic or transport corridors. Further, a corridor can be broken down into national trade corridor, bilateral trade corridor, multilateral trade corridor, intermodal trade corridor or multimodal trade corridor (Arnold, 2006). The Northern Corridor is classified as an economic multilateral trade corridor due to the fact that it links Kenya's port of Mombasa with the landlocked East and Central African countries, enabling them to engage in trade and commerce.

Traditionally, the member states of the Northern Corridor have had a long history of jointly promoting the regional transport industry in East Africa, particularly transit traffic, which is centred at the seaports of Mombasa (Kenya) and Dar-es-Salaam (Tanzania) respectively. The evolution of the transport corridors from the aforementioned seaports is referred to the Northern and Central Corridors respectively. Since 1960, the transport systems in both corridors have been dominated by road and railway transport modes, transporting goods and passengers from Mombasa and Dar-es-Salaam to the landlocked countries (TTCA, 2004).

The Northern Corridor route network comprises of 1333 Km of rail network extending from Mombasa to Kampala, including road routes from Mombasa via Malaba and Busia to Kampala (TTCA, 2004). In addition, the transport corridor consists of a road network which passes through Kampala/Kasese railway, and links the urban centres of Kampala, Mbarara, Kabale, Kigali, Butere, including Bujumbura. The actual physical condition of the road infrastructure in the above-mentioned sections has been improved (Geoffrey, 2006). Similarly, the Central Corridor which accounts for 1254 Km of Dar-es-Salaam/Kigoma rail network, links Bujumbura by motor vessels on Lake Tanganyika, and to Rwanda by road. Whereas the main road network was constructed much later, its routes link the hinterland of Dodoma, Singida, Nzega to Lushaunga into Rwanda and Burundi via Dar es Salaam. Plate 1.1 shows the major nodes in traditional Northern and Central Corridors (Gordon, 1996).

Central to the Region's transport sector are the multi-modal transport corridors, which link the coastal sea ports of Kenya and Tanzania with the landlocked countries (Eastern Zaire, Burundi, Rwanda and Uganda), and handle a substantial volume of intra-regional trade. Over the years, the seaport of Mombasa has been exemplary in its handling of imports and exports from the region, which have far exceeded the capacity of the seaport of Dar-es-Salaam. In particular, reference is made to the Northern Corridor, which has been responsible for a significant proportion of the transit traffic to the Zambia, Burundi Rwanda and Uganda (ZBRU) countries (Geoffrey, 2006). Gordon (1996) established that by 1982, Mombasa was handling approximately 470,000 tons of transit cargo to Zimbabwe, Burundi, Rwanda and Uganda (ZBRU) countries compared to 111,000 tons at the port of Dar -es-Salaam, which handled significant amounts of transit traffic to Malawi and Zambia.

The Northern Corridor rail network currently consists of the rail networks of Kenya and Uganda, linking the port of Mombasa with Kasese in Western Uganda and Pakwach on the River Nile in north-western Uganda. Operated by the East African Railways Cooperation in the past, the rail network was responsible for a significant proportion of Uganda's traffic. Nonetheless, Kenyan based road transporters were the major beneficiaries of the concentration of transit cargo traffic at the port of Mombasa, and subsequently the Northern Corridor, thus providing a bulk of the freight transport to Rwanda, Burundi and Eastern Zaire respectively.

Transport in the region was not limited to the Northern Corridor road. In 1967, the Kenya National Transport Company (KENATCO), a Government of Kenya (GoK) parastatal was founded, which consisted of, a fleet of 350 heavy commercial vehicles. Soon afterwards, a total of 100 heavy commercial vehicles were subcontracted by KENATCO to the Dar-es-Salaam based Tanzania Road Services, in order to exploit the growing potential of the seaport of Dar-es-Salaam which handled transit traffic to Zambia and Malawi. Between 1970 and 1973, the road transport market expanded considerably. Accordingly, the collapse of KENATCO in the early 1980s paved way for many small and medium sized Kenyan operators to enter the transit traffic market (Gordon, 1996). This situation was further exacerbated by Government withdrawal of subsidies following the subsequent failure of the East African Community, which was responsible for the East African Railways and Harbours Corporation. The cooperation's assets were distributed amongst the newly established Kenya Railways Corporation (KRC), the Uganda Railways Corporation (URC) and the Tanzania Railways Corporation (TRC), in order to create an enabling environment for the growth of private investment in the transport industry. Conversely, the competition from the increasing number of road transporters resulted in the efficiency and stability of tariffs (Gordon, 1996).

The encouraging growth-trends exemplified by the region's economies, was threatened by the political instability in Uganda in the late 1970s and early 1980s. As a result, a number of transporters from the Northern Corridor relocated to the Central Corridor resulting in the decline in transit traffic handled at Mombasa from 470,000 tons in 1982 to 374,000 tons in 1985. In contrast, the seaport of Dar-es-Salaam experienced a significant increase in the handling of transit traffic to Zambia, Burundi Rwanda and Uganda (ZBRU) from 111,000 tons in 1982 to 213,000 tons in 1985 respectively. Inevitably, the situation called for new alternative routes to the Zambia, Burundi, Rwanda and Uganda (ZBRU) countries, which ensured security to both cargo and vehicles in transit, and which would provide a basis for shortened transit times and stable tariffs. The declining dominance of the Northern Corridor was further worsened when the Government of Kenya (GoK) introduced various aspects of road user and transit charges, to go towards infrastructure maintenance which involved cumbersome transit procedures. As a result, the overall costs of transportation along the Northern Corridor road have steadily increased (Gordon, 1996).

2.2 Northern Corridor Transit Agreement (NCTA)

The Northern Corridor Transit Agreement (NCTA) was established between four countries namely, Kenya, Uganda, Rwanda and Burundi which rely primarily on the Northern Corridor route and the port of Mombasa in 1985 (Arnold, 2006). The purpose of the transit agreement was to simplify and harmonize procedures deemed as relevant in various transport related fields, and in doing so allow for the expeditious movement of goods in transit between the contracting states, and to and from the sea through the port of Mombasa. Later in 1987, the Democratic Republic of Congo acceded to the Agreement thereby becoming the fifth contracting state (Gordon, 1996).

In line with the provisions of the NCTA was the establishment of Transit Transport Coordination Authority (TTCA) in 1988, which was charged with the responsibility of achieving the aims of the NCTA, particularly on matters relating to transport policy and operational coordination of transit traffic. The TTCA comprises of ministers responsible for transport related matters in each of the contracting states. Situated in Mombasa (Kenya), are the three basic organs of the TTCA, namely the Authority, the Executive Board and the Secretariat, who are assisted by a Transit Transport Coordinator (TTC). Over the years, the TTCA has made tremendous strides in its efforts to maintain the Northern Corridor's importance in the Region as the main route to the neighbouring landlocked countries (Gordon, 1996). However, the NCTA has not been successful in reducing the delays related to cumbersome transit procedures and transit charges along the Northern Corridor. Accordingly, the closure of the Uganda/Rwanda border in 1990, made it difficult for vehicles using the Northern Corridor road to enter Rwanda and Burundi, hence diminished the role of the TTCA. Over the years, the landlocked countries have sought alternative routes to the seaports of Mombasa and Dar-es-Salaam, with the decisions made by the contracting states being largely driven by cost and security concerns. The current interest in transport corridors originates from earlier efforts to promote regional economic growth. These include efforts made in the 1960s and 1970s to improve economic growth factors, specifically infrastructure (Arnold, 2006).

2.3 Importance of Freight Transport

According to research done by Edward (2003), costs incurred by the movement of goods over space affects a number of economic decisions. In addition, recent research undertaken by the World Bank (2006) suggests that isolation from regional and international markets has significantly contributed to poverty in many Sub-Saharan African countries. In many countries, fertile land is left fallow because hauling produce to markets is too expensive, time-consuming and inaccessible to truckers. In Africa, the cost of overland transport is greatly increased due to bad roads, difficult border crossings, and harassment of truckers at police road blocks (Piet et al., 2006).

Numerous empirical studies conducted by Henderson et al (2001) have examined the economic impact of poor roads. Amjadi et al (1995) quoted by the World Bank (2006) found that the relatively low level of Sub-Saharan African exports is essentially due to high transport costs. In a study of transport costs and trade, Limao and Venables (2000) also quoted by the World Bank (2006) showed that poor infrastructure accounts for 60 percent of transport costs for landlocked countries, as opposed to 40 percent for countries with a coastal strip. In addition, the impact of reduction of transport costs has been studied by Rodrigo (2005) in which he shows:

$$\text{Price elasticity of demand} = \frac{\%\ \textit{Increase in Traffic}}{\%\ \textit{Decrease in Cost}} \quad \ldots\ldots (2.1)$$

Mark and Alexandra (2005) presented a paper in Hawaii International Conference on statistics and mathematics in which they captured consumer response to transport cost. The Researchers established that consumers face an exogenous transport cost which increases with distance and not with quantity. Due to the uncertainty, consumers prefer to incur a lump sum transport cost, rather than paying unit cost to the provider. However, this has been explained by Spulber (1981) as profit maximization behaviour by the seller. Further, studies conducted by the World Bank (Bennathan *et al.*, 1989) indicated that factors such as national policies which severely restrict competition for transport services also have a major influence on the level of freight rates. As a result, for the purpose of easy decision-making, models have been developed as a simplified representation of reality, which may be in physical, analogue or mathematical form (Gichaga *et al*, 1988).

It is already established that the truck freight rates for different commodities over a given route vary, including the rate per unit distance for the same commodity over a different route. However, it should be noted that the variation in freight rates might be a normal profit-maximization behaviour which can be attributed to availability of backhauls, demand and value of the commodity (Manufacturers & Distributors, 2006). A report by the World Bank (2005) on Best Practices in Corridor Management, evaluates road performance by considering the quality of services provided along a transport corridor. This is measured in terms of average time and cost for transport units moving along this corridor. Transport costs contribute up to 14 percent of the final price of a commodity. The percentage depends on distance covered, as well as the condition of the road (FHWA, 2002). Moreover, the average cost of moving a ton a mile in 1890 was established as US$0.185 in the United States (Edward, 2003). Currently, studies reveal that this cost is US$0.23.

2.4 Vehicle Operating Costs

Vehicle operating costs (VOC) is the unit cost of running a vehicle given per vehicle-km. It is the total cost incurred by a vehicle owner for every one km covered on the road. VOCs of vehicles plying on the Northern Corridor road vary depending on the condition of the road, as well as the category of the vehicle.

1 Vehicle Operating Costs, in US$ per vehicle-km, is obtained by summing up the following cost components (World Bank, 2007);

- Fuel
- Lubricants
- Tire

- Maintenance Parts and Labour
- Crew Time
- Depreciation
- Interest
- Overhead

2 Time saving costs, in US$ per vehicle-km, is obtained by summing up the following cost components (World Bank, 2007):

- Passenger Time value
- Cargo Time value

3 Road User Costs (RUC), in US$ per vehicle-km, is then obtained by summing up the values of vehicle operating costs and time saving costs (Bennett, 2003).

2.5 Existing VOCs for Goods Vehicles along the NC Road

In 2004, the Ministry for Roads and Public Works (MoRPW) in its appraisal report established that the vehicle operating costs for various categories of goods vehicles along the Northern Corridor road increased alongside with the road International Roughness Index (IRI), as illustrated in Table 2.1 below. It showed that truck VOCs increase with road surface roughness. The vehicle operating costs for the appraisal were computed using the Highway Development and Management Model (HDM-4), and assumptions made based on a discount rate of 12 percent, and economic costs which were given as 78 percent of the financial costs. Likewise, the value of cargo time was estimated based on the average cargo value of US$400 per ton and a cost of working capital of 15 percent (World Bank, 2004).

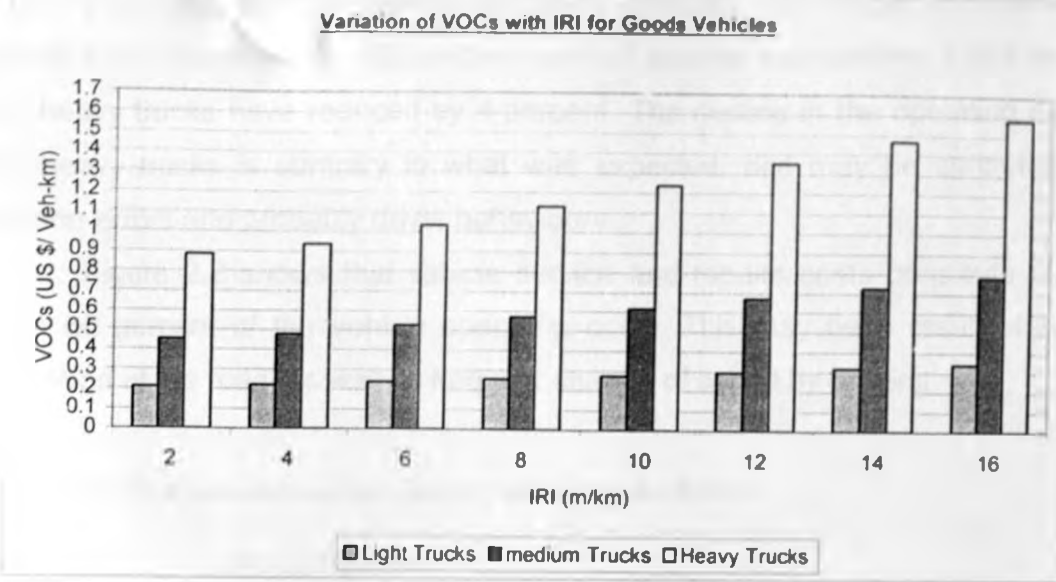
Table 2-1: Typical Unit Road User Costs (US$/v-km)

Road Roughness IRI (m/km)	Light Trucks	Medium Trucks	Heavy Trucks
2	0.209	0.450	0.884
4	0.220	0.477	0.936
6	0.238	0.524	1.033
8	0.255	0.569	1.130
10	0.274	0.619	1.239
12	0.295	0.672	1.353
14	0.318	0.728	1.469
16	0.342	0.784	1.584
Typical Unit Road User Costs Composition for Roughness = 2 IRI (US US$ /v-km)			
Road User Cost Component	Light Truck	Medium Truck	Heavy Truck
Fuel and Oil	0.070	0.105	0.239
Tires	0.004	0.014	0.024
Parts and labour	0.088	0.213	0.346
Depreciation and Interest	0.031	0.086	0.240
Crew Time	0.016	0.032	0.035
Overhead	0.000	0.000	0.000
Passenger and Cargo Time	0.000	0.000	0.002
Total	0.209	0.450	0.884

Source: MoRPW, WB Project Appraisal Document, 2004

Figure 2.1 below is an illustration of vehicle operating costs against road IRI for various truck categories. It depicts a linear relationship between VOCs and IRI. From the Figure, it can also be noted that heavy vehicles have a higher VOC than the light vehicles.

Figure 2-1 VOCs for Goods Vehicles for Various IRI by the WorldBank PAD



Source: MoRPW, WB Project Appraisal Document, 2004

The Vehicle Running Costs Schedule from the Automobile Association (AA) is also presented in Table 2.2 below. Attention is drawn to the fact that the Figures provided by AA vary from those of the vehicle operating cost for commercial vehicles drawn from the MoRPW appraisal document.

Table 2-2: VOCs Components (US$/v-km)

	Light Truck (3-ton)	Medium Truck (7-ton)	Heavy truck (9-ton)
Oil (Lubricant)	0.018	0.027	0.031
Tyres	0.040	0.110	0.114
Fuel	0.153	0.187	0.241
Service and Repairs	0.214	0.336	0.429
VOC US$/v-km	0.425	0.660	0.815

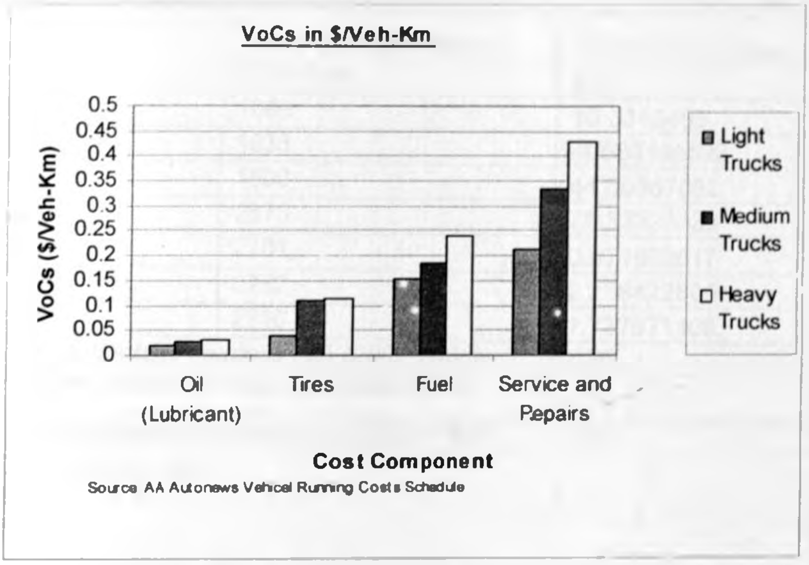
Source: AA Vehicle Running Costs Schedule, 2005

The AA running costs comprise of fuel, lubricant, tyres, repairs and service, and do not include depreciation, interest, overheads, crew time, passenger and cargo time. A comparison of values of VOCs given by the World

Bank (2004) in Table 2.1 and values of the VOCs given by AA-Kenya (2005) in Table 2.2 reveal that the vehicle operating costs for light trucks and medium trucks have increased by 162 percent and 57 percent respectively, whilst those of heavy trucks have reduced by 4 percent. The decline in the operating costs for heavy trucks is contrary to what was expected, and may be attributed to person errors and probably driver behaviours.

Figure 2.2 shows that vehicle service and repairs costs constitute more than 60 percent of the vehicle operating costs. This may be a result of poor condition of the road, as well as frequent change of speed by drivers.

Figure 2-2VOCs Components for Goods Vehicles by AA-Kenya



Source: AA Kenya, 2005

2.6 Trends in VOCs along the NC Road

At the time of this research, the data available for the Kenyan section of the Northern Corridor road was reviewed to establish the annual increase in VOCs, which included fuel consumption and employment labour wages. These variables are discussed below.

2.6.1 Economic Growth Indicators for VOCs

Amongst the existing key economic growth indicators for vehicle operating costs along the Northern Corridor road include the following:

1. *Fuel consumption*

In considering fuel consumption in road transport, it is assumed that an increase in consumption influences change in vehicle operating costs. Table 2.3 gives an overview of the historical records and trends in fuel consumption in Kenya from the year 2000 to 2006. In 2000, a total of 1,089,000 tons of fuel were consumed compared to 2,810,000 in 2006.

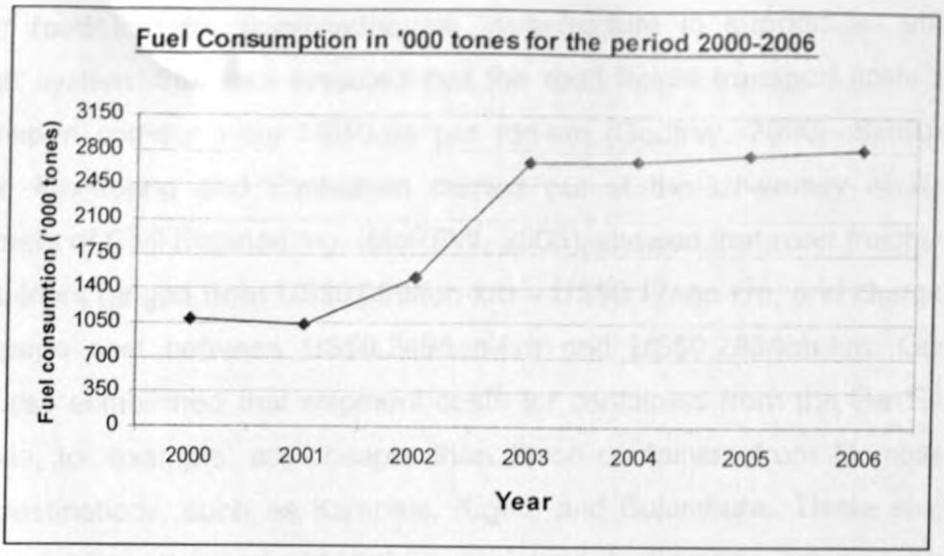
Table 2-3 Historical Records of Fuel Consumption from 2000 to 2006 in Kenya

Year	Total Fuel Consumption ('000 tons)	% annual increase (%)
2000	1089	10.3343465
2001	1038	-4.683195592
2002	1500	44.50867052
2003	2675	78.33333333
2004	2701	0.971962617
2005	2762	2.258422806
2006	2810	1.737871108
Max percentage increase (%) (2002-2006)		2.26
Min percentage increase (%) (2002-2006)		1.74
Mean percentage increase (%) (2002-2006)		0.97

Source: KNBS, 2007

Similarly, the mean growth rates for the seven year period are depicted, and given as 2.26% maximum percentage increase, 1.74% minimum percentage increase, and 0.97% mean percentage increase respectively.

Figure 2-3 Records of Fuel Consumption in Kenya



Source: KNBS, 2007

2. ***Employment wage increase***

A general increase in wages reflects an increase in operating costs incurred by vehicle owners in maintenance, labour and crew. Based on an economic survey carried out in 2007, the national wage employment increased by 4.8 per cent, while average labour wage earnings rose marginally by 0.2 per cent in the year 2006 (KNBS, 2007). The aforementioned results presumably had a multiplier effect on the wage rates as incurred by the transporters.

2.7 Road Freight Industry and Transport Costs along NC Road

A research study conducted by Gordon (1996) for USAID established that road freight industry in Kenya comprises of large and medium sized trucks, with an estimated fleet of 40,000 vehicles. This represents about 10 percent of the total vehicle population in Kenya. Further, the study ascertains that the major transporters have fleets of up to 100 vehicles, with a few having fleet in excess of 200 vehicles. However, about 60-70 percent of the industry's fleet are owned by smaller transporters who carry nearly 75 percent of the available cargo.

Amongst the main constraints which hamper trade along the Northern Corridor road include, poor/inadequate infrastructure to support an efficient transport system. Statistics revealed that the road freight transport costs along the transport corridor were US$0.04 per ton-km (Godfrey, 2006). Similarly, a baseline Monitoring and Evaluation carried out at the University of Nairobi Department of Civil Engineering, (MoRPW, 2006), showed that road freight rates for containers ranged from US$0.089/ton-km – US$0.17/ton-km, and charges for loose cargo cost between US$0.249/ton-km and US$0.293/ton-km. Godfrey (2006) also established that shipment costs for containers from the Far East to Mombasa, for example, are cheaper than those containers from Mombasa to inland destinations, such as Kampala, Kigali, and Bujumbura. These shipping costs to and from the port of Mombasa to inland destinations are presented in Table 2.4 below.

Table 2-4: Freight Transport Costs along NC Road

Origin-Destination	(Average Distance x cargo weight) ton-km	Average freight rate (US$/ton-km)	IMPORTS (US$)			EXPORTS(US$)		
			20ft	40ft	Bulk per ton	20ft	40ft	Bulk per ton
Kampala – Mombasa	11,253	0.121	1800	3000	100	1200	200 0	70
Kigali – Mombasa	15,840	0.129	2450	3700	170	1950	390 0	90
Bujumbura-Mombasa	15,191	0.157	3500	4500	230	2100	380 0	180
Goma – Mombasa	16,472	0.171	3500	7000	220	2000	400 0	180

Source: Godfrey, 2006

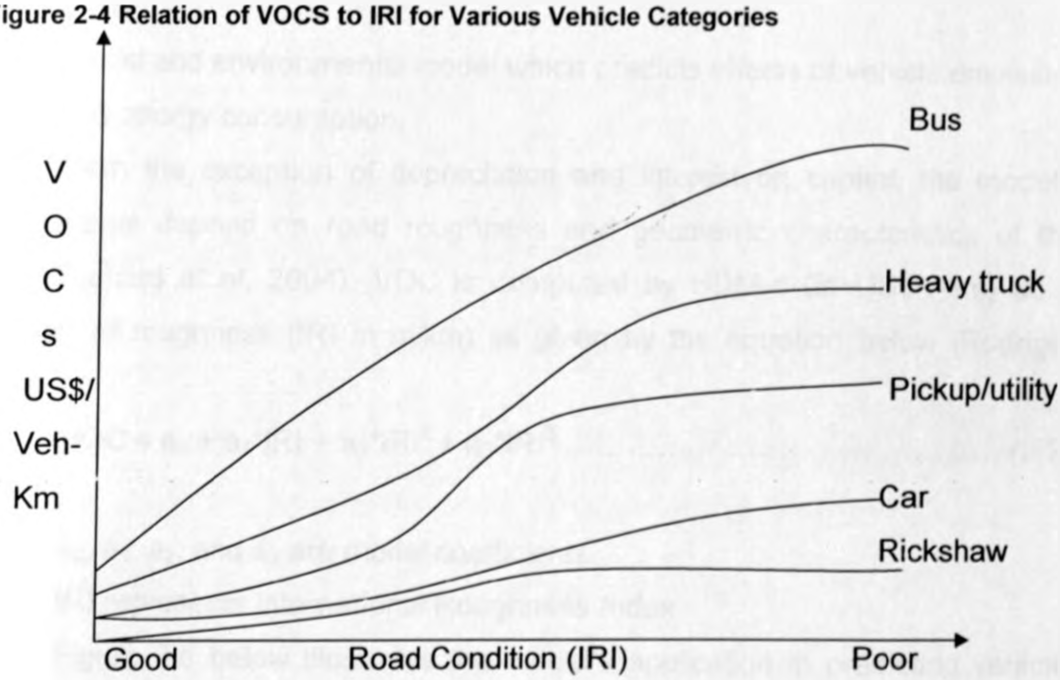
Market forces within the transport industry are amongst factors which influence the in-country road freight rates, as well as the transit freight rates from Mombasa and Dar-es-Salaam, to the neighbouring landlocked countries. Godfrey (2006) observed that the above-mentioned rates (see Table 2.4) may fluctuate depending on the following: return freight; type and make of the vehicle; anticipated delay; the road condition; and the level of competition for cargo by transporters. As a result, road freight rates hardly relate to actual transport costs incurred by the operator, although each transporter needs to realize a profit to remain in business. In addition, the increasing competition between road transport and other modes such as rail, water and air, also play a role in influencing road rates. For instance, the construction of inland container depots at Embakasi, Kisumu and Eldoret in Kenya, has resulted in the diversion of significant proportions of cargo to the railways, thus leading to a reduction in road freight rates. Transit road transport rates have, as a result, remained sTable over long periods of time, which in turn has driven out inefficient road transport operators from the market. Currently however, the available information in road transport costs in the region is not sufficient. An in-depth investigation is required in order to gain a full understanding of the importance of variables which affect road transport. The reason advanced for the higher transport rates in urban areas is that rates are based on time (half day, full day) rather than on distance (Gordon, 1996).

In Kenya, road transport rates ranges between US$0.081 and US$0.123 per ton-km (Gordon, 1996). A large number of operators have however quoted an average of US$0.093 per ton-km which according to Godfrey (2006) equates to the average cost of general and containerised cargo estimated as US$4.0 per ton-km.

2.8 Models for Predicting Vehicle Operating Costs

A number of studies have been undertaken on vehicle operating cost to develop models that predict the VOCs in relation to the road and vehicular characteristics. Research carried out by Pelensky et al (1962) revealed that the unit operating cost of a vehicle in US$/v-km is a function of average operating speed, road geometry and pavement condition. Further research by Pelensky et al (1968) observed that direct running cost per vehicle-km depends on the gross vehicle weight in addition to fuel, lubricants, tyres, wages, and maintenance costs. Contrary to findings by Pelensky et al (1962), tests undertaken by Blanden and Black (1984) ascertained that regular change in vehicle speed has little effect on VOCs. Hence, average journey speed is used as a variable to measure travel time. Pelensky et al (1968) conducted further research and confirmed that overall travel time from origin to destination takes into account a number of key factors affecting speed such as gear changes, braking, engine power, and percent delay. This concurs with the findings of Blanden and Black (1984). Paterson as quoted by Jorge (2001) also performed a study on vehicle operating costs (VOCs) and illustrated that in general, VOCs increase by 2-4 percent for each one m/km of IRI in roughness over a range of good to poor conditions. In addition to the study done by Paterson (2001), further research by Jorge (2001) confirmed that vehicle operating costs (VOCs) and costs of transporting goods increase as road condition deteriorates. Understanding the costs of vehicle operation is essential to sound planning and management of road investments (Rodrigo, 1994). The relationship between VOCs and road condition is illustrated in Figure 2.4 below.

Figure 2-4 Relation of VOCS to IRI for Various Vehicle Categories



Source: Henry, 2000

A number of models have been developed to predict vehicle operating costs based on the road and vehicular characteristics.

2.8.1 Highway Development and Management (HDM-4) Model

Highway Development and Management (HDM-4) is a road investment model (Kerali, 1999), used to assist in the selection of appropriate road design and maintenance standards that minimize the total transport costs (Richard et al 2004). Studies indicate that the early versions of HDM-4 have been broadened and their use extended beyond traditional project appraisals. The model provides a range of tools for analyzing road management and investment alternatives, by undertaking a cost benefit analysis over duration of 20-25 years. Richard et al (2004) proposed the following technical analysis within the HDM-4 using the three sets of models outlined below:

- Road deterioration and ware effect (RDWE) model which predicts pavement deterioration.
- Road user model which predicts VOCs, accidents costs and travel time costs.
- Social and environmental model which predicts effects of vehicle emissions and energy consumption.

With the exception of depreciation and interest on capital, the model's components depend on road roughness and geometric characteristics of the road (Richard et al, 2004). VOC is computed by HDM-4 (in US$/v-km) as a function of roughness (IRI in m/km) as given by the equation below (Rodrigo, 2004).

$$VOC = a_0 + a_1{*}IRI + a_2{*}IRI^2 + a_3{*}IRI^3 \quad \text{.......} \quad (2.2)$$

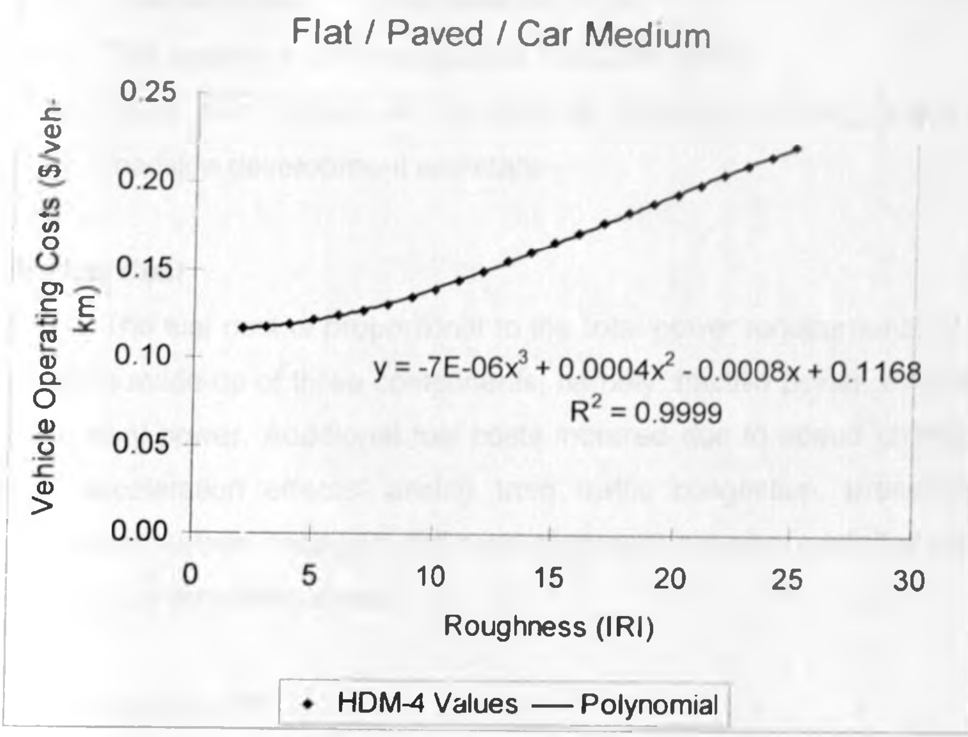
Where:

a_0, a_1, a_2, and a_3 are model coefficients.

IRI represents International Roughness Index

Figure 2.5 below illustrates the model's application in predicting vehicle operating costs. It depicts the variation of VOCs with IRI (m/km) in a flat paved terrain for a medium size car, and shows that VOCs rise as road's IRI (m/km) increases (Rodrigo, 2004).

Figure 2-5 HDM 4 VOCs Prediction Model



Source: Rodriguez, 1996

In Figure 2.5 above,

X is roughness in m-km

Y is VOCs in US$/v-km

R is Regression Residual value

An overview of the components of the HDM-4 model is given below:

i) Vehicle Speed

According to Watanatada, et al, (1987), the prediction of vehicle speeds in HDM-4 is obtained as a function of vehicle characteristics, road geometry, road surface condition, and the desired speed at which a vehicle is assumed to operate, in the absence of limiting constraints. The operating speed of each vehicle type is calculated from the free speed by considering the following influencing factors:

- Total motorized traffic volume and flow
- The presence of non-motorized transport (NMT)
- Road side friction in the form of parking, stopping bays, driveways, roadside development and stalls

ii) Fuel Cost

The fuel cost is proportional to the total power requirements of the engine which is made up of three components, namely: tractive power, engine drag, and accessory power. Additional fuel costs incurred due to speed change cycles or the "acceleration effects" arising from traffic congestion, presence of NMT, pavement surface condition and road alignment are also modelled based on the results of a simulation model.

iii) Lubricating Oil

Vehicle lubricating oil is modelled in HDM-4 as a function of fuel cost and the rate of oil loss due to operation and contamination.

IV) Tyre replacement cost

Due to high energy requirements, the vehicle tyres wear out rather quickly. Likewise, energy requirements are influenced by the road horizontal alignment and pavement surface ride quality as modelled in HDM-4.

V) Spare Parts Cost

The cost of vehicle parts is modelled in HDM-4 as a function of vehicle age (in terms of vehicle cumulative mileage and road surface roughness). Accordingly, the predicted parts replacement is adjusted to account for acceleration effects.

VI) Maintenance Labour Hours

Vehicle maintenance labour hours are predicted in HDM-4 as a function of spare parts cost.

VII) Capital Costs

In HDM-4, capital costs are calculated as a function of vehicle annual utilization, which in turn is a function of speed, and the reduction in vehicle service life, due to road surface roughness.

VIII) Crew Hours

Vehicle crew hour is predicted in HDM-4 as a function of vehicle speed which is indicative of vehicle travel time.

IX) Overhead Costs

The annual overhead cost is modelled in HDM-4 as a function of vehicle annual utilization.

2.8.2 Road User Costs Knowledge System (RUCKS)

Road User Cost Knowledge System (RUCKS) is a component of HDM-4 which computes Road User Cost by adopting the road user effect equations in the HDM-4 version 1.3[2], (World Bank, 2007). These include:

(i) The World Bank's Road User Costs Model that implements the HDM-4 road user affects relationships in Excel.

(ii) A study of typical unit road user costs in developing countries, and

(iii) A road user costs sensitivity analysis study.

The model does not compute effects on environment, road deterioration and ware effects (RDWE), noise or emissions. RUCKS helps to quantify how road user costs are affected by vehicle fleet and road characteristics, including geometric standards. In addition, the model computes the unit costs for all

[2] Can be accessed at, http://worldbank.org/roadsoftwaretools/

components of vehicle operating costs (in US$/v-km). The road user cost (RUC) is calculated as a sum of the cost value of time and vehicle operating costs.

2.8.3 Comparison of RUCKS & RED Model for Computation of RUC

The Road Economic Decision (RED) is a model for decision-making in the development and maintenance of low volume and unpaved rural roads. It is composed of a series of workbooks that contain; input-output worksheets and support worksheets (Rodrigo, 2004). During this research, a desk study comparing HDM-4, RED and RUCKS models was carried out and the following conclusions drawn:

- The RED model does not provide for input of road roughness. On the one hand while RED computes vehicle operating costs for a predefined roughness (IRI) condition in the range 2-25m/km, this leads to the computation of unnecessary results for a single road section. On the other hand, RUCKS model allows for input of road roughness (IRI, m/km) therefore computing RUC for a specific condition of a road section.
- Whereas RED evaluates investment for low volume unpaved roads with a traffic volume of 50-200 vehicles per day (vpd), RUCKS computes results for heavy traffic volume exceeding 200vpd.
- The RED model computes vehicle operating costs only, while RUCKS model computes RUC as a sum of vehicle operating cost and time cost.
- The RED model has a limit of 9 representative vehicles, whilst the RUCKS model allows the user to define the desired number of vehicle categories. However, provisions have been made for a default of 12.
- RUCKS model has a new model for computing fuel consumption which is reliable and accurate. This has reflected changes in vehicle technologies.

2.8.4 The Kenya, Caribbean and India Road User Cost Study Models

The Kenya Road User Cost Study (Hide, et al., 1975), the Caribbean Study (Morosiuk and Abaynayaka, 1982) and the India Study (CRRI, 1982) developed a multivariate model which highlights the following fundamental structure:

$$VOCs = a_1 + a_2RS + a_3F + a_4CURVE + a_5ALT + a_6BI + a_7PWR + a_8WIDT \qquad (2.3)$$

Where;

RS is the rise in m/km

F is the fall in m/km

CURVE is the horizontal curvature in degrees/km

BI is bump integrator roughness given as mm/km

VOCs is vehicle operating costs

a_1 to a_8 are regression coefficients

ALT is altitude

PWR is engine power

WIDT is road width

From equation 2.3, the main variables that were considered in determining VOCs include rise and fall, curvature, altitude, roughness, road width and truck features such as the horse power.

2.9 Existing Models for Predicting Freight Transport Costs

The complexities regarding transport costs can be traced back to the early 1840s when United States economists including Clark and Taussig tried to refine cost allocation models (Button, 2003). However, no specific consideration was given to study the pattern of transport costs. Button (2003) explains that a renewed interest of research in transport economics began in the United States of America when Rakowski (1960) recognized the problem of physical distribution and development of new fields as the responsibility of transport economists. Troxel (1955) also argued that transport plays a key role in decision-making for instance, the location of industrial activities. The need to minimize transport costs means that movement must be limited (Troxel, 1955).

Weber (1929) developed an early model for a mobile plant using transport costs to determine the location of a manufacturing industry. He assumed transport costs to be proportional to distance covered, and the weight of goods carried. During his time, the location of an industry depended on the availability of raw materials and market to sell the products. Hence, the optimum site would be that which minimizes total transport cost, T, given as:

$$T=a_1r_{A1}+a_2r_{A2}+a_3r_{A3} \qquad (2.4)$$

Where:

T is the minimized transport cost.

A_1 is location where goods are consumed

A_2 is location 1 where raw materials are obtained

A_3 is location 2 where raw materials are obtained

a_1 is the physical amount of goods consumed at site A_1

a_2 is the physical amount of raw material available at site A_2 to produce a_1

a_3 is the raw material available at site A_3 to produce a_1

r_{A1}, r_{A2} and r_{A3} are distances from respective sites A_1, A_2 and A_3 respectively.

Weber developed the model based on the assumption that freight rate is proportional to the quantity of goods transported and distance covered. He also assumed that a production unit would be located at either site A_1, A_2 or A_3 but all the products consumed at site A_1. It is discernable from Weber's model that distance covered may be short and quantity of goods may also be less but if the road condition is poor or profit margin is high, freight transport cost will still be high. Weber's model can be best applied in situations where road condition and other characteristics are favourable in a way that vehicle operating costs are low.

In the Kenyan situation, Weber's model is not the best to use due to the deplorable road conditions. In Weber's model, vehicle operating cost is not considered as a variable in the model inputs. It therefore cannot reveal the relationship between VOCs and road freight rates.

A study on the generalized cost by Wilson et al (1969) provided a useful illustration of computing costs of transport as given below;

$$G_{ij}=a_1t_{ij}+a_2e_{ij}+a_3d_{ij}+p_j+\delta \quad \text{...(2.5)}$$

Where;

G_{ij} is generalized cost of travel

t_{ij} is travel time from i to j in minutes

e_{ij} is excess time, for example waiting time

p_j is terminal cost, for example parking charges

δ is a modal penalty reflecting the discomfort and lesser convenience associated with public transport journey (not necessary for freight transport).

a_1, a_2 and a_3 are parameters which, since p_j and δ have unit coefficients; value other cost items in monetary terms.

d_{ij} is distance from i to j, which acts as a substitute for the cost of travel assumed to be proportional to the distance covered.

This model does not consider vehicle operating costs in estimating transport costs. A similar study on the trends of world good's transport from 1971 to 1988 was undertaken by Button (2003) who reviewed the United Nations Statistical Yearbook, and thereafter pointed out that the cost of transport increased faster than the retail price of goods. The main cause of the upward trend in the transport cost is due to simultaneous increase in the number of trips taken, including the physical quantity of goods moved, and the distance over which they are moved. Not only are transport costs instrumental in influencing where firms locate, but they also play an important role in determining the market span served by a firm (Button, 2003). Given the industrial location, transport cost can determine the total quantity of sales, their price and the spatial distribution of the output.

A simple model developed by Van Es and Ruijgrok (1974) treated transport costs to be derived from demand for goods and assumes all supply and demand curves to be linear.

Hence:

$P^s = a_0 + a_1 Q^s + P^t$ .... *(2.6)*

$P^d = b_0 - b_1 Q^d$ .... *(2.7)*

$Q^d = Q^s$ .... *(2.8)*

$P^d = c_0 P^s - c_1 P^t + constant$ .... *(2.9)*

Where:

P^s is supply price of the commodity

P^d is demand price of the commodity

Q^s is quantity of the commodity supplied

Q^d is quantity of commodity demanded

P^t is constant transport cost per unit carried to the customer and treated as cost borne by supplier

Van Es and Ruijgrok (1974) assumed that the transport cost is related to the quantity supplied and not the quantity demanded. In their argument, the Researchers considered that the transport cost is borne by the producer, therefore when transport cost is high, the quantity supplied to the end consumer will be low resulting in an unnecessary shortage. Hence, the objective of the model was to maintain transport cost at a rate where it is at equilibrium. Moreover, it was emphasised that if the quantity supplied exceeds the quantity demanded then there would be a surplus of goods transported, leading to losses for the producer. This model is relevant for manufacturers who are not concerned about vehicle operating costs; therefore it is not appropriate for this study.

The model, however, is inapplicable in this case study of the Northern Corridor road, as it fails to show any relationship between road freight rates and VOCs. The study acknowledges the fact that transport cost affects the distributor and subsequently the consumer. Finally, besides the aforementioned transport costs models, freight consignors are equally concerned with speed, and reliability. The demand for freight transport is therefore not dependent on the cost alone, but on the overall opportunity costs involved.

According to Button (2003), in analyzing freight transport demand, or when forecasting future consumer response, it is possible to asses the responses to the individual components of the overall costs such as money, time, and inconveniences. Button (2003) developed Wilson's (1969) pragmatic devise of the generalized cost to reduce the wide range of costs involved by computing a single cost indicator referred to as generalized cost[3]. The generalized cost of a trip is expressed by Button (2003) as a single monetary measure combining in linear form most of the important but unrelated costs which form the overall opportunity costs of a trip. It therefore reduces all costs to a single index, which is then used in the same way as monetary value in standard economic analysis defined as:

$$G= g\,(C_1+C_2+C_3+\ldots\ldots C_n) \quad \ldots\ldots\ldots\ldots \textit{(2.10)}$$

Where;

G is generalized cost

C_1, C_2, C_3 ......C_n are various time, money and other costs of travel.

The World Bank (2005) expressed the generalized cost function by assigning values to time and reliability in which reliability is a measure of additional time required to ensure on-time delivery. As a result, the generalized cost function for a unit of trade k is then expressed as;

$$C_k=c_k+\alpha_k\,(t_k+\beta\sigma_{t,\,k}) \quad \ldots\ldots\ldots\ldots \textit{(2.11)}$$

Wnere;

C_k is direct cost for the movement of a unit of trade k from origin to destination.

α_k is value of time for a unit of trade k.

t_k is average transit time from origin to destination.

β is reliability criteria e.g. β= 1.96=>2.5%

[3] Is a way of quantifying transport cost by assigning values of time and reliability

$\sigma_{t,k}$ is variation in transit time from origin to destination used to measure unreliability.

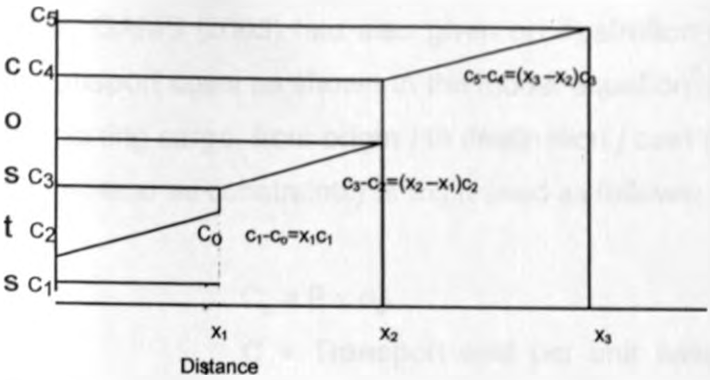
It should be noted that this form of computing transport cost recognizes the value of the JIT (see section 1.1) delivery system. However, it would be necessary to include the analysis of transit time as a measure of transport cost. The longer the transport time, the more expensive the transport cost and vice versa. In developing countries, this model would be very relevant but only to the extent of determining the transit time.

In addition, World Bank, (2005) in a report on best practices in the corridor management, compiled by Arnold (2006) indicates that transport cost can be further divided into two components which are links and nodes[4]. The Arnold's (2006) model is used to compute the generalized cost for a transport route. This is done in order to identify routes that offer greatest savings. Colin (1998) also broadly categorized freight transport costs as fixed and variable. The fixed costs included capital costs, licenses, insurance and depreciation. Variable costs include, fuel, maintenance, tyre and wages.

Arnold (2006) measures transit costs as shown in Figure 2.6 below. The horizontal line represents the costs incurred while transiting a link which is proportional to the distance covered, while vertical line represents the costs incurred at a node for the non-discretionary activities when using the link such as port charges, border post charges, parking charges, and charges at the road tolls (World Bank, 2005).

[4] Any point along the road where a vehicle stops for some time such as at a police check, cross border post, bus stop or a weighbridge.

Figure 2-6 Transit Cost for a Route



Source: Arnold, 2005

(C_1, C_2, C_3, C_4 and C_5 represents costs and X_1, X_2 and X_3 represents distances)

Figure 2.6, indicates that costs incurred for transport between nodes is proportional to the distance covered. Similarly, the distances represent the direct costs incurred by a transporter while en route. It is an approach used to evaluate the performance of alternative corridor routes, whilst taking into consideration the physical capacity of the links and the nodes on the corridor. This model forms a basis for selecting sections of the road for improvement. However, Arnold (2006) further cautions that it would not be possible to identify to what extent the degree of nodal effects are experienced within the urban centres, particularly where there are no direct costs involved, for example toll charges. This refers specifically to a situation in which vehicle passes through a given node without incurring direct charges. Vehicles using the Northern Corridor road pass through major urban centres of Mombasa, Nairobi, Nakuru, Kisumu and Eldoret. Heavy urban traffic has negative effects on traffic flow. Vehicles frequently change speed, increasing fuel consumption in addition to the high number of accidents; subsequently increasing the VOCs. A central challenge lies in identifying the effect of urban traffic. In this regard, urban effect is treated in the same way as the nodes which are outside the scope of this study.

The costs discussed in the preceding paragraph are the direct ones. Other inherent costs highlighted by Colin (2003) include; environmental pollution, visual intrusion, community severances and accidents. Besides the models discussed earlier, GAMS (2005) has also given an illustration of the natural way to model the transport costs as shown in the model equation[5] below. In this model, cost of transporting cargo, from origin *i* to destination *j* over distance *d* (subject to supply and demand as constraints) is expressed as follows:

$$C_{ij} = F \times d_{ij} \qquad (2.12)$$

C = Transport cost per unit case between *i* and *j* given as US$/case

(Where, 'case' refers to the unit of measurements i.e. weight or volume).

i = Origin of a commodity

j = Destination of the commodity

d_{ij} = Distance between *i* and *j*

And:

F = Cost in vehicle operating cost per unit case per unit distance given in US$/v-km

GAMS (2005) model shows the relationship between VOCs, distance and freight rates. Earlier, Blunden and Black (1984) expressed the cost of transportation in a wider perspective to incorporate route factor, cargo factor and profit margin, which provides for adjustments into the actual cost of transporting freight. The model is expressed as follows;

$$\text{Transport Cost} = f\{D+K_{R,} +K_{q,} +Q, +K_{P/S,} +C\} \text{ (US\$)} \qquad (2.13)$$

Where;

D = Direct distance between origin and destination

K_R = Route factor

K_q = Cargo volume/weight (cubic/ton) factor

$K_{P/S}$ = Profit factor

Q = Quantity of goods in ton

[5] Available at, http://www.gams.com/docs/example.htm

C = Operating cost expressed as US$/ton-km

Blanden's model for freight rate can be viewed as all inclusive since it brings into the picture a number of factors controlling the cost of freight. In a case where there is a monopoly enjoyed by the transporters, or where several alternative routes are available, then the application of Blanden's model is suitable. However, it would be difficult to determine the relationship between freight rates, route type and cargo type. The existing models for freight transport costs are summarized in Table 2.5 below:

Table 2-5 Summary of Existing Models for Freight Transport Costs

Author	Model	Comments
Weber's (1929)	$T=a_1 r_{A1}+a_2 r_{A2}+a_3 r_{A3}$	The model does not consider VOCs and assumes that road network and condition is perfect. This model is not applicable to the Northern Corridor road which varies from good to very poor condition.
Wilson's et al (1969)	$G_{ij}=a_1 t_{ij}+a_2 e_{ij}+a_3 d_{ij}+p_j+\varepsilon$	The model does not consider VOCs. It assumes that the road condition is good, and that there is no delay for truckers. Time component used is the travel time and not journey time which assumes that delays are negligible. This model is not applicable for the Northern Corridor road since there are significant delays for truckers. Transport cost has also been used as a variable in obtaining the generalized cost.
Van Es et al (1974)	If $Q^{d}=Q^{s}$, then, $P^{d}= c_0P^{s}-c_1P^{t} + \varepsilon$	The model does not consider VOCs and assumes a perfect road network. This model is used in cases where the manufacturer and distributor are the same.
RTIM (1982)	$VOCs =a_1+a_2RS+a_3F+a_4CURVE+a_5ALT+a_6BI+a_7PWR+ a_8WIDT$	The RTIM is used to compute VOCs. The model does not show the relationship between VOCs and freight rates.
Blanden et al (1984)	$TC = f\{D, +K_R, +K_q, +Q, +K_{P/S}, +C\}$	This model has variables such as route factor (an arbitrary constant attached to every route depending on the cost) and transporter's profit margin which cannot be precisely obtained from the transporters along the NC road.
World Bank (2005)	$C_k=c_k+\alpha_k (t_k+\beta_{\sigma t, k})$	This model has variables such as reliability and variations which are not easy to quantify. The variables used in this model are not easy to collect or measure along the NC road.
GAMS (2005)	$C_{ij} = F \times d_{ij}$	The model assumes that transport cost depend on distance only and ignores other factors like VOCs, demand and supply.

Source: Researcher

The following observations are made from Table 2.5;

- The model developed by Weber (1929) is a multiple linear regression equation. It includes the use of variables such as the physical quantities of raw materials, goods consumed, distance to market and distance to source of raw materials. However, the model does not consider VOCs and assumes that road network and condition is perfect. This model cannot be used to achieve the objective of this research because it does not test the relationship between transport cost and VOCs. Besides, assuming that there is a perfect road network and condition does not apply since the NC road has both good and bad sections.
- Wilson et al (1969) model is a multiple linear regression equation. The Researcher used distance, travel time, buffer time and total transport cost between origin and destination to obtain the generalized cost of transport. However, this model does not consider VOCs. Likewise, it is also assumed that road condition is good and that there are no delays for truckers. The time component used is the travel time and not journey time which presupposes that delays are negligible. Therefore, the model is not applicable to the Northern Corridor road since there are significant amount of delays for truckers. In addition, the buffer time requires a large sample size to be accurately ascertained.
- Vans et al (1974) model is a linear equation model that is used in obtaining economic batch quantity that minimizes cost of transport for manufacturing industries. It is more relevant for manufacturers who distribute their own products. Vans et al's (1974) model did not consider VOCs and assumed that road network and condition is perfect.
- The model by Blanden et al (1984) is an additional multiple linear regression equation that uses distance, route factor (arbitrary value attached to a route), cargo factor (ratio of cargo weight to truck GVW), profit margin, and operating costs to compute transport cost. Blanden's (1984) model cannot be applied to the NC road directly since variables such as route factor and profit margins can not be accurately measured.

- The model by the World Bank (2005) is a multiple linear regression equation model developed using variables namely reliability, travel time and variations in travel time to calculate the generalized cost of transport. This model can not be easily applied along the NC road since reliability and variations in travel time are not easy to measure and quantify.
- The model developed by GAMS (2005) is a linear equation model which uses distance and the unit cost only, to compute the transport cost. Assumptions are made that transport cost is related to distance covered.

All the models for freight transport cost shown in Table 2.5 share one thing in common; they are all multiple linear regression equation models.

2.10 Limitations of the Existing Models for Freight Transport Cost

The major short comings of the existing models reviewed for freight transport cost are summarised below:

- √ The models fail to show the relationship between transport cost and vehicle operating cost, while considering other variables such as travel time, cargo weight, backhauls and truck model.
- √ It is expensive to collect and determine the variables used in the existing models for the Northern Corridor road due to high precision and variability of data requirements.

3 MODEL DEVELOPMENT

3.1 Introduction

This chapter describes the Freight Transport Cost Prediction Model (FTCPM) developed from this research. The variables used in this model and the basis of choice of each variable are presented. In addition the assumptions made in model formulation are included.

3.2 Model Overview

The Freight Transport Cost Prediction Model (FTCPM) is a multiple linear regression equation model. It addresses the shortcomings of the existing models for freight transport cost reviewed in the preceding chapter, depicting the following:

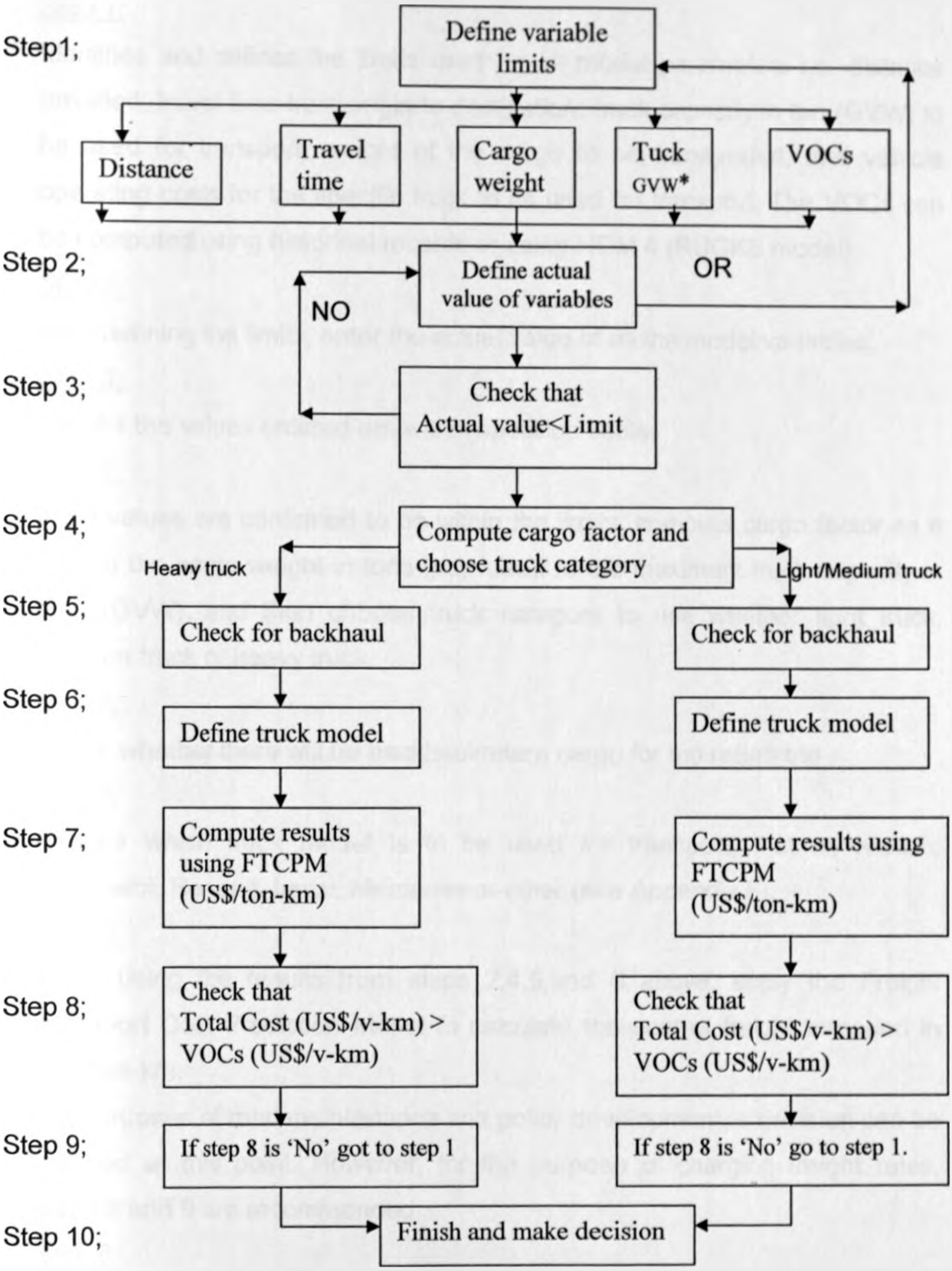
- √ The relationship between freight transport cost and VOCs including variables such as travel time, cargo weight, truck model, truck category and return cargo. Ultimately, a sensitivity analysis is undertaken to illustrate the response of transport costs to changes in VOCs.
- √ The model identifies measurable variables that are easier to collect from the field and simple to use in application.

3.3 Flow Chart for the FTCPM

A flow chart illustrating the FTCPM[6] application to estimate transport cost is shown in Figure 3.1;

[6] Freight Transport Cost Prediction Model

Figure 3-1 FTCPM Flowchart



*Gross Vehicle Weight

The following section describes the steps presented in Figure 3.1;

<u>*Step 1:*</u>

Identifies and defines the limits used for all model parameters i.e. distance travelled; travel time from origin to destination; truck capacity in ton (GVW) to be used for transport; weight of the cargo to be transported; and vehicle operating costs for the specific truck to be used for transport. The VOCs can be computed using historical records or using HDM 4 (RUCKS model).

<u>*Step 2:*</u>

After defining the limits, enter the actual value of all the model variables.

<u>*Step 3:*</u>

Checks the values entered are within specified limits.

<u>*Step 4:*</u>

If the values are confirmed to be within the limits, compute cargo factor as a ratio of the cargo weight in tons (pay load), to the maximum truck capacity in tons (GVW), and then choose truck category to use whether light truck, medium truck or heavy truck.

<u>*Step 5:*</u>

Check whether there will be backhaul/return cargo for the return trip

<u>*Step 6:*</u>

Choose which truck model is to be used for transport, that is, Nissan, Mitsubishi, Renault, Isuzu, Mercedes or other (see Appendix F).

<u>*Step 7:*</u>

Then, using the results from steps 2,4,5,and 6 above, apply the Freight Transport Cost Prediction Model to calculate the cost of freight transport in US$/ton-km.

For purposes of road maintenance and policy development, a decision can be reached at this point. However, for the purpose of charging freight rates, steps 8 and 9 are recommended.

<u>*Step 8:*</u>

Check whether the total transport costs (US$/v-km) is greater than the VOCs (US$/v-Km) to avoid incurring a loss.

Step 9:

If step 8 is "NO" that is, if the vehicle operating cost in US$/v-km is greater than transport cost in US$/v-km, go back to step1 to revise the transport rate per ton-km.

Step 10:

If step 8 is "YES", routine ends and a decision is made.

An algebraic description developed by GAMS is used to compare the transport cost in US$/v-km to vehicle operating cost in US$/v-km described in step 8 above (see also Figure 3.1) as described below.

That is;

Given that,

i = Origin of a commodity

j = Destination of the commodity

a_i = Supply of commodity at i

b_j = Demand of commodity at j

d_{ij} = Distance between i and j

Then;

Cost of transporting cargo, from origin i to destination j over distance d subject to supply and demand as constraints can be expressed as;

$$C_{ij} = F \times d_{ij} \qquad (3.1)$$

(Transport cost per unit case between i and j given as US$/case)

(Where, 'case' refers to the unit of measurements i.e. weight or volume).

And;

F = Cost in vehicle operating cost per unit case, per unit distance. (Vehicle Operating Cost is given in US$/-v-/km)

Decision variables;

X_{ij} =Amount of commodity to be transported from *i* to *j* where

$X_{ij} \geq 0$ for all *i* and *j*

Constraints;

The supplies limit at origin *i*: $\sum_j X_{ij} \leq a_i$ for all *i*

The demand limit at destination *i*: $\sum_i X_{ij} \geq b_j$ for all *j*

Considering that;

$b_j \leq a_i$,

Then;

Supply constraint will always apply unless a given demand is quoted.

Objective function;

Limit Total Cost = $\sum_j X_{ij} * C_{ij}$ (US$/v-km)........... *(3.2)*

Where

X_{ij} is pay load to transport comparable to supply constraint

C_{ij} is cost of transport in US$/ton-km

3.4 The Freight Transport Cost Prediction Model Parameters

The following considerations were made in the development of the Freight Transport Cost Prediction Model (FTCPM);

- Availability of the data
- Accuracy of the data

Based on the parameters investigated, two freight transport cost models were developed which are used to estimate and to predict the freight transport rates (US$/ton-km) when the input variables are known. Components of the models are described below;

1. Vehicle operating cost (VOCs) in US$/v-km is used to establish the relationship between transport cost and VOCs.

2. Travel time (days) is used to investigate the relationship between transport cost and cargo delivery time.
3. The availability of backhauls/return cargo is used to find out if availability of return cargo affects transport cost.
4. Distance travelled (km) is used to establish the relationship between transport charge per ton-km and the distance travelled.
5. Cargo factor (a ratio of pay load to the truck Gross Vehicle Weight) is used to investigate the relationship between transport costs per ton-km and total weight of cargo carried.
6. Truck Model is used to establish the relationship between transport cost and truck model, based on the assumption that different truck models have varying operating costs depending on manufacturer's specification (see appendix F).

The first FTCPM used to estimate freight rates was formulated as shown below;

Freight Rate (US$/ton-km) $= aD + bK_R + cK_T + dQ + eVOC + fB + \varepsilon$ .... *(3.3)*

Where;

D = Direct distance in km.

K_R = Truck model factor;

K_T = Time allowed in days

Q = Cargo factor given as a ratio of pay load to GVW.

VOC = Vehicle operating cost given as US$/v-km.

ε = Error factor

B = Backhauls/Return cargo factor.

a, ,b, c, d, e, f, are variable coefficients.

From the model inputs above;

- Distance is computed in kilometre between origin and destination.
- Cargo factor is computed as a ratio of cargo weight carried in ton (pay load) to total truck capacity in ton (GVW).

- Vehicle operating cost (US$/v-km), is calculated as a sum of VOC components namely fuel, tyre, lubricant, maintenance, crew, insurance, cargo time value, passenger time value, depreciation and interest given in US$/v-km.
- Truck models were assigned arbitrary values between 1 and 6. This was done based on the truck cumulative mileage during the years of service. That is, truck model with longest service life was assigned a value of [1] while the truck model with the shortest service life was assigned a value of [6] in an ascending manner as shown below;

[1] = Renault	[2] = Mercedes
[3] = Isuzu	[4] = Nissan
[5] = Mitsubishi and	[6] = Other.

- Travel time is computed as time taken from origin to destination and back to origin in days.
- Backhaul is coded as;

  [0] ='Yes' (when the truck has a return cargo)

  [1] ='No' (when the truck has no return cargo)
- The freight rate is estimated in dollars per ton-km.

The second FTCPM is used to establish the relationship between freight rates and VOCs in addition to projecting freight rates as formulated below;

Freight Rate (US$/ton-km) $= aVOCs + bVOCs^2 + cVOCs^3 + \varepsilon$ .... *(3.4)*

Where;

VOC = Vehicle operating cost expressed as US$/v-Km.

ε = Error factor

a, ,b, c, , are variable coefficients obtained by undertaking a multiple linear regression analysis.

3.5 Assumptions made in formulating the FTCPM

The assumptions made when formulating the FTCPM were that;

- There is some linear relationship between transport cost and vehicle operating cost. It assumes that freight rates are directly proportional to VOCs.
- There is a linear relationship between transport cost and cargo delivery time. It assumes that transport cost increases when cargo delivery time is long and decreases when cargo delivery time is short. This is also based on the assumption that a shorter delivery time enables the transporter to make many round trips.
- FTCPM component variables are not dependent on one another. The assumption is that the value of each variable and its relationship to the transport cost, has no relationship or bearing on the value of another variable in the dataset
- The residuals of the model were normally distributed around the mean of the sample.
- There are minimal delays at the weighbridges, border posts and police checks, hence journey time (sum of travel time and stop time) is approximately equal to the travel time (time when the truck is actually moving without stopping).
- There is stability in the market, and that there is no monopoly or restriction towards transport cost in the industry.
- The FTCPM assumed that all weighbridges operate effectively with minimal delay and that trucks do not overload the cargo carried.
- Finally, that any other factor affecting the freight transport cost that was not used as a variable in the model is insignificant or constant.

3.6 Application of the FTCPM

The formulated FTCPM is applied in two ways namely;

1. As a model for estimating the freight rate (US$/ton-km) when the variables are known. This is by applying the model shown in equation 3.3 in section 3.4.
2. As a model for predicting trends in freight rates. This is by applying the model shown in equation 3.4 in section 3.4.

4 DATA COLLECTION

4.1 Introduction

This chapter describes the specific field research methods employed based on the literature reviewed in the preceding chapters. The data collection was carried out in two phases. Firstly, a pilot survey was done to assess the tools and the anticipated constraints. This was thereafter followed by the collection of primary and secondary data. The various research methods employed during the two phases are discussed in the following sections.

4.2 Objectives of Data Collection

The main objectives for collecting the data along the NC road included the following:

1. To establish the freight transport rates;
2. To establish vehicle operating costs for goods vehicles;
3. To establish travel time for goods vehicles;
4. To establish truck category and truck models used for cargo transport;
5. To establish the absence or presence of return cargo for transporters; and
6. To establish the hauled cargo weights and GVW of the trucks.

4.3 Methods of Data Collection

The following methods were used to collect data for this study:

- ✓ Semi-structured interviews were carried out through the administration of questionnaires; and
- ✓ Direct measurements for travel time were taken using GPS equipment.

4.4 Pilot Survey

A pilot survey was undertaken from the 25th to 30th January 2007. The trial run covered the entire NC road on the Kenyan side using a five-seater car. The main objective of this approach was to establish the general road characteristics along the Northern Corridor road, as well as assess the GPS equipment. In addition, it allowed for the researcher to obtain a sample of the GPS data, and subsequently formulated a method for data analysis. Amongst the characteristics that were examined included the general road cross sections; road surface condition; the horizontal and vertical road alignment; and the traffic condition. During the pilot survey, offices of Kenya Transport Association (KTA) and the selected transporters in Mombasa and Nairobi were visited. Accordingly, the researcher was introduced to key resource persons such as the industry players by the KTA officials. The researcher used the aforementioned opportunity to test the tools as well as acquaint himself with the research area.

4.5 Authorities Visited prior to Data Collection

Prior to the collection of data, a number of authorities were visited to facilitate the process namely; the Ministry of Roads and Public Works in Nairobi and University of Nairobi Enterprises and Services (UNES) Ltd, who issued letters introducing the research team to key stakeholders such as the Kenya Transport Association (KTA) and the Northern Corridor Transit Transport Coordination Authority (NCTTCA) in Mombasa respectively. The reasons for this were two-fold: (i) to ensure confidentiality in the research process, (ii) to enable the researcher to gain access to available data.

4.6 The Survey Team

The survey team consisted of two research assistants previously trained to undertake the exercise. Due to the nature of the work, a taxi was hired to facilitate the movement of the researchers. The main equipment used in this exercise was the Global Positioning System (GPS). Porters were hired to transport the equipments to and from the survey stations. Similarly, 16 field assistants were engaged to collect data for travel time. The field assistants were grouped in teams of two including the driver and the turn boy, and underwent training prior to the actual data collection. The process entailed data entry of details such as truck stops locations, the reasons for stopping at the said locations, as well as the duration. During the data collection process, the researcher called the assistants at three hour intervals to confirm that the GPS was working, as well as to receive feedback on the process.

4.7 Data Coding

The qualitative data which was collected for example the truck model and availability of return cargo, were coded by assigning numbers (see section 3.4). This was carried out in order to facilitate the ease of analysis when using analytical software e.g. SPSS and Microsoft Excel. Similarly, the information obtained from the questionnaires, was also coded (see Appendix B).

4.8 Sample Size

A sample population of 16% was drawn from Kenya Transport Association (Appendix A). The total number of transport companies which were interviewed as listed below (see also Appendix A);

Table 4-1 List of Transport Companies Interviewed

• A.O. Bayusuf & Sons Transporters,	• Hakika Transporters,
• M.A. Bayusuf & Sons Transporters,	• Tornado Carriers,
• Roadtainers Transporters,	• Coast Haulliers,
• Transpares (Kenya) Transporters Ltd,	• Group 4 Securicor Services,
• Multiple Haulliers,	• Mombasa Maize Millers,
• A to Z Transporters,	• DHL Courier Services,
• Transeast Transporters,	• Cadbury Kenya Limited,
• Kenfreight Transporters,	• Unga Company (Farm Care),
• Shiva Carriers,	• Timsales Nairobi,
• Siginon Transporters	• Roy Parcel Services Nairobi,
• Panal Freighters,	• P.N. Mashru Transporters,
• Awale Transporters,	• A.K. Abdulgani Transporters,
• Motrex transporters	• Anwarali Transporters,

Source: Researcher

The number of trucks whose details were obtained from transport companies was 1861. According to the traffic census conducted by UNES Ltd in April 2006, this is approximately 34% of ADT along the A109 road for the Mombasa and Nairobi section. Out of the surveyed volume, it was established that most trucks had similar operating features namely distance travelled, truck model, travel time, cargo carried, and absence of return cargo. Nonetheless, findings also revealed that 166 trucks had differing operating characteristics. Hence, only 166 of the sampled volume were used to calibrate the FTCPM which comprised of 48 light/medium trucks and 118 heavy trucks. Light and Medium trucks were grouped together since the volume of individual categories was not adequate to calibrate a model. According to Bennet (1994) it is recommended that a minimum of 40 samples is required to calibrate a model with five or more predictor variables. In addition, in order to attain a 95% level of confidence in the multiple linear regression analysis, a minimum of 33 samples are required (Pignataro, 1973).

4.9 Data Collection Procedure

The data type, survey area and dates for data collection are summarized in Table 4.1.

Table 4-2 Data Type, Survey Area and Dates of Data Collection

Data type	Survey area	Date
Travel time using GPS	Mombasa to Malaba road. Mombasa to Busia road.	From 19th March 2007 to 13 April 2007
VOCs by Interview of transporters.	Mombasa	From 26th March 2007 to 12th April 2007
	Kisumu	From 2nd April 2007 to 5th April 2007.
	Nairobi	From 13th April 2007 to 20th April 2007.

Source: Researcher

During the data collection process, the survey team was based at the Kenya Transport Association office in Mombasa. All equipment, materials and data forms were stored at their offices, throughout the field investigations. Daily interviews were carried out from 8 am to 6 pm. The key informant interviews consisted of semi-structured interviews with the transporters, through the use of questionnaires (See Appendix B). Whereas the direct interview approach is expensive to administer, it was selected by the research due to its accuracy and reliability. Besides, based on the nature of the work, the direct interview provided an opportunity to clarify questions to respondents. Data collection in Kisumu and Eldoret was not successful since the transporters were unwilling to give their company's transport costs details.

All information was provided by company transport managers, or operations managers. In some companies, the data required was given by the managing director. However, for companies that were reluctant to give their cost information, costs were estimated. Still, some companies suggested that the questionnaire be left at their company office to be completed by their relevant departmental heads. Detailed explanations were given to the interviewed to avoid errors while completing the questionnaires. For every transport company visited, more than one questionnaire was completed depending on the number of trucks in the company. Findings from the survey revealed that the smallest company had 30 trucks while the largest company had 500 trucks. Detailed description of the information gathered is discussed below;

4.9.1 Freight Rates

Freight transport charges (in US$) were obtained for various trips made along the Northern Corridor road. These trips were made within Kenya, to and from the urban centres of Mombasa, Nairobi, Eldoret, Kisumu, and Nakuru. However, only a few freight rates were obtained for trucks travelling to Kampala, Entebbe and Kasese in Uganda from the seaport of Mombasa. In calibrating the Freight Transport Costs Prediction Model (FTCPM), freight rate (in US$/ton-km) was used as the dependent variable.

4.9.2 Vehicle Operating Costs

Data gathered for the calculation of vehicle operating costs comprised of the following (See section 2.4):

- Fuel - quantity (litres) and price per litre (US$).
- Lubricant – quantity (litres), price (US$) and variety of lubricants.
- Maintenance and spare parts – costs (US$) of minor and major maintenance and the corresponding truck mileage (km) before minor and major maintenance service respectively.
- 3rd party insurance policy - sum assured per year (US$).
- Crew - crew number, wage (US$) and trips per month.
- Tyre - number of wheels, number of axles, tyre mileage (km) and price (US$).

The freight transport cost obtained from the transport companies corresponded to a given return trip made by a truck. Each component of the operating costs was calculated in US$/v-km. VOCs was obtained by summing up the cost components which were, fuel, tyre, lubricant, maintenance, crew, depreciation, interest, cargo time value, passenger time value and insurance consumptions. The VOCs was used as a predictor/independent variable in calibrating FTCPM, and was based on the assumption that cargo transport rates vary, depending on the operating cost of the truck.

4.9.3 Travel Time

Truck travel time along the Northern Corridor road was obtained using six GPS equipment. For every truck, the researcher placed the GPS next to the driver's seat inside the truck, positioning the antenna on the front board of the truck in order to receive satellite signals without obstructions. The gadget was fastened using a tape to avoid interference with the connections, in particular the accumulator when the truck is in motion. Likewise, all the GPS gadgets were calibrated to record time at interval of three minutes as the truck moved. In addition, two research assistants went to Mombasa and installed the GPS equipment on trucks as follows;

- "One" GPS was installed on a truck moving from Mombasa to Kampala via Busia. This equipment was removed in Busia and relocated to another truck which was moving from Malaba to Mombasa.
- Three GPS equipment were installed on trucks moving from Mombasa to Kampala via Malaba. These were later removed at the Kenya/Uganda border post at Malaba and transferred onto other trucks moving from Malaba to Mombasa.
- One GPS was installed on a truck moving from Mombasa to Kisumu and back to Mombasa. This equipment was removed upon return to Mombasa.
- One GPS was installed on a truck moving from Mombasa to Eldoret and back to Mombasa. This equipment was removed upon return of the truck in Mombasa.

During the interval between installation and removal of the GPS equipment, the truck driver was instructed to ensure that the antenna was always blinking, and the GPS power input indicator was also on (showing red light). The researcher maintained constant communication with the truck driver to ensure no problems were encountered with the equipment. In addition to the GPS, the truck drivers were given data forms to record where they made lengthy stops, time taken and reason for stopping. Data recorded by the GPS were downloaded using software called Track Loader and Ozi Explorer, which were later analyzed and used to compute values of cargo time and passenger working time in US$/v-km. Furthermore, travel time was obtained through direct interviews which employed the use of questionnaires (Appendix B). The resulting travel time (in days) was used as a forecasting variable in calibrating FTCPM.

4.9.4 Truck Category and Truck Model

Goods vehicles were grouped in categories depending on the number of axles as follows:

- Light trucks - 2 to 3 axles
- Medium trucks - 4 to 5 axles
- Heavy trucks - 6 or more axles

The varying model of trucks obtained from the transport companies comprised of the following: Renault, Isuzu, Mercedes, Mitsubishi and Nissan (see also Appendix F). These were used as a forecasting/independent variable in calibration of FTCPM.

4.9.5 Return Cargo

It was assumed that the transport cost charged was dependant on the availability of return cargo. To be more accurate on the VOC, it was not advisable to factor in any return cargo since the operating expenses were the same, as long as a truck made a trip. However, data was also obtained on the freight rates when there was return cargo. This variable was used as a predictor/independent variable in calibrating FTCPM.

4.9.6 Pay Load/Cargo Weight and Truck Capacities.

Generally, transport cost depends on weight of cargo to be transported, which also depends on the capacity, GVW of the truck used for the transport. The values of pay load (cargo weight in tons) and truck capacity (GVW in tons) were used to calculate cargo factor as a ratio of pay load to truck capacity.

Results obtained were thereafter used as a forecasting/independent variable in calibrating FTCPM. Information was also obtained for the cargo weight, which was normally transported by the truck for every specified origin and destination pair.

4.10 Data Collection Problems and Accuracy

Several difficulties were encountered during the data collection process, such as:

1. A number of the transport company offices both in Nairobi and Mombasa are widely scattered, therefore a lot of time was spent travelling from one office to the other.
2. Some of the field assistants experienced great difficulties in completing and preparing the data forms as instructed, due to their level of literacy. As a result, it was not easy to identify the stop time and travel durations by the truck.
3. Despite the introductory letters issued by the KTA office for the purpose of the research, some transport companies declined to provide exact freight cost which they considered to be confidential information. In some cases, a company was visited more than three times which proved to be a costly exercise.

The data recorded by the GPS equipment was voluminous. This was because calibration of the GPS was carried out to record time and spatial location at an interval of every three seconds.

4.11 Solution for the Data Collection Problems and Accuracy

In order to solve the aforementioned problems of data collection and accuracy, the following measures were undertaken:

1. After data entry, sorting and cleaning was done prior to data analysis, in order to remove erroneous values.
2. A taxi was hired to facilitate movement of the research team, particularly during the interviews conducted with the transportation companies.
3. Despite the fact that the field assistants were semi illiterate, the law stipulated that only the driver and their assistant were allowed to travel in the trucks. The travel time data obtained from direct interview of the crew were complemented with the records obtained from the GPS equipments.
4. The transport companies that could not provide their exact operating costs were allowed to give approximate values. These were used to calculate average cost.
5. The large volume of data obtained from the GPS was solved by allocating 2.5 months for analysis.

5 DATA ANALYSIS

5.1 Introduction

The primary and secondary data collected during the field investigations were analyzed and used to calibrate the Freight Transport Cost Prediction Model. The results of the analysis are also discussed in the subsequent sections.

5.2 Vehicle Operating Costs

The total vehicle operating cost (US$/v-km) was computed by summing up the individual components as defined below:

5.2.1 Fuel

Fuel costs was computed per vehicle-kilometre (US$/v-km), by dividing the total cost of fuel used by the return mileage for every sampled origin-destination pair.

$$\text{Fuel Costs} = \frac{\text{Fuel used (l) x cost of fuel (US\$/l)}}{\text{Return mileage (km)}} \qquad (5.1)$$

5.2.2 Lubricant

Lubricant costs was computed per vehicle-kilometre (US$/v-km) by dividing the total cost of lubricant used, by the return mileage for every sampled origin-destination pair.

$$\text{Lubricant Costs} = \frac{\text{Lubricant used (l) x cost of Lubricant (US\$/l)}}{\text{Return mileage (km)}} \qquad (5.2)$$

5.2.3 Crew

Crew costs was computed per vehicle-kilometre (US$/v-km) by dividing the total cost of crew, by the return mileage for every sampled origin-destination pair.

$$\text{Crew Costs} = \frac{\text{Crew wage per month}}{\text{Trips per Month x Return mileage}} \quad \ldots\ldots (5.3)$$

5.2.4 Maintenance Parts and Labour

Maintenance parts and Labour costs (US$/v-km) was computed by adding the total cost of minor maintenance service and major maintenance service, then dividing the results by the total mileage before minor maintenance service and major maintenance service.

$$\text{Maintenance and Parts} = \frac{\text{Cost of Minor Service + Cost of Major Service}}{\text{Total mileage before minor and major service}} \quad \ldots\ldots (5.4)$$

5.2.5 Insurance

Insurance costs (US$/v-km) was computed by dividing the annual insurance cost (Sum assured) by the truck annual mileage.

$$\text{Insurance Costs} = \frac{\text{Annual cost of Insurance}}{\text{Annual mileage}} \quad \ldots\ldots (5.5)$$

5.2.6 Tyre Cost

Tyre costs (US$/v-km) was computed by diving average cost of new tyre by the tyre mileage, and then multiplying by the total number of wheels in the truck.

$$\text{Tyre Costs} = \frac{\text{Number of Wheels x average cost of tyre}}{\text{Average tyre mileage}} \quad \ldots\ldots (5.6)$$

5.2.7 Depreciation and Interest

Cost of depreciation and interest (US$/v-km) was estimated on the basis of an annual interest rate of 15% (Kenya Commercial Bank, 2007), average service life of 12 years and an average truck cargo value of US$143,000.

$$\textit{Depreciation and interest} = \frac{\textit{truck value x Interest rate}}{\textit{Average service life x Annual mileage}} \quad (5.7)$$

5.2.8 Established Vehicle Operating Costs along the NC Road

A summary of the analyzed VOCs (US$/v-km) for light, medium and heavy trucks is shown in Table 5.1 below. It was observed that heavy trucks had higher VOCs than light and medium trucks, ranging from US$0.6312/v-km – US$2.3424/v-km while light trucks had lower VOCs than heavy and medium trucks, which ranged between US$0.3320/v - km-US$1.0458/v-km. The average VOCs for heavy and light trucks were US$1.1002/v-km and US$0.8135/v-km respectively. It was also noted that the highest VOCs for heavy trucks was at 200% more than that of light trucks. However, the average standard deviation of VOCs for both light and heavy trucks was 0.242.

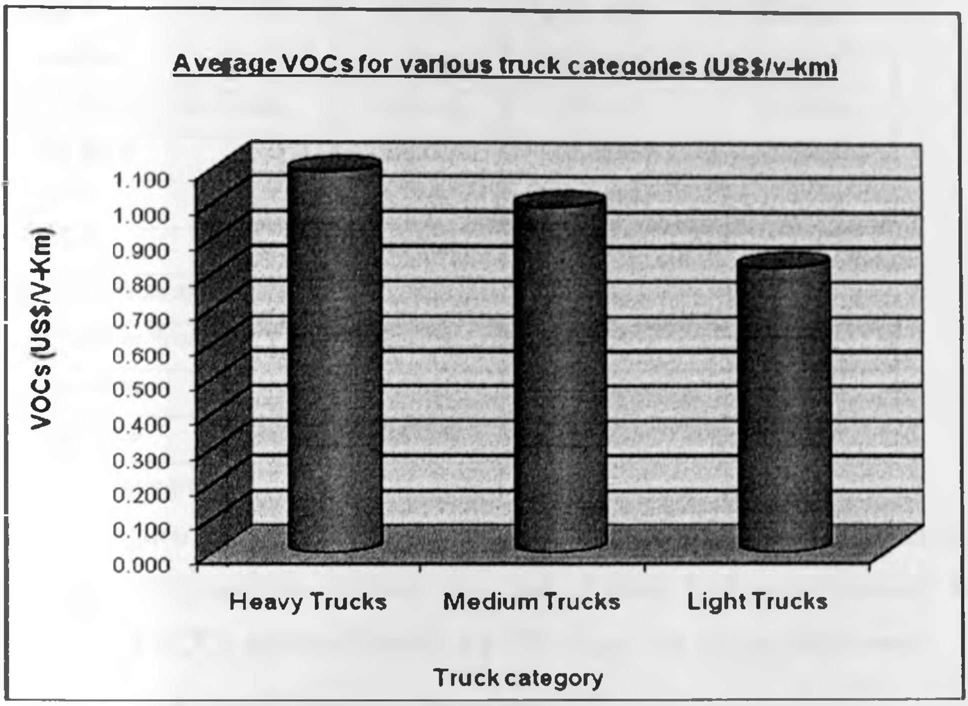
Table 5-1: Average Vehicle Operating Costs (US$/v-km)

Total VOCs (US$/v-km)	*Truck*		
Item	Heavy Trucks	Medium Trucks	Light Trucks
Mean	1.1002	1.0010	0.8135
Median	1.0186	0.8876	0.8376
Mode	1.4059	0.8123	0.3320
Standard Deviation	0.2796	0.0054	0.2048
Minimum	0.6312	0.7211	0.3320
Maximum	2.3424	1.2200	1.0458

Source: Researcher

Figure 5.1 below represents the average vehicle operating costs for various truck categories. It shows that, heavy trucks have higher VOCs than light and medium trucks, while light trucks have lower VOCs than the heavy and medium trucks. A full summary of vehicle operating costs is shown in appendix C.

Figure 5-1 Average VOCs for Various Truck Categories



Source: Researcher

Table 5.2 shows the components of average VOCs in US$/v-km for light, medium and heavy trucks. The VOCs values are obtained by analyzing the VOCs data (see Appendix C).

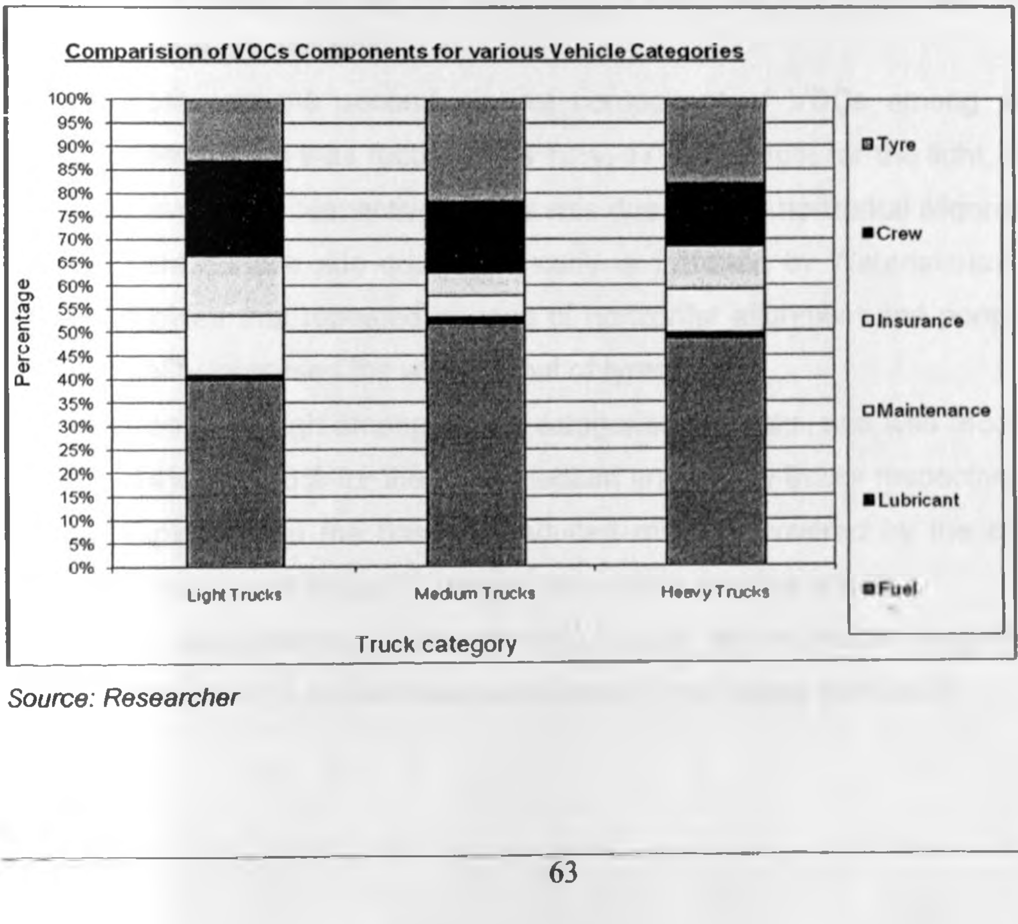
Table 5-2: Average Costs of Components of VOCs (US$/v-km)

VOCs Component	Average VOCs in US$/v-km		
	Light trucks	Medium trucks	Heavy trucks
Fuel	0.2852	0.4307	0.4706
Lubricant	0.0078	0.0117	0.0128
Maintenance and Parts	0.0919	0.0405	0.0910
Insurance	0.0311	0.0505	0.0618
Crew	0.1457	0.1289	0.1319
Tyre	0.0962	0.1829	0.1765
Depreciation and Interest	0.1457	0.1457	0.1457
Passenger time	0.0018	0.0018	0.0018
Cargo time	0.0082	0.0082	0.0082
Total Vocs	0.8135	1.0010	1.1002

Source: Researcher

Figure 5.2 illustrates the components of the VOCs by percentage. The Figure is obtained by dividing the cost of each VOCs component, by the total amount of VOCs and multiplying by 100 to get the percentage value.

Figure 5-2 VOCs Components by Percentage



Source: Researcher

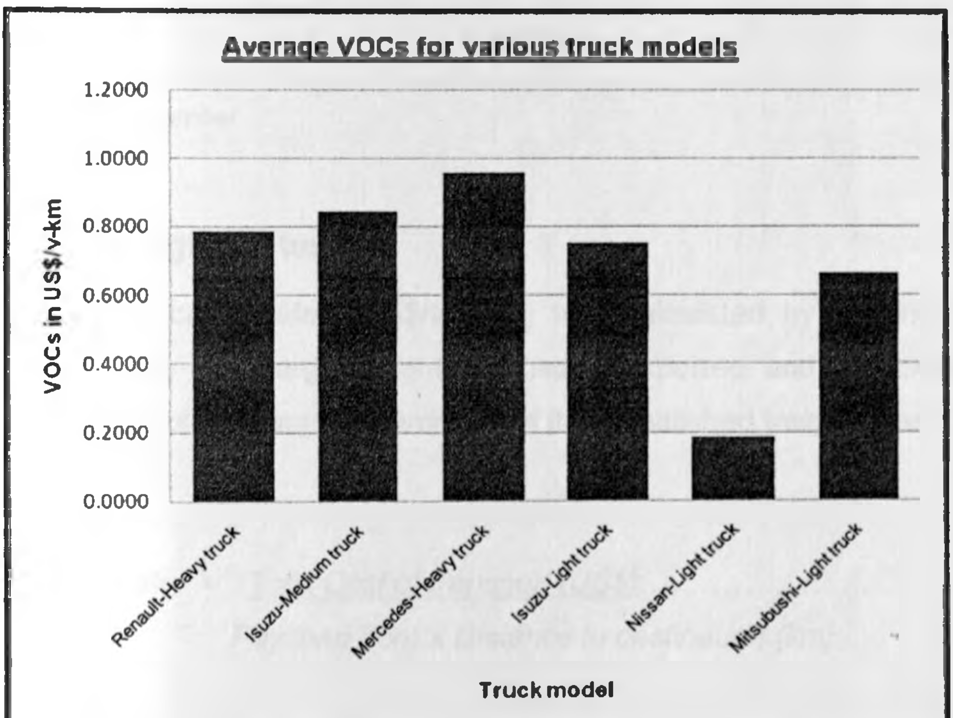
From the VOCs components shown in Figure 5.2 above, the following conclusions were drawn:

- Fuel costs were high for light, medium and heavy trucks at 33%, 44% and 42% respectively. This can be attributed to;
  - Poor pavement surface condition (IRI). Road roughness is directly proportional to VOCs (Rodrigo, 2004).
  - Studies undertaken by Watanatanda (1987) showed that fuel consumption increases when there is frequent acceleration and decelerations. The NC road has recurrent changes of alignment that force drivers to frequently change speeds.
  - Since the NC traverses major urban centres, there is a congestion effect which results in repeated acceleration and deceleration of the vehicles.
  - The high fuel expenditure was also attributed to the incidences of fuel theft along the road, whereby it was reported that truck drivers sold fuel to vendors while on transit. Members of transport crews argued that the reason behind the siphoning of fuel was due to the fact that they were not well paid.
- Tyre cost was the second highest component of VOCs among all truck categories, which was recorded as 12%, 17% and 16% for the light, medium and heavy trucks respectively. This was due to poor horizontal alignment and pavement surface ride quality. A study undertaken by Watanatanda (1987) also showed that repeated change of horizontal alignment and poor surface ride quality increases the wearing out of tyres.
- Crew cost was high among all the categories of trucks, and was recorded as 17%, 14% and 13% for the light, medium and heavy trucks respectively. This was explained on the basis of reduced mileage covered by the crew per month which contributed to, delays, travel time and low speed.
- Costs of depreciation and interest were high for all the vehicle categories, and were attributed to reduced annual utilization and shorter service life.

- Insurance cost was also unexpectedly high among all the vehicle categories. These indicated that the annual mileage per truck was short, implying higher delays and longer travel time.
- In terms of cost of parts, it was the second lowest in all vehicle categories. Hence, it can be deduced that a number of the trucks were new.
- The cost of lubricants, and cargo time value were low among all truck categories.

A comparison of VOCs for various truck categories and models along the Northern Corridor road is presented in Figure 5-3. It was observed that Nissan-light trucks had the lowest vehicle operating costs of less than US$0.2/v-km, while Mercedes-heavy trucks had the highest vehicle operating costs of US$0.9675/v-km. Mitsubishi, Renault and Isuzu trucks had vehicle operating costs ranging between US$0.65/v-km – US$0.85/v-km. The variations in VOCs for respective truck models may be attributed to the vehicle manufacturers' specification (see Appendix F).

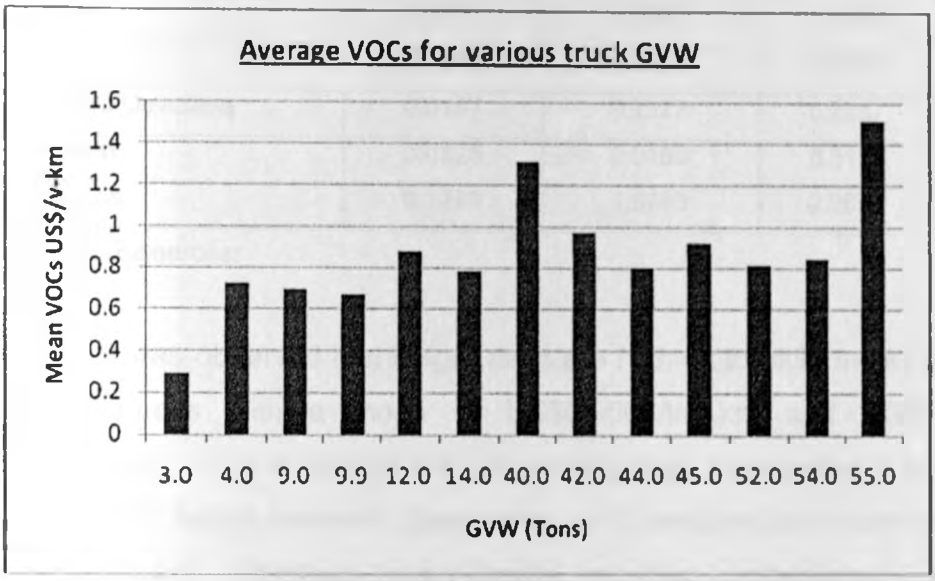
Figure 5-3 VOCs for Various Truck Models



Source: Researcher

Figure 5.4 is an illustration of the relationship between vehicle operating costs and the gross vehicle weight. As the average vehicle operating cost increases so does the gross vehicle weight in the graph. Cases of vehicle operating costs being low for trucks with high gross vehicle weights may be due to high maintenance cost and poor driver behaviour.

Figure 5-4 Average VOCs for Various Truck GVW



Source: Researcher

5.3 Freight Rates

The cargo rates (US$/ton-km) was calculated by dividing the cost of transport by the cargo weight/pay-load transported and the distance to the destination of the cargo. A summary of the established freight rates is included in appendix C.

$$\text{Freight Rate} = \frac{\text{Total Cost of transport (US\$)}}{\text{Pay load (ton)} \times \text{Distance to destination (km)}} \quad \text{...... (5.8)}$$

5.3.1 Established Freight Rates along NC Road

Table 5.3 is a summary of the freight rates that were calculated for various truck categories that use the Northern Corridor road.

Table 5-3: Statistics for Freight Rates (US$/ton-km)

Freight Rates(US$/ton-km)	Truck		
Item	Heavy Trucks	Medium Trucks	Light Trucks
Mean	0.0773	0.2500	0.9564
Median	0.0775	0.2000	0.7909
Mode	0.0847	0.1922	0.3555
Standard Deviation	0.0157	0.2377	0.2237
Minimum	0.0325	0.0458	0.3125
Maximum	0.1290	1.5740	2.2676

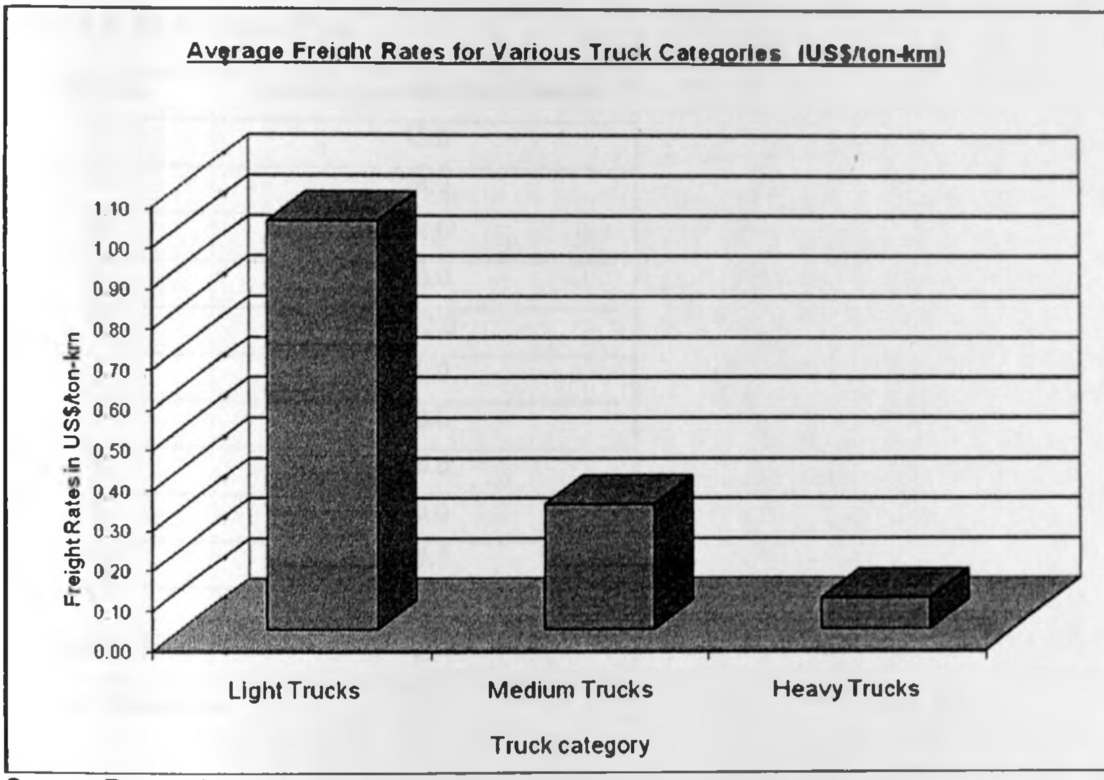
Source: Researcher

It was observed that freight rates are highest for light trucks and lowest for heavy trucks with a mean of US$0.9564/ton-km and US$0.0773/ton-km respectively. This is due to the nature of goods transported. In a number of cases, light trucks transport loose cargo, and therefore more time is taken to load and off load. Whereas, heavy trucks transport containerized cargo that are easier to load and off load.

Similarly, it was observed that the determinants of freight rate for light trucks had the highest standard deviation as compared to heavy trucks, and was recorded as 0.2237 and 0.0157 respectively. These findings suggest that factors influencing freight rates for light tracks vary while those for heavy trucks do not. In addition, the payload for light trucks varies, due to the fact that there was a tendency by the owners to charge more to recover their losses.

Figure 5.5 shows the freight rates for various truck categories. It clearly depicts that there is substantial difference in the freight rates (US$/ton-km) charged by owners of heavy trucks and light trucks.

Figure 5-5 Freight Rates for Various Truck Categories



Source: Researcher

5.4 Travel Time

Data on truck travel time was obtained for 11 different trucks (See Table 5.4 below). These consisted of 7 heavy trucks, 2 medium trucks and 2 light trucks and comprised of 6.6% of the total number of trucks whose data were gathered from the transport companies. The travel times obtained from the Global Positioning System were analyzed for Nairobi to Mombasa. This was based on the fact that all trucks travelling from Malaba, Busia, Kisumu or Eldoret passed through Nairobi and eventually to Mombasa. Although vehicles travelling to Busia, Malaba, Eldoret and Kisumu passed through Mau Sumit, the travel time data for Mau Summit-Mombasa section was not analysed since it would not capture the time for vehicles that did not travel beyond Nairobi. The data recorded by the GPS equipment was downloaded using Ozi explorer and analyzed in Microsoft Excel. In order to reduce the data volume and errors, the data was cleaned and sorted prior to the analysis. The results of the travel time obtained from the GPS are shown in Table 5.4 below.

Table 5-4: Truck Travel Time

Sample	Average journey time in Hours
1	15.0
2	24.0
3	24.0
4	20.0
5	112.0
6	20.0
7	30.0
8	78.0
9	30.0
10	15.0
11	34.0
Av. Travel Time	**37**

Source: Researcher

5.4.1 Cargo Time Value

The average travel time was used to calculate the value of cargo time (in US$/v-km) based on an average cargo value of US$400 per ton. Besides, a cost a rate of return on working capital of 15 percent was adopted (World Bank PAD, 2004). This was confirmed from clearing and forwarding firms sampled in Nairobi and considered accepTable. The averaged cargo value was divided by the average trip mileage and travel time in hours as shown below.

$$\text{Time value of Cargo} = \frac{\text{Rate of return} \times \text{Cargo value}}{\text{Annual mileage} \times \text{Travel time}} \quad \ldots\ldots\ldots\ldots (5.9)$$

5.4.2 Passenger Time Value

Computations were also made for the passenger time value (US$/v-km) by dividing the crew cost by the average travel time (hours) per trip.

$$\text{Passenger time value} = \frac{\text{Crew Cost}}{\text{Average travel time per trip}} \quad \text{..........} \quad (5.10)$$

5.5 Calibration of the FTCPM

5.5.1 Model for Estimating Freight Rates

The Freight Transport Cost Prediction Model (FTCPM) was formulated on the basis of independent and dependent variables in which freight rate (US$/ton-km) was considered to be predicTable, due to the following independent variables (see section 3.3);

- Vehicle operating costs,
- Distance to destination,
- Cargo factor,
- Travel time,
- Truck model and
- Whether the truck will have a return cargo or not.

The FTCPM was formulated as follows;

Freight Rate (US$/ton-km) $= aD + bK_R + cK_T + dQ + eVOC + fB + \varepsilon$ .... *(5.11)*

(See section 3.4 for definition of the model variables).

The vehicle operating cost was computed in US$/v-km, and the distance calculated in kilometres. Likewise, the cargo factor was calculated as a ratio of the cargo weight to the gross vehicle weight. Moreover, travel time was calculated as time allowed in days to the destination and back to the origin. Truck models considered in the FTCPM include Renault, Mercedes, Isuzu, Nissan, Mitsubishi and others which were coded as [1], [2], [3], [4], [5] and [6] respectively. The return cargo was grouped in two categories: whether a truck will have a return cargo [0] denoting "Yes", and [1] denoting "No" respectively. The FTCPM was formulated by undertaking a multiple regression analysis of the data. A summary Table of all the variables used to develop the FTCPM is shown in appendix D.

5.5.2 Light and Medium Trucks

The coefficients of the Freight Transport Cost Prediction Model for light and medium trucks were obtained from regression analysis and computed at a 95% level of confidence, shown in Table 5.5 below.

Table 5-5: FTCPM Coefficients for Light/Medium Trucks

Variable	*Constant*	*Coefficients*
Intercept	ε	3.07109
Distance to Destination (km)	*a*	-0.00245
Truck Model	*b*	0.03347
Cargo Factor	*d*	-3.28864
Time Allowed	*c*	-0.34995
Return Cargo	*f*	1.00714
VOCs (US$/v-km)	*e*	0.82349

Source: Researcher

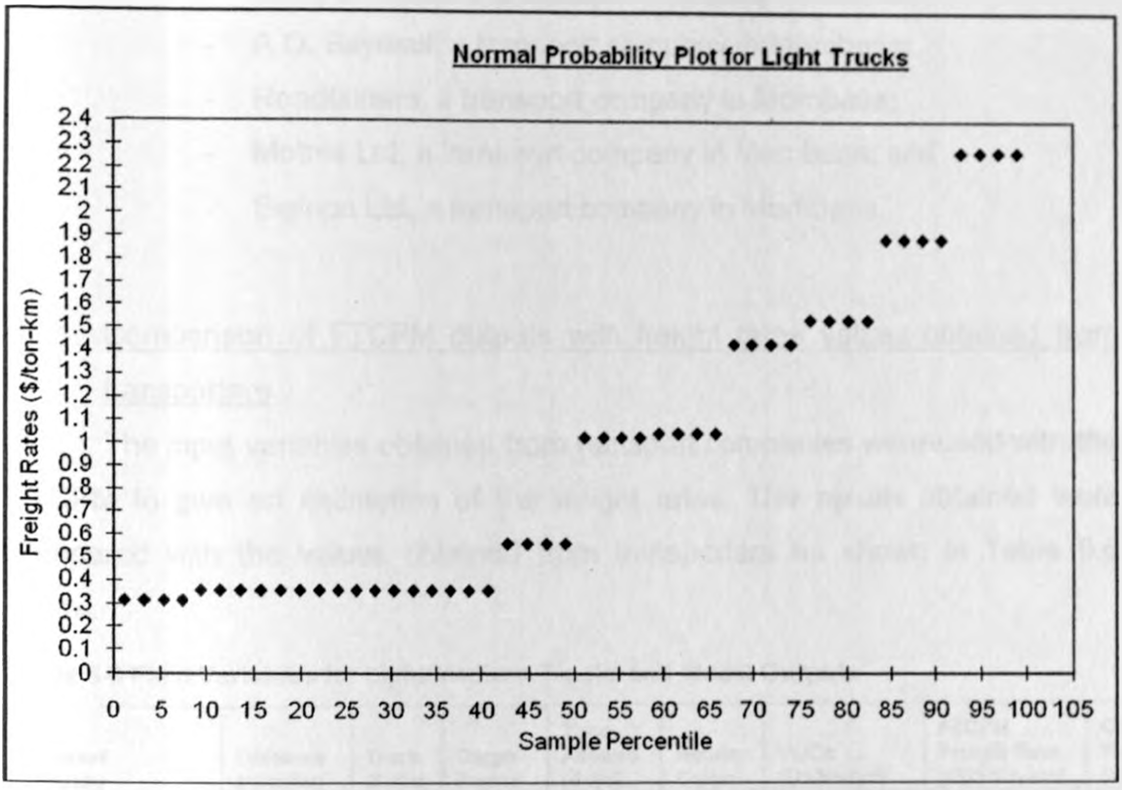
Using the above coefficients, the model becomes;

Freight Rate (US$/ton-km)

$$= -0.00245D + 0.03347K_R - 0.34995K_T - 3.28864Q + 0.82349VOC + 1.00714B + 3.07109 \quad \ldots\ldots (5.12)$$

Figure 5.6 shows a probability plot for light and medium trucks. It shows the probability of obtaining any random value of freight rate using the FTCPM. From the graph, it is noted that there was approximately a 43% chance that a predicted freight rate will be less than US$0.4/ ton-km. However, there was also a 50% chance that a predicted rate would be less than US$0.6/ton-km. It also shows that the maximum possible rate was US$2.3/ton-km, whereas the minimum possible rate was US$0.312/ton-km.

Figure 5-6 Normal Probability Plot for Light/Medium Trucks



Source: Researcher

5.5.3 Validity of the FTCPM for Light/Medium Trucks

In validating the FTCPM (equation 5.12), the researcher collected current freight rates from five different established transport companies and compared these with the output values which were generated using the FTCPM. The input variables obtained from transport companies for purposes of the validation included:

- Distance travelled;
- Truck model;
- Cargo weight transported;
- Travel time;
- Availability of return cargo;
- VOCs

The five companies whose freight rates were used for validation of the FTCPM outputs include:

- Multiple Hauliers, a transport company in Nairobi;
- A.O. Bayusuf, a transport company in Mombasa;
- Roadtainers, a transport company in Mombasa;
- Motrex Ltd, a transport company in Mombasa; and
- Siginon Ltd, a transport company in Mombasa.

1. Comparison of FTCPM outputs with freight rates values obtained from transporters

The input variables obtained from transport companies were used with the FTCPM to give an estimation of the freight rates. The results obtained were compared with the values obtained from transporters as shown in Table 5.6 below.

Table 5-6 Field Variables for Light/Medium Trucks and Model Outputs

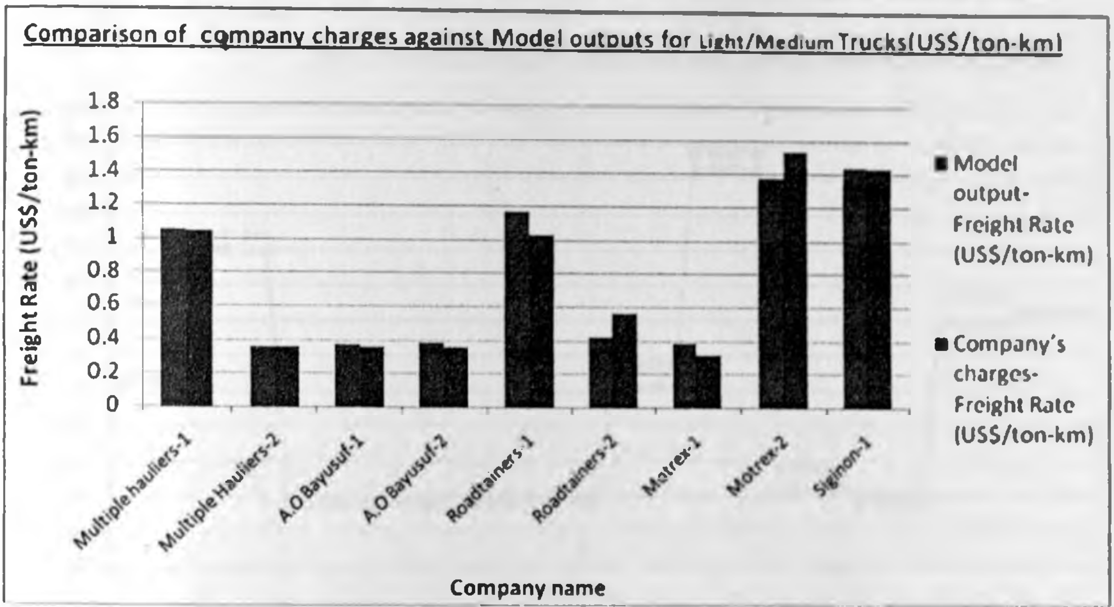
Transport Company	Distance travelled	Truck Model	Cargo Factor	Time Allowed (days)	Return Cargo	VOCs (US$/v-km)	FTCPM Freight Rate (US$/ton-km)	Company's Freight Rate (US$/ton-km)
Multiple hauliers-1	490	4	0.467	2	1	0.33202	1.048908	1.041233
Multiple Hauliers-2	490	5	0.497	2	0	0.79587	0.357551	0.355543
A.O Bayusuf-1	490	5	0.497	2	0	0.79587	0.370492	0.355543
A.O Bayusuf-2	490	5	0.497	2	0	0.79587	0.383432	0.355543
Roadtainers-1	155	3	0.6	1	0	0.84168	1.161239	1.024066
Roadtainers-2	155	3	0.85	1	0	0.94051	0.420469	0.557642
Motrex-1	195	2	0.727	2	0	0.99275	0.385545	0.3125
Motrex-2	240	3	0.417	2	0	1.04197	1.370628	1.533716
Siginon-1	240	5	0.417	2	0	1.04578	1.440701	1.428571

In column 6, 1=return cargo, 0=no return cargo

Source: Researcher

Values of the freight rates tabulated in the last two columns of Table 5.6 are presented graphically as shown in Figure 5.7.

Figure 5-7 Comparison of company charges to Model outputs for Light/Medium Trucks

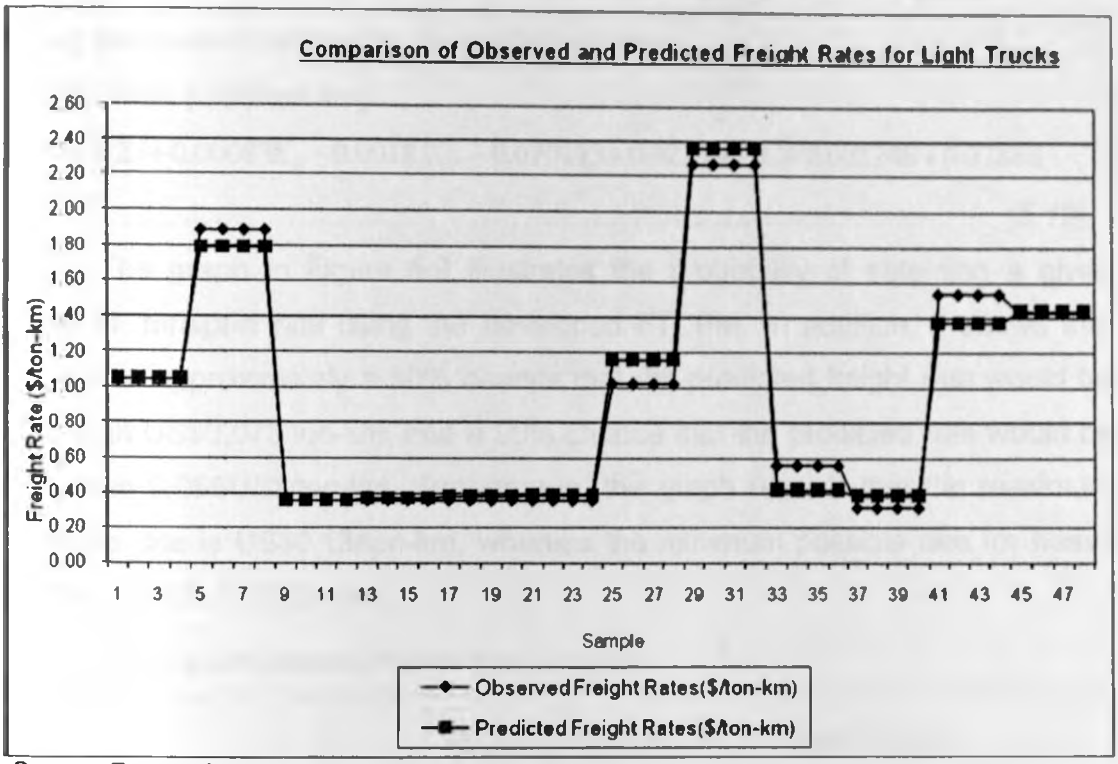


Source: Researcher

While the values of the FTCPM outputs and the companies' rates are not exact, the study argues that they are within accepTable limits of error attribuTable to calibration errors. Findings revealed that the FTCPM outputs are almost at par with the actual freight rates obtained from the field. The difference in the freight rates obtained can be explained in the variation of the residual factor of the model equation.

Further, in order to check the validity of the FTCPM developed in section 5.5.2 for light/medium trucks, the FTCPM (equation 5.12) was used to calculate values of freight rates (US$/ton-km). This was done for a set of the input variables and compared with the actual freight rates (US$/ton-km) obtained from the field. The predicted values of freight rates (US$/ton-km) and the observed values of freight rates (US$/ton-km) were graphed as shown in Figure 5.8, which shows that there is little difference between the observed freight rate and the predicted freight rate.

Figure 5-8 Comparison of Observed and Predicted Rates for Light/Medium Trucks



Source: Researcher

5.5.4 Heavy Trucks

The coefficients of the Freight Transport Cost Prediction Model for heavy trucks were obtained from the regression analysis which was carried out at 95% level of confidence (see Table 5.7).

Table 5-7: FTCPM Coefficients for Heavy Trucks

	Coefficient	*Coefficients*
Intercept	ε	0.07888
Distance to Destination (km)	*a*	0.00002
Truck Model	*b*	0.00083
Cargo Factor	*d*	-0.07011
Time Allowed	*c*	-0.00181
Return Cargo	*f*	0.00574
VOCs(US$/v-km)	*e*	0.02134

Source: Researcher

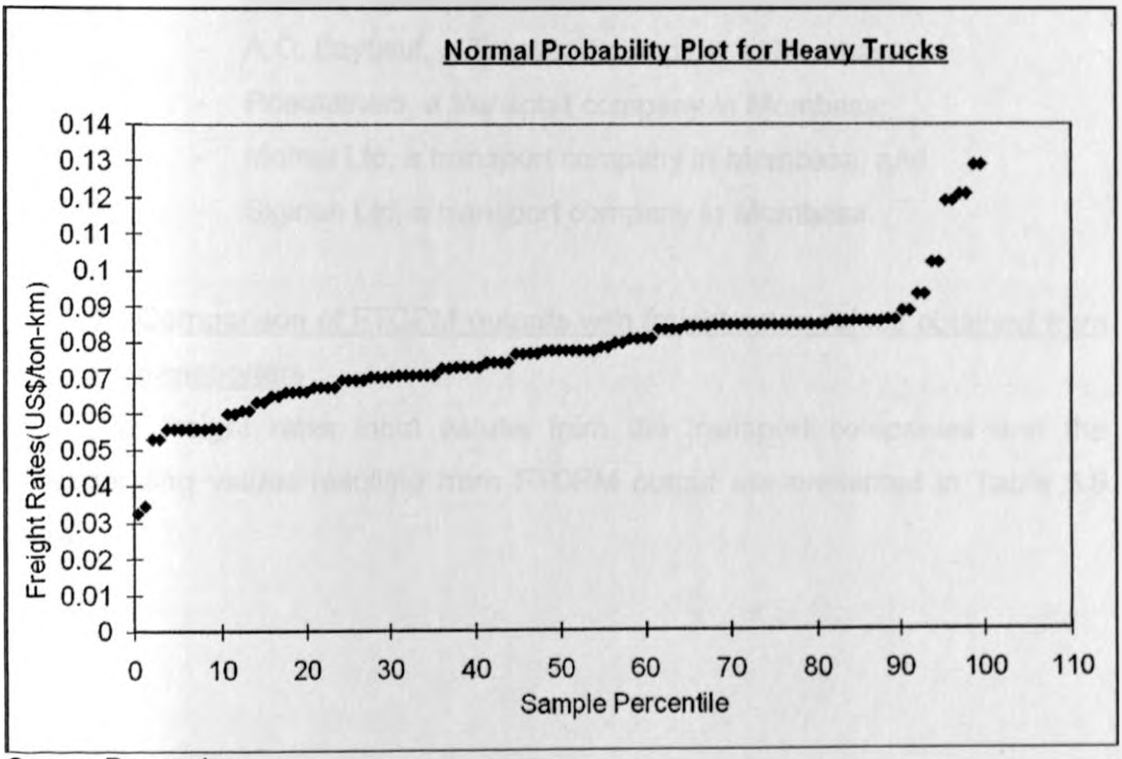
Using the above coefficients, the model becomes;

Freight Rate (US$/ton-km)

$$= 0.00002D + 0.00083K_R - 0.00181K_T - 0.07011Q + 0.02134VOC + 0.00574B + 0.07888 \quad \text{.......... (5.13)}$$

The graph in Figure 5.9 illustrates the probability of obtaining a given value of transport rate using the developed FTCPM. In addition, it shows that there was approximately a 50% chance that the predicted freight rate would be less than US$0.075/ton-km, and a 90% chance that the predicted rate would be less than 0.085US$/ton-km. Furthermore, the graph reveals that the maximum possible rate is US$0.13/ton-km, whereas the minimum possible rate for heavy trucks is US$0.0312/ton-km.

Figure 5-9 Normal Probability Plot for Heavy Trucks



Source: Researcher

5.5.5 Validity of the FTCPM for Heavy Trucks

In validating the FTCPM (equation 5.13), the researcher collected current freight rates from five different established transport companies and compared these with the outputs values obtained using the FTCPM. Data from the companies included the following;

- Distance travelled;
- Truck model;
- Cargo weight transported;
- Travel time;
- Availability of return cargo;
- VOCs

To validate the model output, data was obtained from the following companies:

- Multiple Hauliers, a Transport company in Nairobi;
- A.O. Bayusuf, a Transport company in Mombasa;
- Roadtainers, a transport company in Mombasa;
- Motrex Ltd, a transport company in Mombasa; and
- Siginon Ltd, a transport company in Mombasa.

1. Comparison of FTCPM outputs with freight rates values obtained from transporters

The freight rates input values from the transport companies and the corresponding values resulting from FTCPM output are presented in Table 5.8 below:

Table 5-8: Comparison of company charges to FTCPM outputs for Heavy Trucks

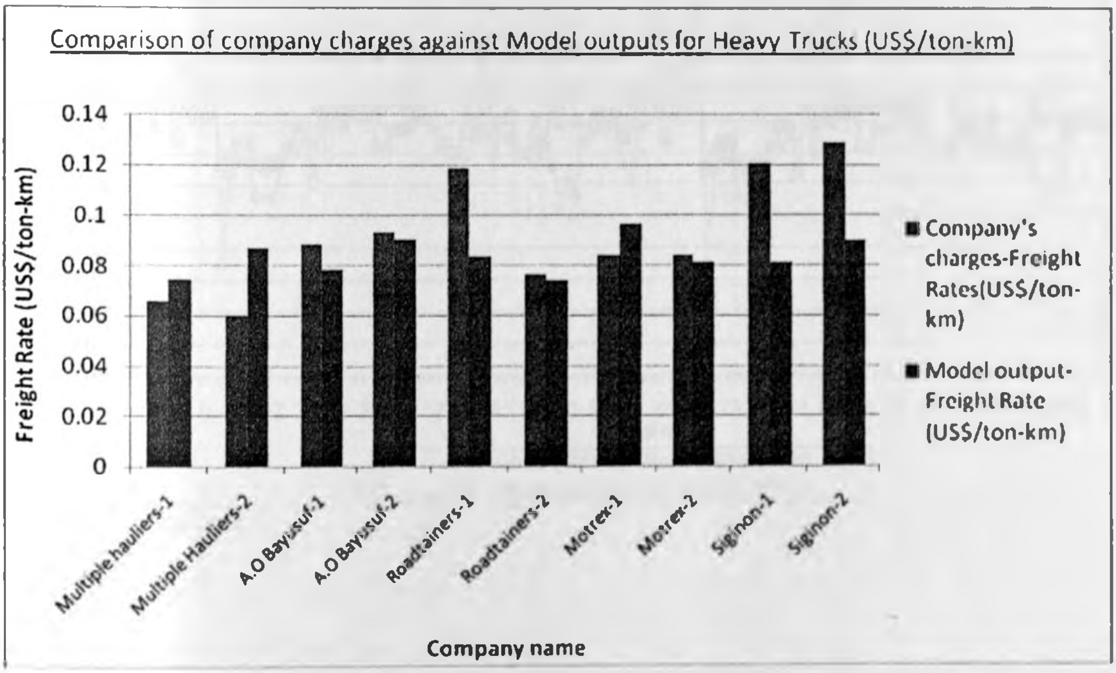
Transport Company	Distance travelled (km)	Truck Model	Cargo Factor	Time Allowed (days)	Return Cargo	VOCs (US$/v-km)	FTCPM output (US$/ton-km)	Companies' Freight Rates (US$/ton-km)
Multiple Hauliers-1	490	2	0.59	2	1	1.0243	0.074756	0.0661
Multiple Hauliers-2	1,200	2	0.60	7	1	1.2418	0.086936	0.0600
A.O Bayusuf-1	700	2	0.60	6	1	1.3323	0.078638	0.0886
A.O Bayusuf-2	1,130	2	0.61	6	1	1.4478	0.090672	0.0932
Roadtainers-1	1,245	2	0.58	3	1	0.6312	0.083489	0.1190
Roadtainers-2	700	2	0.62	4	1	1.0035	0.074156	0.0765
Motrex-1	240	2	0.59	2	1	2.3424	0.096864	0.0843
Motrex-2	490	2	0.59	3	1	1.4253	0.081506	0.0843
Siginon-1	545	2	0.58	5	1	1.4983	0.081531	0.1209
Siginon-2	545	6	0.55	5	1	1.6247	0.090079	0.1290

In column 6, 1=return cargo, 0=no return cargo

Source: Researcher

The values documented in the last two columns of Table 5.8 are presented graphically in Figure 5.10.

Figure 5-10 Comparison of company charges to Model outputs for Heavy Trucks

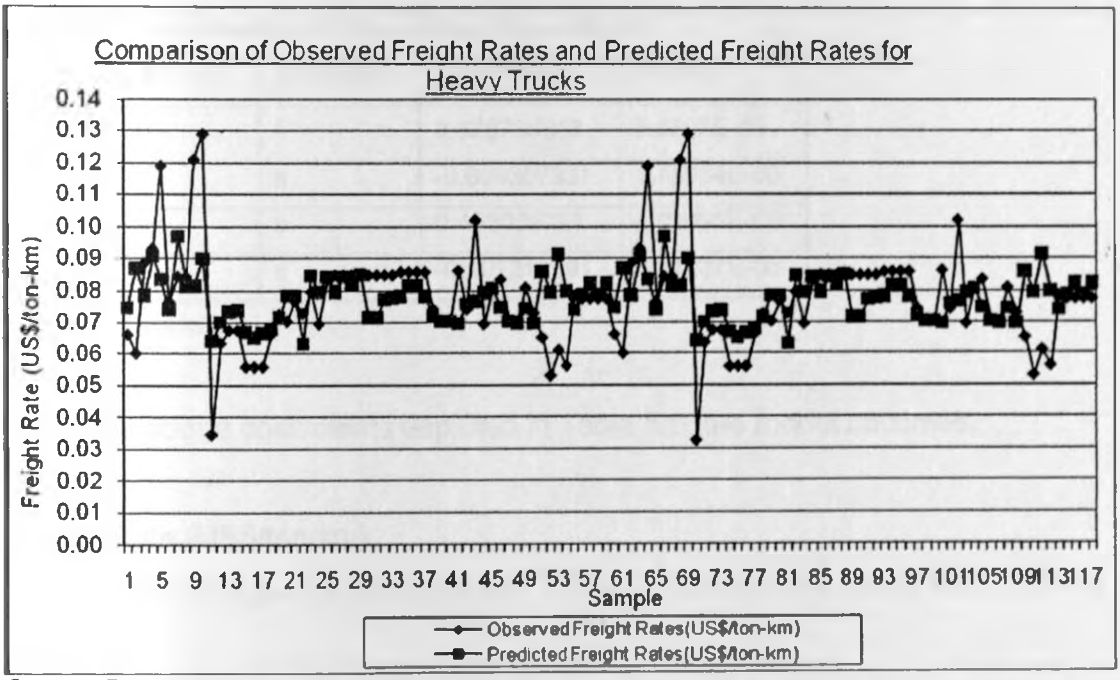


Source: Researcher

The study established that the FTCPM outputs are close to the actual values of freight rates obtained during the field investigations. Moreover, the difference in the values of freight rates can be attributed to the variation in the residual factor of the model equation.

Further, in order to check the validity of the FTCPM developed in section 5.3.5 for heavy trucks, the model (equation 5.13) was used to calculate values obtained for freight transport cost (US$/ton-km). This was done for a set of input variables and comparisons made with the corresponding observations of the transport cost (US$/ton-km). Additionally, the predicted values of freight rates (US$/ton-km) and the observed values of freight rates (US$/ton-km) were plotted on a graph shown in Figure 5.11. Findings revealed that the model formulated (equation 5.13) can be used to estimate freight rates reliably.

Figure 5-11 Comparison of Observed and Predicted Freight Rates for Heavy Trucks



Source: Researcher

5.6 Model for Predicting Freight Rates

The FTCPM discussed in section 5.5 above is used to estimate the freight rates. Besides, a second model has also been developed to project future freight rates in the years to come. This is based on the relationship between freight rates and VOCs and is formulated as shown in equation 5.14 below:

Freight Rate (US$/ton-km) $= aVOCs + bVOCs^2 + cVOCs^3 + \varepsilon$ .... *(5.14)*
(see section 3.4 for variable definitions)

A multiple linear regression analysis was done at 95% level of confidence to obtain the coefficients shown in Table 5.9 below:

Table 5-9: Coefficients for VOCs-Freight Rates Model

Variable(US$/v-km)	*Coefficient*	*Coefficients*	*P-value*
Intercept	ε	0.328709363	6.4303E-09
VOCs	a	-0.609357331	1.75984E-06
$VOCs^2$	*b*	0.453009221	1.02095E-06
$VOCs^3$	*c*	-0.101217201	1.21237E-06

Source: Researcher

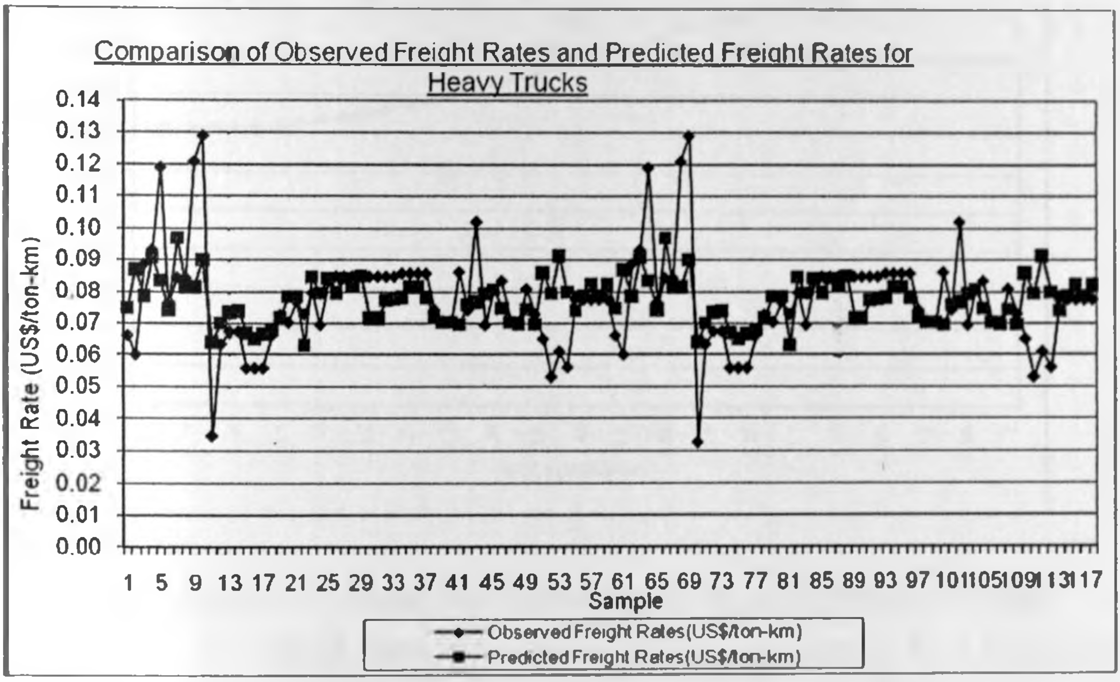
Using the above coefficients depicted in Table 5.9, the model becomes;

Freight Rate (US$/ton-km)
$= -0.609357331VOCs + 0.453009221VOCs^2 - 0.101217201VOCs^3 + 0.328709363$ .... *(5.15)*

Hence, from the equation, it was established that the second degree of vehicle operating costs, is more significant than the first and third degrees since it had the least p-value. This implies that the rates increase when the square of the VOCs increases, and reduce with the corresponding increase in first and third degrees of VOCs, as evidenced by the variable coefficients (See Appendix E).

Figure 5.12 shows a relation between the observed and calculated freight rates using the multiple linear exponential equation 5.15. The aforementioned equation was used to relate the freight rates to vehicle operating costs. Findings established that the calculated freight rates were within an acceptable range, in comparison to the observed freight rates. Similarly, the statistical p-values given in Table 5.9 are below 0.05 which implies that the variables are all significant in the model.

Figure 5-12 Plot of Freight Rates Sensitivity to VOCs

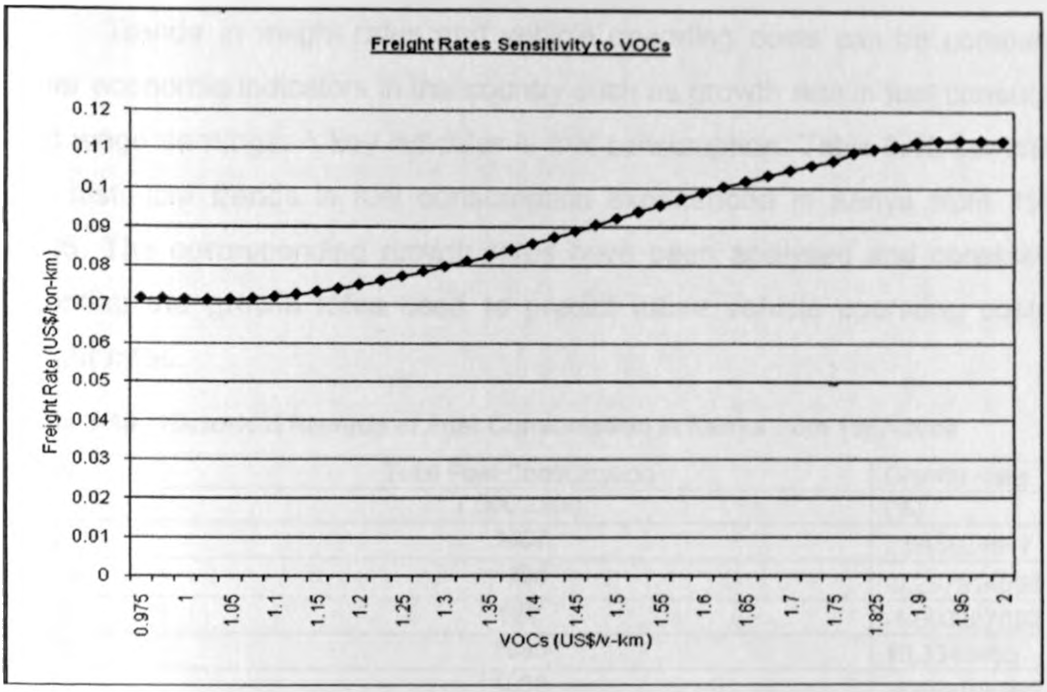


Source: Researcher

5.6.1 Relationship between VOCs and Freight Rates

The model developed in section 5.6 (see equation 5.15) was used to plot a graph relating VOCs and freight rates as demonstrated in Figure 5.13, which shows that freight rates generally increase with the corresponding rise in vehicle operating costs within a given range.

Figure 5-13 Variation of Freight Rates with VOCs



Source: Researcher

From Figure 5.13 above, the following general observations are made;

- Freight rates increases as VOCs increase up to a maximum value of US$1.95/v-km.
- Freight rates become stable when VOCs exceeds US$1.95/v-km. This is the maximum value obtained beyond which freight rates are not directly related to VOCs.
- Further reduction of VOCs below US$1.05/v-km, does not cause a proportional reduction in freight rate.
- Freight rates depend on VOCs within a specific range, beyond which VOCs become insignificant.

5.7 Forecasting Freight Rates

The model developed in section 5.6 (see equation 5.15) was used to predict annual trends in freight rates, based on the relationship between freight rates and VOCs as discussed in the following section.

5.7.1 Economic and General Growth Indicators

Trends in freight rates and vehicle operating costs can be compared to other economic indicators in the country such as growth rate in fuel consumption and wage earnings. A key indicator is fuel consumption. Table 5.10 summarizes the historical trends in fuel consumption experienced in Kenya from 1997 to 2006. The corresponding growth rates have been analysed and considered in adopting the growth rates used to predict future vehicle operating costs and freight rates.

Table 5-10: Historical Records of Fuel Consumption in Kenya from 1997-2006

Year	Total Fuel Consumption ('000 tons)	Growth Rate (%)
1997	1007	2.545824847
1998	1004	-0.297914598
1999	987	-1.693227092
2000	1089	10.3343465
2001	1038	-4.683195592
2002	1500	44.50867052
2003	2675	78.33333333
2004	2701	0.971962617
2005	2762	2.258422806
2006	2810	1.737871108
Max Reasonable Annual Growth Rate (%) (2002-2006)		2.26
Min Reasonable Annual Growth Rate (%) (2002-2006)		1.74
Mean Reasonable Annual Growth Rate (%) (2002-2006)		0.97

Source: KNBS, 2007

The study also established that in 2006, employment in private sector increased by 4.8 per cent, while average wage earnings rose marginally by 0.2 per cent (KNBS, 2007)

5.7.2 Yearly Vehicle Operating Costs Forecast

Fuel and lubricant consumption contribute to 50% of vehicle operating costs along the Northern Corridor road (see also section 5.2.8). Other components of vehicle operating costs include crew, maintenance/labour, insurance, tyre and depreciation costs. It was assumed that the high rates of fuel costs and the rise in wage earnings experienced in Kenya from 1997 to 2006 resulted in to the rapid increase in vehicle operating costs. Table 5.10 gives a summary of the fuel consumption growth rates computed to predict VOCs, through the application of an exponential equation adopted from (O'Flaherty, 2005) as follows:

$$VOC_t = VOC_0(1+r)^t; \quad (5.16)$$

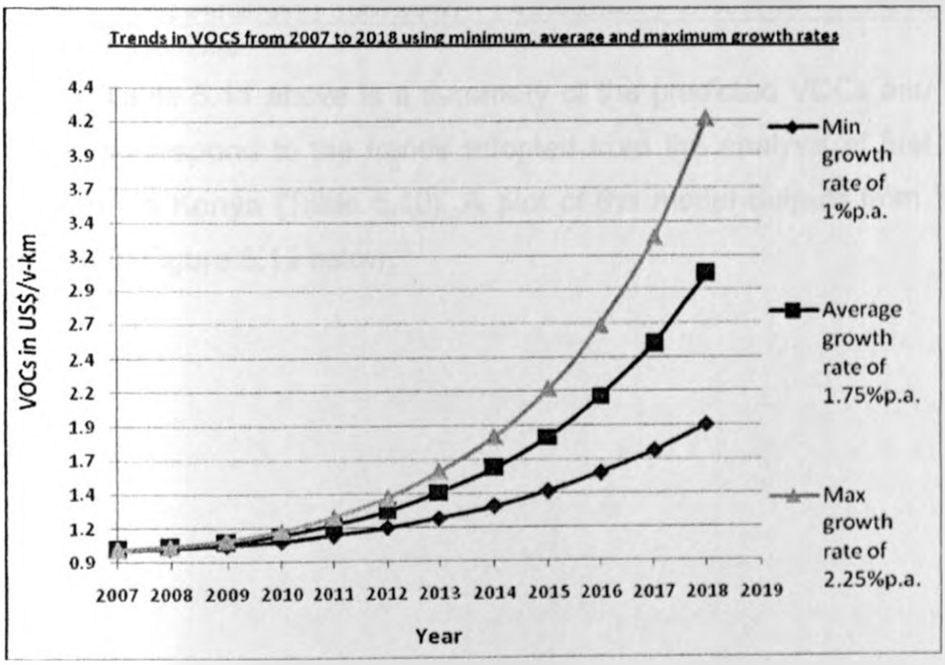
Where, VOC_t = VOC in a future year after time t;

VOC_0 = VOC at a given time t=0;

r = the annual growth rate as a fraction.

Using equation 5.16, VOCs was projected for the next ten years after 2007. Figure 5.14 illustrates the trends in the predicted VOCs using minimum, average and maximum growth rates (see Table 5.10).

Figure 5-14 Predicted Vehicle Operating Costs for the Period 2007-2018



Source: Researcher

5.7.3 Predicting Freight Rates

After projecting vehicle operating costs as discussed in section 5.7.2 and applying equation 5.15 (see section 5.6), freight rates have been projected for the next ten years from 2007 as shown in Table 5.11 below.

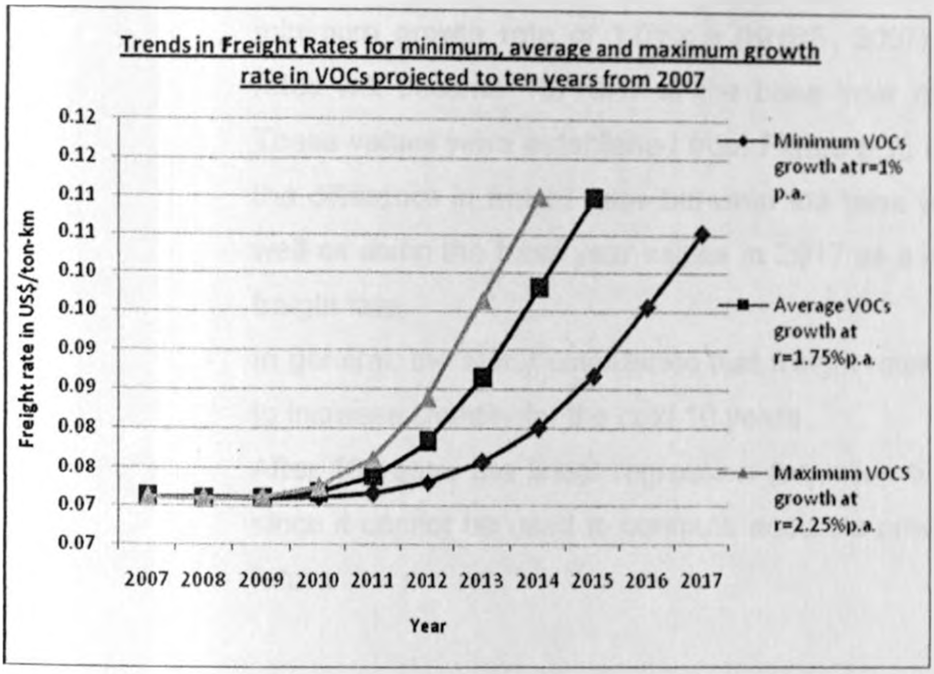
Table 5-11: Summary of Predicted VOCs and Freight Rates

r=Growth rate	Minimum r=1% p.a.		Average r=1.75%p.a.		Maximum r=2.25%p.a.	
Year	VOCs (US$/v Km)	Freight Rate (US$/ton-km)	VOCs (US$/v- Km)	Freight Rate (US$/ton-km)	VOCs (US$/v- Km)	Freight Rate (US$/ton-km)
2007	0.99	0.071228994	0.99	0.071228994	0.99	0.071228994
2008	0.9999	0.071144753	1.00683	0.071103242	1.01178	0.071082265
2009	1.01999799	0.071063178	1.041353194	0.07110323	1.056788022	0.0712102
2010	1.050904949	0.071161882	1.095370176	0.071748046	1.12808174	0.072486225
2011	1.093575904	0.071714817	1.171776338	0.073837331	1.230677194	0.076236699
2012	1.149359266	0.073094607	1.27482182	0.078402538	1.372140653	0.084010486
2013	1.220068021	0.075760288	1.410506871	0.086441645	1.563522036	0.096521467
2014	1.308078057	0.080206654	1.587164264	0.098042713	1.82079175	0.110058671
2015	1.416461096	0.086826333	1.816308017	0.109905917	2.167042573	0.105524612
2016	1.54916264	0.095585134	2.113869031	0.108785839	2.635879215	0.016298095
2017	1.711239328	0.105309606	2.502001728	0.054618993	3.276683268	-0.365041755
2018	1.909175552	0.11218028	3.011744234	-0.162537742	4.162884077	-1.659427655
2019	2.151306798	0.106606384	3.68696931	-0.832858587	5.405116598	-5.713557414
2020	2.448387811	0.066800427	4.590308886	-2.71304139	7.172436505	-18.08422249

Source: Researcher

Table 5.11 above is a summary of the predicted VOCs and freight rates, which correspond to the trends adopted from the analysis of fuel consumption patterns in Kenya (Table 5.10). A plot of the model outputs from Table 5.11 is shown in Figure 5.15 below.

Figure 5-15 Predicted Freight Rates for the Period 2007-2017



Source: Researcher

In assuming 2007 as the base year for freight rates for this research, the following general observations were made from Figure 5.15;

- If fuel consumption and wage earnings continue to grow at the maximum growth rate of 2.25%p.a (KNBS, 2007), then freight rates will become 154.51% of the base year rates in 2014. These values were established from Figure 5.15 by calculating the difference in freight rates between the base year value, and using the base year values in 2014 as a percentage of the freight rate.
- If fuel consumption and wage earnings continue to grow at the average growth rate of 1.75%p.a (KNBS, 2007), then freight rates will become 154.30% of the base year rates in 2015. These values were established from Figure 5.15 by calculating the difference in freight rates between the base year value, as well as using the base year values in 2015 as a percentage of freight rate.

- If fuel consumption and wage earnings continue to grow at the minimum growth rate of 1.0%p.a (KNBS, 2007), then freight rates will become 157.49% of the base year rates in 2017. These values were established from Figure 5.15 by calculating the difference in freight rates between the base year value, as well as using the base year values in 2017 as a percentage of freight rate.
- In general, the study established that freight rates will continue to increase steadily for the next 10 years.
- After 10 years, the linear regression (equation 5.15) is limited since it cannot be used to compute accurate predictions in the future.

6 STATISTICAL TESTS AND APPLICATION OF THE FTCPM

6.1 Introduction

This chapter presents the assessments made of the model, its reliability and accuracy based on statistical parameters, which were used to establish the most significant variables of the Freight Transport Cost Prediction Model. Illustrations of how the FTCPM can be applied are also discussed.

6.2 Statistical Tests

In developing the FTCPM, one of the assumptions made was that the model components are independent of one another and that the residuals are normally distributed around the sample mean (see section 3.5). This assumption is evaluated using correlation coefficient which shows the degree of relationship between the variables and is given by the square root of the sum of model residual values (Andy, 2005). Table 6.1 below gives the correlation coefficients.

Table 6-1: Correlation Coefficients for FTCPM Variables

Truck category	Variable	Distance travelled (km)	Truck Model factor	Cargo Factor (ratio of cargo weight to GVW)	Time Allowed (days)	Return Cargo	Total VOCs (US$/v-km)
Light/ Medium Trucks	Distance to Destination (km)	1.0000	-	-	-	-	-
	Truck Model factor	0.4287	1.0000	-	-	-	-
	Cargo Factor (ratio of cargo weight to GVW)	-0.4304	-0.6210	1.0000	-	-	-
	Time Allowed (days)	0.4606	0.4804	-0.6760	1.0000	-	-
	Return Cargo	-0.1363	0.3721	-0.2426	0.2582	1.0000	-
	Total VOCs(US$/v-km)	-0.4345	-0.3832	0.2493	-0.1573	-0.7146	1.0000
Heavy Trucks	Distance to Destination (km)	1.0000	-	-	-	-	-
	Truck Model	0.0623	1.0000	-	-	-	-
	Cargo Factor	0.2129	0.0609	1.0000	-	-	-
	Time Allowed	0.8548	0.0259	0.0483	1.0000	-	-
	Return Cargo	-0.1963	0.1380	0.1109	-0.2947	1.0000	-
	Total VOCs(US$/v-km)	-0.1028	-0.0390	0.3325	0.0124	0.1817	1.0000

Source: Researcher

Arising from the above findings, the following observations are made:

- In light/medium trucks, there was a strong positive correlation between time allowed (days) and distance travelled (km), resulting in a value of 0.4606. This indicates that 46.06% of the changes evidenced in travel time are caused by the changes between the travelled distances. Similarly, there was a correlation between truck model and time allowed, with a resulting value of 0.4804. This implies that 48.04% of changes in travel time are due to the truck model used. In addition, these findings are as a result of the travel speed and manufacturer's specifications. From these above-mentioned correlations, the study established that the most significant factor influencing freight transport rates for Light/medium trucks include the distance to destination, travel time and truck model.

- A positive correlation between the distance covered (km) and time allowed (days), was observed from heavy trucks, with a resultant value of 0.8548. These findings suggest that 85.48% of changes in travel time are caused by the change in travelled distances. Likewise, there was also a strong positive correlation between the vehicle operating costs and cargo factor, which had a resulting value of 0.3325. As a result, the study argues that 33.25% of changes in vehicle operating costs are due to the weight of cargo transported. From these aforementioned correlations it is evident that the most significant factor influencing freight transport rates by heavy trucks are VOCs, distance travelled, cargo weight and travel time.

Table 6.2 below gives a summary of both standard errors and p-values for the light/medium and heavy trucks, including the variable used in FTCPM. The findings in the Table show that freight rates in light/medium trucks depend on the distance covered (km), cargo factor and whether the truck had return cargo or not. This was evidenced by the parameters with the minimum p-values.

Table 6-2: Statistical Outputs for FTCPM

Item	Light/Medium Trucks		Heavy Trucks	
	Standard Error	*P-value*	*Standard Error*	*P-value*
Intercept	0.26239	0.00000	0.01308	0.00000
Distance to Destination (km)	0.00031	0.00000	0.00001	0.00641
Truck Model	0.01798	0.06987	0.00085	0.33244
Cargo Factor	0.16881	0.00000	0.02382	0.00396
Time Allowed	0.08173	0.00011	0.00115	0.11840
Return Cargo	0.12962	0.00000	0.00298	0.05659
Total VOCs(US$/v-km)	0.27053	0.00407	0.00557	0.00021

Source: Researcher

However, for heavy trucks, the most significant variable in determining freight rates were the vehicle operating cost, and cargo factors respectively. This was established by the variables having the minimum p-values. It is recommended that the R-square value should range between 0 and 1 (Andy, 2005). A model whose R-Square value has a level of significance of less than 0 or greater than 1 is trivial in predicting the dependent variable. The R-square values shown in Table 6.3 below were established for the FTCPM and fall within the recommended range.

Table 6-3: Regression Statistics

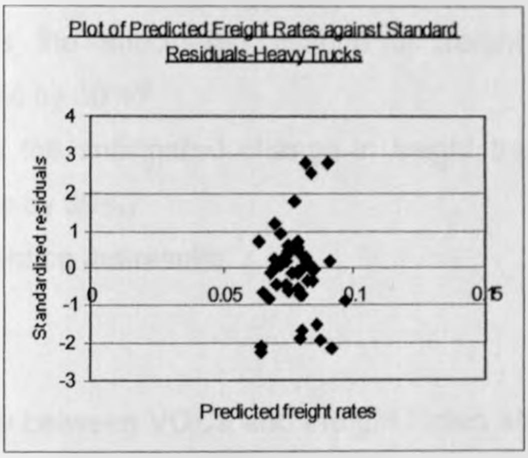
Regression Statistics	Truck	
	Light/Medium	Heavy
R Square	0.9826	0.2022
Standard Error	0.0938	0.0144

Source: Researcher

6.3 Checking Assumptions

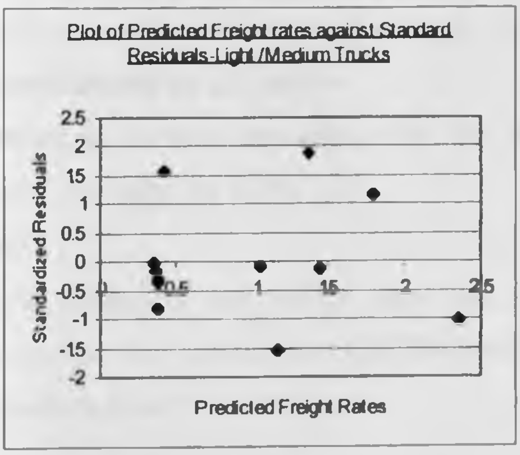
Multiple linear regressions assume a linear relation between the independent and dependent variables. According to Andy (2005), this assumption is checked by plotting the standardized residuals against the predicted values (Figures 6.1 and 6.2). In the likelihood that the plot produces a curved shape in the resultant graphs, then the assumption of a linear relationship between the independent and dependent variables is deemed invalid. Figures 6.1 and 6.2 show how points are randomly dispersed throughout the plot. This pattern is indicative of a situation in which the assumption of linearity holds (Andy, 2005).

Figure 6-1Checking Assumptions 1



Source: Researcher

Figure 6-2 Checking Assumptions 2



Source: Researcher

6.4 Application of the FTCPM

The following are illustrative problems of how the FTCPM can be applied:

Example 6.1:

For a given road section, the average VOCs for heavy trucks plying the road is US$1.22/v-km.

a) What is the anticipated change in freight rates if the VOCs decrease by 30%?
b) What is the anticipated change in freight transport rates if VOCs increase by 30%?
c) Comment on the results.

Solution:

Using the relationship between VOCs and Freight Rates shown in equation 5.15 (see section 5.6) the following conclusions are derived;

a) A reduction in vehicle operating cost by 30% would make the freight rates reduce by 8%; while
b) An increase in vehicle operating cost by 30% would make the freight rates increase by 0.7%.
c) Comment

It is generally expected that freight rates will increase when VOCs increase. However, it is not obvious that the freight rates would reduce when VOCs are reduced.

Example 6.2:

The three major roads in Kenya have the following hypothetical truck traffic characteristics as shown in Table 6.4 below:

Table 6-4: Truck Traffic Characteristics for Sample Roads in Kenya

Name	Class	LGV				HGV				Length (km)
		MAPL (tons)	Traffic Volume	Travel Time (hours)	VOCs (US$/v-km)	MAPL (tons)	Traffic Volume	Travel Time (hours)	VOCs (US$/v-km)	
M/Sumit-Kisumu	B1	5	805	19	1.232	34	2002	34	1.342	250
M/Sumit-Eldoret	A104	7	1050	21	1.02	32	2044	21	1.255	190
Mombasa-Malindi	B8	5	900	34	0.998	32	477	50	1.0321	350
Nakuru-Nyahururu	B5	5	1090	14	0.873	33	389	24	1.447	169

Source: Field Survey, 2007

MAPL-Maximum Allowable Pay Load

By rehabilitating the roads, the VOCs will reduce by 30% and the volume of traffic will increase by 8% p.a. On the other hand, if the road condition remains poor the traffic volume would increase at a rate of 5% p.a. Nonetheless, the rehabilitation of NC may take time due to the slow process in decision making. At any given time, only two roads can be rehabilitated using the fuel levy fund, thus making it challenging to draw a conclusion when using the FTCPM in section 5.5.2 and 5.5.4.

Solution:

Given the above-mentioned fleet characteristics, the resultant freight rates using FTCPM of section 5.5.2 and 5.5.4 are as shown in Table 6.5 below:

Table 6-5: Generated Freight Rates using FTCPM

Name	Class	Freight rates		Total Transport Cost in US$
		LGV	HGV	Rate*Distance*Truck volume*MAPL
M/Sumit-Kisumu	B1	3.092735394	0.073704	4366285.051
M/Sumit-Eldoret	A104	2.5603548	0.073606	4490275.93
Mombasa-Malindi	B8	2.445068734	0.069877	4224295.997
Nakuru-Nyahururu	B5	3.065542484	0.075804	2987971.077

Source; Field survey, 2007

MAPL-Maximum Allowable Pay Load

In the event that the roads are not improved, the new fleet characteristics reflecting the increase in VOCs and traffic volume would be as follows (see Table 6.6);

Table 6-6: Truck Traffic Characteristics on unimproved Road

Name	Class	LGV				HGV				Length (km)
		MAPL (tons)	Traffic volume	Travel time (hrs)	VOCs (US$/v-km)	MAPL (tons)	Traffic volume	Travel time (hrs)	VOCs (US$/v-km)	
M/Sumit-Kisumu	B1	5	932	19	1.426	34	2318	26	1.5535	250
M/Sumit-Eldoret	A104	7	1216	21	1.180	32	2366	21	1.4528	190
Mombasa-Malindi	B8	5	1042	34	1.155	32	552	50	1.1948	350
Nakuru-Nyahururu	B5	5	1262	14	1.010	33	450	24	1.6751	169

Source: Field survey, 2007
MAPL-Maximum Allowable Pay Load

From the unimproved road fleet characteristics outlined in the preceding section, using the FTCPM equations 5.12 and 5.13, the resulting freight rates would be as follows (Table 6.7);

Table 6-7: Freight Rates on unimproved road

Name	Class	Freight rates		Total Transport Cost in US$
		LGV	HGV	Rate*Distance*Truck volume*MAPL
M/Sumit-Kisumu	B1	3.25265221	0.078218	5329726.267
M/Sumit-Eldoret	A104	2.69275346	0.077827	5472826.163
Mombasa-Malindi	B8	2.57461174	0.073349	5147811.823
Nakuru-Nyahururu	B5	3.17886016	0.080671	3591996.584

Source; Field survey, 2007

MAPL-Maximum Allowable Pay Load

If the roads are improved, using FTCPM equation 5.12 and 5.13, the new fleet characteristics reflecting the reduction in VOCs and increase in truck volume would be as follows (Table 6.8);

Table 6-8: Truck Traffic Characteristics when Improved

Name	Class	LGV				HGV				Length (km)
		MAPL (tons)	Traffic volume	Travel time (hours)	VOCs (US$/v-km)	MAPL (tons)	Traffic volume	Travel time (hours)	VOCs (US$/v-km)	
M/Sumit-Kisumu	B1	5	1014	19	0.8624	34	2522	26	0.9394	250
M/Sumit-Eldoret	A104	7	1323	21	0.714	32	2575	21	0.8785	190
Mombasa-Malindi	B8	5	1134	34	0.6986	32	601	50	0.7225	350
Nakuru-Nyahururu	B5	5	1373	14	0.6111	33	490	24	1.0129	169

Source: Field survey, 2007

MAPL-Maximum Allowable Pay Load

From the above-mentioned improved road traffic characteristics, using the FTCPM equation 5.12 and 5.13, the resulting freight rates would be as follows (Table 6.9);

Table 6-9: Freight Rates when Improved

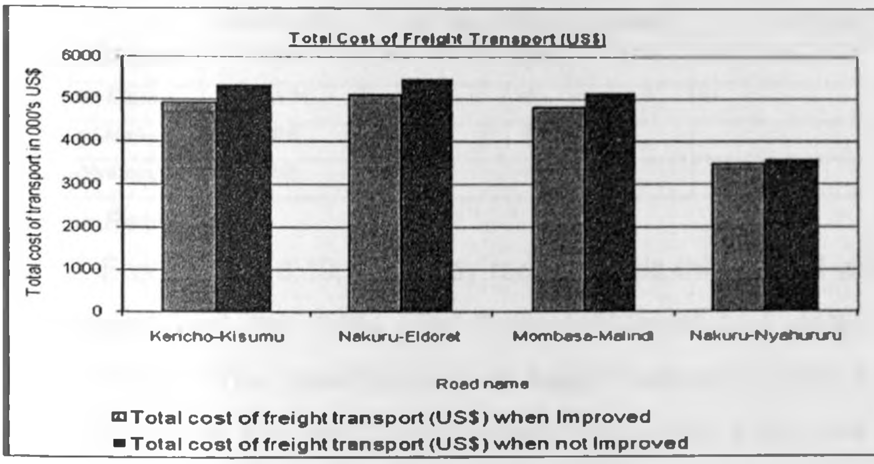
Name	Class	Freight rates		Total Transport Cost in US$
		LGV	HGV	Rate*Distance*Truck volume*MAPL
M/Sumit-Kisumu	B1	2.788373	0.065112	4930285.52
M/Sumit-Eldoret	A104	2.308367	0.065572	5087379.33
Mombasa-Malindi	B8	2.198516	0.06327	4787756.21
Nakuru-Nyahururu	B5	2.84987	0.06654	3488431.26

Source: Field survey, 2007

MAPL-Maximum Allowable Pay Load

Figure 6.3 below compares the total freight transport cost with and without improvement. It shows that by improving the roads there would be 7.1 percent reduction in the freight transport cost. This is attributed to improvement in road surface ride quality (IRI) which subsequently reduces VOCs and freight rates as depicted by equation 5.15.

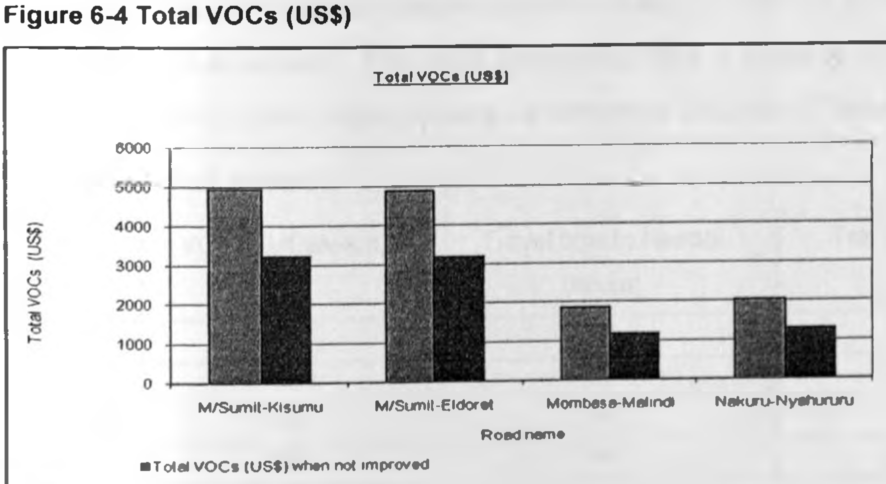
Figure 6-3 Total Costs of Freight Transport (US$)



Source: Researcher

Figure 6.4 below compares VOCs for the improved and unimproved road conditions. It shows that by improving the roads vehicle operating cost reduce by 34.1 percent. VOCs increases as road IRI increase (see section 2.8). From the graph, all the roads are observed to experience savings in vehicle operating cost after improvement.

Figure 6-4 Total VOCs (US$)



Source: Researcher

Considering the resultant characteristics of the road after improvement, in relation to total costs of cargo transport (Figure 6.3) and total VOCs (Figure 6.4), the order of priority, would be as follows (Table 6.10);

Table 6-10: Priority of Road Improvement

Name	Road classification	Order of Priority based on total cost of cargo transport	Order of Priority based on total VOCs of goods vehicle
M/Summit-Kisumu	B1	2	1
M/Summit-Eldoret	A104	1	2
Mombasa-Malindi	B8	3	4
Nakuru-Nyahururu	B5	4	3

Source: Researcher

From Table 6.10, the study recommends that the B1 road from M/Summit to Kisumu and the A104 road from M/Summit to Eldoret be prioritized for improvement. The consideration of freight transport costs is simply a way of ensuring that in the likelihood of scarce resources, funds are used where there would be maximum benefits.

Example 6.3:

A transporter has a tender to transport 30tons of cargo from Mombasa to Nairobi. The same transporter has another tender to transport 25tons of cargo from Mombasa to Eldoret. On arrival at Eldoret, he will have return cargo. Findings reveal that the distance from Mombasa to Nairobi and Eldoret are 500 and 960km respectively. The said transporter has 4 models of trucks with GVW of 54 and travel time characteristics as shown in Table 6.11 below;

Table 6-11: Truck Details

Model	VOCs (US$/v-km)	Travel time to Nairobi (hours)	Travel time to Eldoret (hours)
Isuzu	1.85	44	120
Renault	1.775	60	130
Mercedes	1.96	54	150
Mitsubishi	1.67	48	160

Source: Researcher

a) Which model of trucks should he use for the two respective O-D pairs if he is to offer the most competitive rates?

b) Which model of trucks should he use for the two respective O-D pairs in order to make the maximum possible profit?

Solution:

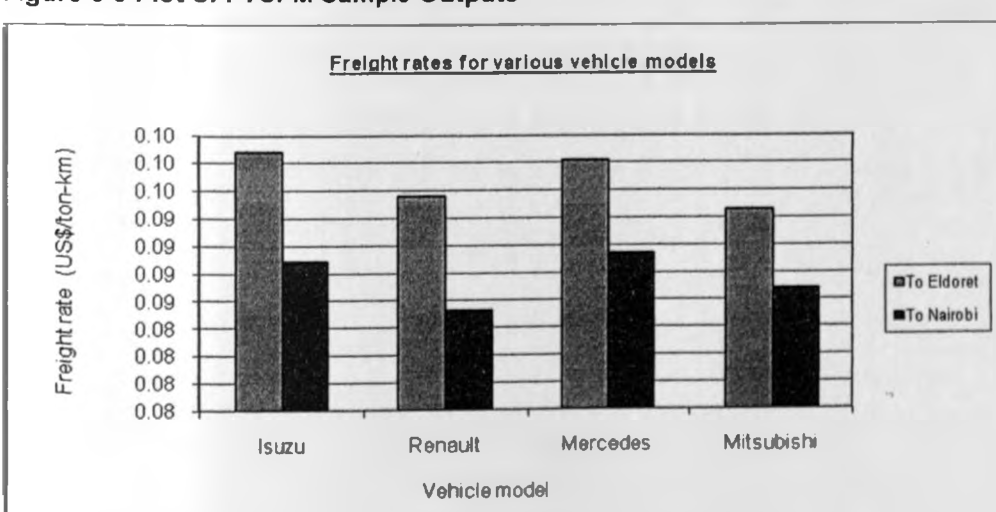
Using the FTCPM equation 5.13 (Section 5.5.4), the corresponding freight rates would be as follows (Table 6.12);

Table 6-12: Freight Rates obtained using FTCPM and given Variables

	Model	Model Code	Cargo Factor	Time Allowed (hour)	Distance (km)	VOCs (US$/v-km)	Rate (US$/ton-km)	Rate (US$/v-km)
	Isuzu	3	0.46	120	960	1.85	0.0985	2.4615
	Renault	1	0.46	125	960	1.775	0.0944	2.3612
	Mercedes	2	0.46	150	960	1.96	0.0977	2.4429
Eldoret	Mitsubishi	5	0.46	160	960	1.67	0.0933	2.3316
	Isuzu	3	0.56	44	500	1.85	0.0885	2.6550
	Renault	1	0.56	60	500	1.775	0.0840	2.5210
	Mercedes	2	0.56	54	500	1.96	0.0893	2.6779
Nairobi	Mitsubishi	5	0.56	48	500	1.67	0.0860	2.5805

Source: Researcher

Figure 6-5 Plot of FTCPM Sample Outputs



Source: Researcher

Evidence drawn from the analysis shows that competitive rates to Eldoret and Nairobi are US$0.0933/ton-km and US$0.0840/ton-km derived for Mitsubishi and Renault at respectively. In order to maximize profit, the most desirable rate to Eldoret and Nairobi should be the Isuzu at US$0.0985/ton-km and the Mercedes at US$0.0893/ton-km respectively.

7 DISCUSSION

7.1 Introduction

An efficient and economical freight transport system allows for the expansion of the market for trade, and promotes Just-in-Time [7](JIT) production techniques. As a result, the total cost of freight transport and logistics is deemed as important, for it has a direct bearing on the efficiency and growth of an economy. The cost of freight transport is a function of many factors which include the vehicle operating costs. This depends on road characteristics. The theoretical aspects of trade and economics are based on transportation costs. In other words, it is not possible to achieve economies of scale in trade if the costs of cargo transport are not considered and objectively optimised. The demand for freight transport will continue to increase, thus measures such as improved infrastructure should be applied, in order to minimize the transport costs. If industries continue to move in the direction of Just-In-Time production and distribution, the economic consequences of disruptions in the transportation system will be adverse. One way in which a transport system can be disrupted is in the fluctuation and escalation of transport costs

The main purpose of carrying out road economic evaluation studies is to minimize road user costs and encourage economic growth. This study maintains that freight road transport costs would only contribute to the country's overall economic growth if the following conditions are satisfied;

- The costs of transporting raw materials to the industry and finished products to the market do not lead to inflation.
- Time component of cost of transport is low so as to enable Just-In-Time (JIT) production techniques.

[7] Is an approach to operations planning control based on the idea that goods and services should be produced only when they are needed and neither too early (so that inventory build up) nor too late (so that customers have to wait)

- The cost of transporting goods does not grossly affect the prices of the final products, thus rendering them unaffordable to the local consumers.

7.2 The Study Data

The primary and secondary data used in this research study were obtained from established transport companies plying the Northern Corridor road. Data types comprised of vehicle operating costs, freight rates and travel time which were collected through direct interviews. The research method used in this study guarantees reliability and accuracy of the data. However, the data is still subject to errors such as recording mistakes, unwillingness of the interviewees to give accurate information and errors due to the Global Positioning System (GPS).

Previous studies done on freight rates along the NC road were carried out by the Northern Corridor Transit Transport Coordination Authority (NCTTCA, 2004). During data collection, direct interviews were carried out. This gives a good basis for comparison with the data collected for this research. Findings revealed that the values of transport costs established from this study were higher than the values obtained by the NCTTCA. This depicts an increase in freight rates.

Similarly, another study on travel time along the NC road was undertaken by NCTTCA (2006) using direct interviews. However, the travel time data used in this study were obtained using GPS equipment which was fitted on the trucks while on transit. For the purposes of this research, the researcher considered GPS equipment records to be more accurate and reliable than the direct interview method.

Economic studies on vehicle operating costs by the World Bank (Arnold, 2005) was undertaken using HDM-4, while the vehicle operating costs used in this research were established by direct interviews. The data used in HDM-4 to establish the VOCs were obtained from the Ministry of Roads and Public Works

(MoRPW). One limitation of the records used by MoRPW is that they were outdated; hence the values of VOCs obtained do not accurately depict the true values of the existing VOCs. A comparison of the methods which were used is discussed in the following section.

7.3 Vehicle Operating Costs

Vehicle operating costs (VOCs) is a major component of road user costs (RUCs) and has been widely used in the appraisal of road projects. A number of models such as Road User Cost Knowledge System (RUCKS), Highway Development and Management-4 (HDM-4) and Highway Development and Management-III (HDM-III) have been developed to relate vehicle operating costs to road characteristics, and are mostly used for project appraisals.

The HDM-4, for instance, was used in appraisal of the Northern Corridor Transport Improvement Projects (NCTIP). It should not be ignored that inasmuch as these models are used in Africa, they were developed under environmental conditions that are not directly comparable to the local conditions such as rainfall, pavement types, temperature, traffic characteristics and general economic patterns. Hence, the need for economic appraisal techniques that are relevant for the local conditions is quite important. This illustrates an area in which the model developed in this study could be applied, to enhance the appraisal of road projects.

An economic study by the World Bank (Arnold, 2003) on the NC road using HDM-4 established that the highest component of VOCs for heavy trucks along the NC road, was spare parts and labour expense, followed by the depreciation and interest expense (see section 2.5). This contradicts the actual values of VOCs obtained from this study through direct interviews. The study established that the highest component of VOCs were fuel and lubricant expense (comprising of more than 50% of VOCs) followed by tyre expense (see section 5.2.8). Moreover, the projection of VOCs done in this study established a maximum increase of 2.26% p.a. and a minimum increase of 0.97% p.a.

High fuel and tyre expense along the Northern Corridor road was as a result of poor road condition and repeated change of alignment, which causes frequent accelerations and decelerations. This concurs with earlier studies done by Rodrigo (2004) and Watanatanda (1987) which established that VOCs increase with the corresponding rise in road IRI and repeated change of alignment.

7.4 Freight Rates

This study established that freight rates increase with a rise in vehicle operating costs within a specific range of VOCs. Light trucks had the highest transport rate per ton-km, while heavy trucks had the lowest per ton-km transport charge. It was further established that light trucks carry less than the actual truck capacity weight of cargo, whilst heavy trucks carry the full truck capacity weight of cargo. Additionally, findings revealed freight rates varied significantly with distance (km) and cargo situation, for light and medium trucks. Similarly, trucks carrying light cargo over short distances and having a return cargo had low freight rates. For heavy trucks, the most important variables in determining freight rates were vehicle operating cost, travel time and cargo factor (ratio of cargo weight carried to truck GVW). The transport rates increased with the corresponding increase in travel time and decreased with the increase in cargo factor.

A previous study conducted on freight rates along the NC road by Geoffrey (2006) showed that freight rates by road were higher than sea transport costs. Consequently, the study established that freight rates for export cargo from Kenya were lower than freight rates for import cargo. This agrees with the findings of this study, which showed that the freight rates were higher for imports due to delays caused at weighbridges, including higher VOCs.

7.5 FTCPM and Model for Predicting Freight Rates

Earlier models for predicting freight transport costs were found to be unsuitable for use on the NC road as discussed in Table 2.5, section 2.9. Generally, the existing models do not show the relationship between transport cost and vehicle operating cost, while considering other variables namely; travel time, cargo weight, backhauls and truck model. Data requirement for the variables used in the existing models were also expensive to collect and determine for the Northern Corridor road.

From this study, two multiple linear regression models have been developed to estimate (see section 5.5) and to predict (see section 5.6) freight rates. The models developed addressed the shortcomings of the existing models by depicting the relationship between freight transport cost and VOCs while considering freight rate determinants.

In developing the models, it was assumed that there is a linear relationship between freight rates and factors influencing freight rates. Key consideration was given to the relationship between freight rates and VOCs which revealed that freight rates increase as VOCs increases within a given range of VOCS only beyond which VOCs becomes insignificant.

The trends in freight rates which were computed using the model developed from this study are reliable for the next ten years. Future forecasting shows that the rates are likely to increase by 57.5% by 2018 assuming that fuel consumption, employment wage rate and traffic growth rates remain the same. Hence, the model developed for this study promises a wide application on road projects particularly the NC road. However, further investigation on other appraisal techniques is still necessary.

8 CONCLUSIONS AND RECOMMENDATIONS

8.1 Conclusions

The main objective of this thesis was to develop a model for determining freight transport rates and for forecasting yearly VOCs and the freight rates trends along the Northern Corridor road-Kenya. In developing the models, the research questions and objectives (see section 1.4 and 1.5) were addressed and the following conclusions drawn;

- ✓ Freight transport costs increased with rise in vehicle operating costs, within a specific range of VOCs. The range of VOCs varied depending on the age of truck, truck capacity and truck model. Beyond a given range of VOCs, transport costs charged by a transporter do not depend on the vehicle operating cost.
- ✓ Heavy trucks had the highest VOCs along the NC road, while light trucks had the lowest VOCs. Fuels and tyre expense comprised of an average of 55% of the total VOCs for all truck categories that operate on the NC road. This was due to poor road surface conditions and long distances covered, including the repeated change of horizontal alignment. Findings revealed that the distance travelled increased fuel expense, resulting in high VOCs and freight rates per ton-km. VOCs for Heavy trucks was at least 200% more than that of light trucks.
- ✓ Nissan-light trucks had the lowest vehicle operating costs less than US$0.2/v-km, while Mercedes-heavy trucks had the highest vehicle operating costs of US$0.9675/v-km. Mitsubishi, Renault and Isuzu were observed to have vehicle operating costs in the range US$0.65 – 0.85/v-km.
- ✓ Light trucks had the highest transport rate per ton-km while heavy trucks had the lowest per ton-km transport charge. This was attributed to the fact that most of the light trucks carry less than the actual truck capacity weight of cargo, while heavy trucks carried the full truck capacity weight of cargo.

Additionally, was the fact there was a low supply of light/medium truck transport services, against the high demand for the service.

- ✓ It was established that the freight rates for light/medium trucks varied significantly with the distance travelled, cargo factor and whether the truck had a return cargo or not. The transport rates were lower for shorter distances, lighter weights and when the truck had a return cargo. For heavy trucks, the most important variable in determining freight rates was found to be vehicle operating cost, travel time and cargo factor (ratio of cargo weight carried to truck GVW). As a result, the transport rates increased with the increase in travel time, and decreased with increase in cargo factor.
- ✓ Two models have been developed from this study to relate freight rates to factors influencing the freight rates. These models are multiple linear regression equations which generally assumed that there is a linear relationship between the variables. Further analysis to forecast freight rates depicted a compounded growth trend in freight rates for the next ten years. Key consideration was also given to the relationship between freight rates and VOCs which revealed that freight rates increase as VOCs increases within a given range of VOCS only beyond which VOCs become insignificant. The trends in freight rates which were computed using the model developed from this study are reliable for the next ten years.

8.2 Recommendations

The following recommendations have been proposed following this study;

- To lower the VOC, design consistency should be maintained. The Northern Corridor road has several sections with frequent change of horizontal alignment. These sections need to be redesigned, in order to shorten the distance covered and reduce the repeated change of speed. If implemented, the redesign will lower both fuel consumption and additional expense on tyres, which would result in lower freight rates, (per-ton-km).

- Improved efficiency at the weighbridges. Currently, the operations at the weighbridges are inefficient which contribute to delays in vehicle clearance. In addition, the inefficiency plays a part in the minimal enforcement of recommended axle load. In order to reduce the delays, an additional portable axle load for weighing machines should be installed. This will enhance the speed of clearance. Furthermore, the machine handlers also need further training in the use of the equipment.
- Transporters should use the FTCPM while working out freight rates. This would ensure they remained competitive in the market, as well as a return on investment. Hence, this model will assist industry players in understanding factors which need to be taken into consideration when charging clients.
- There is a need for further research that would contribute to the strengthening of the FTCPM model. An in-depth investigation into such variables such as truck travel time along the NC is deemed as necessary.
- Study on the relationship between freight rates and VOCs (see section 5.6) revealed that freight rates rise as VOCs increase within a specific range beyond which, VOCs become insignificant.
- Due to the limitations in the budget and time, the researcher was unable to investigate on competing modes of transport such as rail, water and air. Thus, it is recommended that studies be carried out on freight rates for these competing modes in the future, as they too have an impact on freight along the Northern Corridor Road network.
- This research did not investigate other aspects of freight costs such as transit charges, maritime charges, and terminal charges. These costs contribute to the overall cost of goods passing through the Northern Corridor road network.

REFERENCES

AA Kenya, 2005, *Autonews,* Issue Number 14, January-February, 2005

Amjadi, Azita and Alexander Y, 1995, "*Have transport costs contributed to the relative decline of African exports? Some preliminary evidence,*" World Bank Working Papers on International Economics, Trade, and Capital Flows, No. 1559

Andy F, 2005, Discovering Statistics Using SPSS, Second Edition, SAGE Publication

Archondo-Callao, R and Faiz, A, 1993, *Estimating Vehicle Operating Costs.* World Bank Technical Paper Number 234, the World Bank, Washington, DC

Arnold J December, 2006, *Best Practices in Management of International Trade Corridors,* the World Bank Group, Washington, D.C.

Arnold J February, 2005, *Best Practices in Corridor Management,* the World Bank Group, Washington, D.C

ASHTO, 2003, *Proposal paper,* Available online at, http://freight.transportation.org/doc/freight2pager2003.pdf Accessed July 2007

Bennathan, E (1989). "*Deregulation of Shipping: What is to be Learned from Chile,*" World Bank Discussion Paper No. 67, (Washington: World Bank, December).

Bennett C. R. 1994, *A Speed Prediction Model for Rural Two-Lane Highways*, A dissertation submitted in partial fulfilment of the requirements for the degree of Doctor of Philosophy in Engineering Supervised by Roger C.M. Dunn Department of Civil Engineering The University of Auckland New Zealand

Bennett C. R. 2007, *Differences in the HDM-4 RUE Model over HDM-III*, Report to the World Bank, Washington, D.C.

Bennett C. R. and Ian D. G. 2003, *Modelling Road User and Environmental Effects in HDM-4*, the World Bank, Washington D.C.

Burkes M. L. and Alexandra K. 2005, a paper on "*A Nonlinear Pricing Model with Lump-Sum Transportation Costs*," presented at Hawaii international conference on statistics and mathematics.

Button, K. J. 2003, *Transport Economics*. – Second Edition, Edward Elgar Publishing Limited, Massachusetts.

Caldwell H, Kate H, Jacob M, John S and Lance G, 2002, *Potential Impacts of Climate Change on Freight Transport* climate change and transportation workshop, for the centre for climate change and environmental forecasting, U.S. Department of Transport.

CBS Kenya, 2007, *Economic Survey 2007 Launch*

Colin G. B. 2001, *Transport Economics*, Second edition, Heinemann Education Publishers, Oxford Ch 3-4

Colin G. B. 2001, *Transport Economics*, Third edition, Heinemann Education Publishers, Oxford Ch 3-4

COWI Consulting Engineers DK, 1999, *Pavement and Structure Management System*, Project for EC-DG-VII RTD Programme - Contract No. RO-97-SC 1085/1189, Work Package 2, Review of road infrastructure systems and models in EU member states, Road Infrastructure Maintenance Evaluation Study

Edward L. G. and Janet E. K. J. 2003, *Cities, Regions and the Decline of Transport Costs* Discussion Paper Number 2014 Harvard University Cambridge, Massachusetts This paper can be downloaded without charge from: http://post.economics.harvard.edu/hier/2003papers/2003list.html Accessed July 2007

GAMS Example Available online at, http://www.gams.com/docs/example.htm Accessed September 2006

Gichaga J and Parker A, 1988, *Essentials of Highway Engineering*, Macmillan Publishers. Pp 17-26.

Godfrey M. O. 2006, a Paper on *Borderless Trade: Breaking Down Barriers* Presented In the African Ports and Harbours Conference 2006 for the Northern Corridor Transit Transport Coordination Authority

Gordon A. 1996, *USAID, Comparative Transportation Cost Analysis in East Africa Final Report*, Project CA 623-0478-00-3180-00 Publication services provided by AMEX International, Inc.

Guidebook on Statewide Travel Forecasting, 1999, Prepared for Federal Highway Administration

Henderson J. V. Shalizi Z. and Venables A. J. 2001, "*Geography and development*," Journal of Economic Geography 1, 81-105

Hide, H., Abaynayaka, S.W., Sayer, I. and Wyatt R.J. 1975. The Kenya Road Transport Cost Study: Research on Vehicle Operating Costs. *Transport and Road Research Laboratory Report LR672,* Department of the Environment, Crowthorne.

http://www.cbs.go.ke/downloads/pdf/ES2007.pdf?SQMSESSID=101561fb04e4511cde553e35a3da421e&SQMSESSID=730fdc7224d6d5bfbe0957ccdcd28303 Accessed September 2007

Jorge A. P., 2001, *Modeling Pavement Performance by Combining Field and Experimental Data*, a PhD Dissertation, University of California, Berkeley.

Kerali G. R. H. 2000, *Version 1.0 edition of Overview of HDM-4,* Volume one, the World Road Association (PIARC) Paris, the World Bank, Washington, D.C.

Kerali H. R, 1999, *Overview of HDM-IV, the Highway Development and Management Series*, Volume 1, Paris: PIARC World Bank Road Association.

Limao, N. and Venables A. J., 2000, "*Infrastructure, geographical disadvantage, transport costs and trade,*" World Bank Economic Review, 15(3), 451-79

Manufacturers & Distributors Publication available on-line at http://www.plantemoran.com/Industries/Manufacturing/Manufacturers/Resources/Manufacturer/2006+Issue+No+2/PMA%E2%80%99s+Benchmarking+Report+Helps+Manufacturers+Assess+Performance.htm Accessed December 2006

Ministry of Roads and Public Works, (MoRPW), 2003, *Project Appraisal Document*, Northern Corridor Transport Improvement Project Kenya

Neter J., Wasserman W. and Kutner, M.H. (1989), *Applied Linear Regression Models*, Richard D. Irwin Publishers, Illinois

Odoki J.B and Kerali H.R, 1999, *HDM-IV Analytical Framework and Model Description, Highway Development and Management Series*, Volume 4, Paris: PIARC World Bank Road Association.

O'Flaherty C.A, 2005, *Transport Planning and Traffic Engineering*, Butterworth-Heinemann publication

PIARC, 1999, HDM-IV: *Highway Development and Management Series*, Paris: PIARC World Bank Road Association.

Piet B. Uwe D. and David W. 2006, *Development Research Group, "Road Network Upgrading and Overland Trade Expansion in Sub-Saharan Africa"* World Bank Policy Research Working Paper 4097

Pignataro J. Louis, 1973, *Traffic Engineering Theory and Practice*, Prentice-Hall, ISBN: 0139262202 / 0-13-926220-2 Accessed December 2006

Robinson R. and Bent T. 2004, *Road Engineering for Development*, Second Edition, Spon Press Ch 21

Rodrigo A. 2004, *Roads Economic Decision Model, HDM-4 Vehicle Operating Costs Module, Version 3.2, Road Management initiative, sub-Saharan Africa Transport Policy Program*, available online at: Web: http://www.worldbank.org/html/fpd/transport/roads/tools.htm
Accessed July 2007

Rodrigo S. A. and Asif Faiz, 1994, *Estimating Vehicle Operating Costs* World Bank Technical Paper Number 234 The World Bank Washington, D.C.

Rokowski J.P, 1976, *Transport Economics*: A guide to information source, Detroit, Gale research Co.

Simuyemba, S. 2000, "*Linking Africa Through Regional Infrastructure*," African Development Bank, Economic Research Papers, No 64

Spulber, D. F, 1981. "*Spatial Nonlinear Pricing*," *The American Economic Review*, vol. 71, no. 5, p, 923-933.

The East African News Paper dated May 1-7, 2006, page 8.

Transit Transport Coordination Authority, 2004, a Paper on *Investment Opportunities in the Northern Corridor with emphasis in Transport Infrastructure*, for Presentation at the COMESA Business Summit Kampala, Uganda, available online at: **http://www.oecd.org/dataoecd/22/36/34879173.pdf** Accessed July 2007

Troxel C.E. 1955, *Economics of Transport*, Rinehart and Company limited, Inc., New York.

Tutorial Paper on Introduction to Transport Economics available online at: http://www.tutor2u.net/economics/content/topics/transport/introduction.htm Accessed April 2007

United Nations (Annual) *Statistical Yearbook*, New York, UN.

US Department of Transport, Federal Highway Administration, 2002, *Office of Freight Management and Operations*-Funding and Institutional Options for Freight Infrastructure Improvements, Sections 1 and 3, html

Van Es J and Ruijgrok C.J, 1974, *Modal Choice in Freight Transport*, in E, J, Visser (Ed) '*Transport Decisions in an Age of Uncertainty*,' The Hague, Martinus Nijhoff

Weber A, 1929, *Theory of Location of Industry*, Chicago University Press.

Wilson A.G, Hawkins, H.F, Hill G, J and Wagon D.J, 1969, *Calibration and Testing of the SELNEC Transport Model*, Regional Studies

World Bank Road Software Tools, 2007, http://worldbank.org/roadsoftwaretools/ Accessed January 31, 2007

World Bank, 1999, *Infrastructure, Geographical Disadvantage, and Transport Costs*, Economic Review, Vol 15 no 3, pp 451-479

World Bank, 2004, *Project Appraisal Document for A Northern Corridor Transport Improvement Project,* Report No: 28826. The World Bank Washington D.C

World Bank, 2005, *Best Practices in Corridor Management*, Trade Logistics Group, Prepared by Arnold J

World Bank, 2007, *HDM-4 Road Use Costs Model Documentation Version 1.10*, Technical Documentation, The World Bank Washington D.C.

APPENDICES

Appendix A:

Transport companies and Authorities visited during the study

1. Kenya Transport Association,
2. Northern Corridor Transit Transport Coordination Authority
3. Ministry of Roads and Public Works.
4. University of Nairobi Enterprises and Services Limited
5. A.O. Bayusuf & Sons Transporters,
6. M.A. Bayusuf & Sons Transporters,
7. Roadtainers Transporters,
8. Transpares (Kenya) Transporters Ltd,
9. Multiple Haulliers,
10. A. to Z. Transporters,
11. Transeast Transporters,
12. Kenfreight Transporters,
13. Shiva Carriers,
14. Siginon Transporters,
15. Panal Freighters,
16. Motrex transporters,
17. Awale Transporters,
18. P.N. Mashru Transporters,
19. A.K. Abdulgani Transporters,
20. Anwarali Transporters,
21. Hakika Transporters,
22. Tornado Carriers,
23. Coast Haulliers,
24. Group 4 Securicor Services,
25. Mombasa Maize Millers,
26. DHL Curor Services,

27. Cadbury Kenya Limited,
28. Unga Company (Farm Care),
29. Timsales Nairobi,
30. Roy Parcel Services Nairobi,

Appendix B:

Questionnaires and data forms for VOCs and Freight Rates

FREIGHT/CARGO RATES AND VEHICLE OPERATING COSTS FOR GOODS' VEHICLES PLYING THE NORTHERN CORRIDOR ROAD		Sheet Number.
DATA FROM TRANSPORT COMPANIES		-
	COMPANY NAME {OPTIONAL}	
	What is the Total Number of trucks owned by the company?{Specify}	
	All data in the remaining sections of the questionnaire should be completed per truck of choice. Each questionnaire should contain details for four trucks. More than one questionnaire may be completed depending on the number of trucks owned by the company	

A			TRUCK DETAILS			
	Item/Trucks		**Truck 1.**	**Truck 2.**	**Truck 3.**	**Truck 4.**
I	What is the **Make** of the truck?					
	{1} = Renault	{4} = Nissan				
	{2} = Mercedes	{5} = Mitsubishi				
	{3} = Isuzu	{6} = Other				
II	What is the **Category** of the truck?					
	{1} = Light Truck (2-3 Axles)					
	{2} = Medium Truck (4-5 Axles)					
	{3} = Heavy Truck (6 or More Axles)					

I	How many **Axles** does the truck have?	
II	How many **Wheels** does the truck have?	
III	What type of **Tyre** does the truck use? {0=Radial-ply or 1=Bias-ply}	
IV	At what **Price** do you buy the tyre? {Specify in Kshs}	
V	**How frequently** do you **Replace** the tyres? {Specify per number of trips, duration OR kilometer}	
III	What is the **Year of Manufacture** of the truck?	
IV	What is the **Gross Vehicle Weight** of the truck? {in kg or ton}	
V	What is the **Gross Tare Weight** of the truck? {In kg or ton}	
VI	What is the **Average Cargo Weight** normally carried by the truck? {In kg or ton}	
VII	**How long** do you expect to use this truck before disposal? {Specify in years}	
VIII	What would be the **salvage value** of the truck upon disposal? {in Kshs}	

IX	What is the Current **Price** of a similar **New truck**? {Specify in Kshs}				
B	Item	**ADMINISTRATION DETAILS**			
I	What is the **Total Number of Crew** working on the truck?				
II	How much **Money** do you pay per **Crew**? {Per trip or month or day in Kshs}				
III	How frequently do you take the truck for **Normal Maintenance Services**?				
IV	How frequently do you take the truck for **Major Maintenance Services**?				
V	How much **money** do you spend on **Normal Maintenance Services per visit**?				
VI	How much **money** do you spend on **Major Maintenance Services per visit**?				
VII	How much **money** do you spend on **Insurance** {Per month or year?}				
VIII	How much **money** do you spend on **Administration and Overheads**? {Per month or year}				
C	Item	**FUEL DETAILS**			
I	What **Type of Fuel** does the truck use? {0=Petrol,				

	1=Diesel}				
II	At what **Price** do you buy the Fuel? { Specify in kshs}				
III	What **Type of Lubricant** does the truck use?				
IV	At what **Price** do you buy the Lubricant? {Specify in kshs}				
	Item	**ROUTE DETAILS**			
	Which Route is Frequently Plied by the truck? {1} Nairobi - Mombasa; {3} Nairobi - Eldoret {2} Nairobi - Kisumu; {4} Mombasa - Kisumu {5} Mombasa - Eldoret; {6} Other [Specify Origin and Destination]				
	For the Route Specified above, fill the following details per truck.	**TRANSPORT DETAILS**			
	Fuel used {In Litres or Kshs}				
	Lubricant used {In Litres or Kshs}				
	Cargo type frequently transported {0}=loose, {1}= 20TEU,{2}=40TEU}				
	Trip frequency {specify per month or week}				

	Travel time from Origin to Destination {In Hours or Weeks}	
	Transport Charge {in khs}	
	Is there **backhaul** cargo for Return trip? {0=yes, 1=No}	
	Backhaul Cargo type frequently transported {0}=loose, {1}= 20TEU,{2}=40TEU}	
	Backhaul Cargo Transport Charge {in khs}	

Appendix C:

Summary of Vehicle Operating Costs and Freight rates

Fuel	Lubricant	Maintenance/Labour	3rd Party Insurance	Crew	Tyre	Passenger Time Value	Cargo Time Value	Depreciation and Interest	Total VOCs	Freight Rates
US$/V-km	US$/V-km	US$/V-km	US$/V-km	US$/V-km	US$/V-km	US$/V-km	US$/V-km	US$/V-km	US$/V-km	US$/Ton-km
0.1962	0.0053	0.1592	0.0201	0.0471	0.2204	0.0018	0,0082	0.1457	0.7959	0.3555
0.1962	0.0053	0.1592	0.0201	0.0629	0.2204	0.0018	0,0082	0.1457	0.8116	0.3555
0.1962	0.0053	0.1592	0.0201	0.0786	0.2204	0.0018	0,0082	0.1457	0.8273	0.3555
0.1962	0.0053	0.1592	0.0201	0.0849	0.2204	0.0018	0,0082	0.1457	0.8336	0.3555
0.0681	0.0019	0.0194	0.0155	0.0740	0.0057	0.0018	0,0082	0.1457	0.3320	1.0412
0.1051	0.0029	0.0223	0.0365	0.1746	0.0068	0.0018	0,0082	0.1457	0.4957	1.8896
0.0635	0.0017	0.1155	0.0876	0.4190	0.0444	0.0018	0,0082	0.1457	0.8793	2.2676
0.6413	0.0174	0.0667	0.0300	0.1048	0.0343	0.0018	0,0082	0.1457	1.0420	1.5337
0.4499	0.0050	0.0497	0.0310	0.2263	0.0312	0.0018	0,0082	0.1457	0.9405	0.5576
0.3829	0.0050	0.0335	0.0310	0.2263	0.0156	0.0018	0,0082	0.1457	0.8417	1.0241
0.6413	0.0174	0.0667	0.0300	0.1048	0.0381	0.0018	0,0082	0.1457	1.0458	1.4286
0.1962	0.0053	0.1592	0.0201	0.0471	0.2204	0.0018	0,0082	0.1457	0.7959	0.3555
0.1962	0.0053	0.1592	0.0201	0.0629	0.2204	0.0018	0,0082	0.1457	0.8116	0.3555
0.1962	0.0053	0.1592	0.0201	0.0786	0.2204	0.0018	0,0082	0.1457	0.8273	0.3555
0.1962	0.0053	0.1592	0.0201	0.0849	0.2204	0.0018	0,0082	0.1457	0.8336	0.3555
0.0681	0.0019	0.0194	0.0155	0.0740	0.0057	0.0018	0,0082	0.1457	0.3320	1.0412
0.1051	0.0029	0.0223	0.0365	0.1746	0.0068	0.0018	0,0082	0.1457	0.4957	1.8896
0.0635	0.0017	0.1155	0.0876	0.4190	0.0444	0.0018	0,0082	0.1457	0.8793	2.2676
0.6413	0.0174	0.0667	0.0300	0.1048	0.0343	0.0018	0,0082	0.1457	1.0420	1.5337
0.4499	0.0050	0.0497	0.0310	0.2263	0.0312	0.0018	0,0082	0.1457	0.9405	0.5576
0.3829	0.0050	0.0335	0.0310	0.2263	0.0156	0.0018	0,0082	0.1457	0.8417	1.0241
0.6413	0.0174	0.0667	0.0300	0.1048	0.0381	0.0018	0,0082	0.1457	1.0458	1.4286
0.1962	0.0053	0.1592	0.0201	0.0471	0.2204	0.0018	0,0082	0.1457	0.7959	0.3555
0.1962	0.0053	0.1592	0.0201	0.0629	0.2204	0.0018	0,0082	0.1457	0.8116	0.3555
0.1962	0.0053	0.1592	0.0201	0.0786	0.2204	0.0018	0,0082	0.1457	0.8273	0.3555
0.1962	0.0053	0.1592	0.0201	0.0849	0.2204	0.0018	0,0082	0.1457	0.8336	0.3555

0.0681	0.0019	0.0194	0.0155	0.0740	0.0057	0.0018	0,0082	0.1457	0.3320	1.0412
0.1051	0.0029	0.0223	0.0365	0.1746	0.0068	0.0018	0,0082	0.1457	0.4957	1.8896
0.0635	0.0017	0.1155	0.0876	0.4190	0.0444	0.0018	0,0082	0.1457	0.8793	2.2676
0.6413	0.0174	0.0667	0.0300	0.1048	0.0343	0.0018	0,0082	0.1457	1.0420	1.5337
0.4499	0.0050	0.0497	0.0310	0.2263	0.0312	0.0018	0,0082	0.1457	0.9405	0.5576
0.3829	0.0050	0.0335	0.0310	0.2263	0.0156	0.0018	0,0082	0.1457	0.8417	1.0241
0.6413	0.0174	0.0667	0.0300	0.1048	0.0381	0.0018	0,0082	0.1457	1.0458	1.4286
0.1962	0.0053	0.1592	0.0201	0.0471	0.2204	0.0018	0,0082	0.1457	0.7959	0.3555
0.1962	0.0053	0.1592	0.0201	0.0629	0.2204	0.0018	0,0082	0.1457	0.8116	0.3555
0.1962	0.0053	0.1592	0.0201	0.0786	0.2204	0.0018	0,0082	0.1457	0.8273	0.3555
0.1962	0.0053	0.1592	0.0201	0.0849	0.2204	0.0018	0,0082	0.1457	0.8336	0.3555
0.0681	0.0019	0.0194	0.0155	0.0740	0.0057	0.0018	0.0082	0.1457	0.3320	1.0412
0.1051	0.0029	0.0223	0.0365	0.1746	0.0068	0.0018	0,0082	0.1457	0.4957	1.8896
0.0635	0.0017	0.1155	0.0876	0.4190	0.0444	0.0018	0,0082	0.1457	0.8793	2.2676
0.6413	0.0174	0.0667	0.0300	0.1048	0.0343	0.0018	0,0082	0.1457	1.0420	1.5337
0.4499	0.0050	0.0497	0.0310	0.2263	0.0312	0.0018	0,0082	0.1457	0.9405	0.5576
0.3829	0.0050	0.0335	0.0310	0.2263	0.0156	0.0018	0,0082	0.1457	0.8417	1.0241
0.6413	0.0174	0.0667	0.0300	0.1048	0.0381	0.0018	0,0082	0.1457	1.0458	1.4286
0.4307	0.0117	0.0405	0.0505	0.1289	0.1829	0.0018	0,0082	0.1457	0.9927	0.3125
0.4307	0.0117	0.0405	0.0505	0.1289	0.1829	0.0018	0,0082	0.1457	0.9927	0.3125
0.4307	0.0117	0.0405	0.0505	0.1289	0.1829	0.0018	0,0082	0.1457	0.9927	0.3125
0.4307	0.0117	0.0405	0.0505	0.1289	0.1829	0.0018	0,0082	0.1457	0.9927	0.3125
0.4001	0.0109	0.0786	0.0518	0.1247	0.2106	0.0018	0,0082	0.1457	1.0243	0.0661
0.4107	0.0112	0.0786	0.0635	0.1964	0.3340	0.0018	0,0082	0.1457	1.2418	0.0600
0.4429	0.0120	0.0786	0.0816	0.2357	0.3340	0.0018	0,0082	0.1457	1.3323	0.0886
0.6324	0.0172	0.0773	0.1011	0.2295	0.2429	0.0018	0,0082	0.1457	1.4478	0.0932
0.1138	0.0031	0.0773	0.0262	0.0775	0.1857	0.0018	0,0082	0.1457	0.6312	0.1190
0.3290	0.0089	0.0786	0.0544	0.1422	0.2429	0.0018	0,0082	0.1457	1.0035	0.0765
0.5970	0.0162	0.0877	0.0635	0.8381	0.5924	0.0018	0,0082	0.1457	2.3424	0.0843
0.3010	0.0082	0.0843	0.0466	0.4105	0.4271	0.0018	0,0082	0.1457	1.4253	0.0843

0.8088	0.2174	0.1167	0.1415	0.2181	0.1461	0.0018	0.0082	0.1457	1.4665	0.1006
0.8088	0.2174	0.1167	0.1415	0.2181	0.3456	0.0018	0.0082	0.1457	1.8247	0.1096
0.4327	0.0117	0.0348	0.1172	0.1266	0.2514	0.0018	0.0082	0.1067	1.0825	0.0525
0.3608	0.0098	0.0833	0.0547	0.0321	0.1371	0.0018	0,0082	0.1457	0.8253	0.0633
0.4421	0.0120	0.1006	0.0752	0.0662	0.1314	0.0018	0,0082	0.1457	0.9971	0.0674
0.4900	0.0133	0.1006	0.0564	0.0662	0.1424	0.0018	0,0082	0.1457	1.0164	0.0674
0.3739	0.0102	0.0381	0.0569	0.0625	0.1420	0.0018	0,0082	0.1457	0.8212	0.0557
0.4570	0.0124	0.0381	0.0569	0.1074	0.1420	0.0018	0,0082	0.1457	0.9614	[illegible]
0.3157	0.0086	0.0381	0.0569	0.0537	0.1420	0.0018	0,0082	0.1457	0.7626	0.0557
0.5179	0.0141	0.0702	0.0952	0.1729	0.1204	0.0018	0,0082	0.1457	1.1381	0.0862
[illegible]	0.0136	0.0702	0.0952	0.1729	0.1264	0.0018	0,0082	0.1457	1.0891	0.0726
[illegible]	0.0136	0.0702	0.0952	0.1729	0.1264	0.0018	0,0082	0.1457	1.0891	0.0703
[illegible]	0.0147	0.4444	0.0218	0.1746	0.1321	[illegible]	0,0082	0.1457	1.4760	0.0767
0.3936	0.0107	0.2357	0.0170	0.1425	0.2039	[illegible]	0,0082	0.1457	1.1509	0.0729
0.5268	0.0143	0.4888	0.0338	0.1964	0.1321	[illegible]	0,0082	0.1457	1.5395	0.0798
0.5089	0.0138	0.0540	0.0635	0.0942	0.1327	[illegible]	0,0082	0.1457	1.0186	0.0694
0.4741	0.0129	0.0589	0.0635	0.0942	0.1161	[illegible]	0,0082	0.1457	0.9712	0.0633
0.3863	0.0105	0.1270	0.0367	0.1440	0.1671	[illegible]	0,0082	0.1457	1.0122	0.0647
0.3863	0.0105	0.1365	[illegible]	0.0917	0.1426	[illegible]	0,0082	0.1457	0.9550	0.0647
0.3863	0.0105	0.1830	[illegible]	0.2161	0.1316	[illegible]	0,0082	0.1457	1.1336	0.0647
0.3863	0.0105	0.1830	0.0367	0.0917	0.1316	[illegible]	0,0082	0.1457	0.9807	0.0647
0.4214	0.0115	0.0988	0.0476	0.1726	0.1426	[illegible]	0,0082	0.1457	1.2428	0.0647
0.4214	0.0115	0.1131	0.0476	0.1726	0.1316	[illegible]	0,0082	0.1457	1.2448	0.0647
0.4214	0.0115	0.1038	0.0476	0.1726	0.1316	[illegible]	0,0082	0.1457	1.2204	0.0647
0.4214	0.0115	0.1131	0.0476	0.1726	0.1426	[illegible]	0,0082	0.1457	1.2888	0.0647
0.8871	0.0233	0.0825	0.0298	0.0876	0.1661	[illegible]	0,0082	0.1457	1.4056	0.0607
0.8871	0.0233	0.0825	0.0298	0.0876	0.1661	[illegible]	0,0082	0.1457	1.4056	0.0607
0.8871	0.0233	0.0825	0.0298	0.0876	0.1661	[illegible]	0,0082	0.1457	1.4056	0.0607
0.8871	0.0233	0.0825	0.0298	0.0876	0.1661	[illegible]	0,0082	0.1457	1.4056	0.0607
0.4341	0.0118	0.0843	0.0346	0.0471	0.1087	[illegible]	0,0082	0.1457	0.8602	0.0742

0.4479	0.0122	0.0643	0.0456	0.0471	0.1123	0.0018	0,0082	0.1457	0.8768	0.0707
0.4479	0.0122	0.0643	0.0456	0.0471	0.1123	0.0018	0,0082	0.1457	0.8768	0.0707
0.4557	0.0124	0.0643	0.0489	0.0471	0.1163	0.0018	0,0082	0.1457	0.8923	0.0861
0.4051	0.0110	0.0643	0.0346	0.0471	0.1163	0.0018	0,0082	0.1457	0.8259	0.0742
0.4300	0.0117	0.0643	0.0456	0.0471	0.0980	0.0018	0,0082	0.1457	0.8442	0.1020
0.4917	0.0134	0.0587	0.0828	0.0982	0.1538	0.0018	0,0082	0.1457	1.0461	0.0694
0.4741	0.0129	0.0968	0.0762	0.0982	0.1461	0.0018	0,0082	0.1457	1.0518	0.0806
0.4821	0.0131	0.0258	0.0476	0.0746	0.1164	0.0018	0,0082	0.1457	0.9072	0.0833
0.5179	0.0141	0.0258	0.0476	0.0746	0.1381	0.0018	0,0082	0.1457	0.9656	0.0707
0.4821	0.0131	0.0258	0.0476	0.0746	0.1381	0.0018	0,0082	0.1457	0.9289	0.0703
0.4821	0.0131	0.0258	0.0476	0.0746	0.1177	0.0018	0,0082	0.1457	0.9085	0.0808
0.4821	0.0131	0.0258	0.0476	0.0746	0.1381	0.0018	0,0082	0.1457	0.9289	0.0729
0.4875	0.0133	0.0971	0.1190	0.0655	0.2971	0.0018	0,0082	0.1457	1.2271	0.0649
0.5510	0.0150	0.1000	0.1166	0.1603	0.2971	0.0018	0,0082	0.1457	1.3876	0.0530
0.5333	0.0145	0.0952	0.0979	0.0582	0.2971	0.0018	0,0082	0.1457	1.2438	0.0609
0.3214	0.0087	0.0500	0.0476	0.0982	0.0891	0.0018	0,0082	0.1457	0.7626	0.0560
0.3214	0.0087	0.0500	0.0476	0.0982	0.0891	0.0018	0,0082	0.1457	0.7626	0.0784
0.3895	0.0106	0.0147	0.0861	0.1340	0.1300	0.0018	0,0082	0.1457	0.9123	0.0775
0.4056	0.0110	0.0147	0.0861	0.1340	0.1300	0.0018	0,0082	0.1457	0.9289	0.0775
0.3895	0.0106	0.0147	0.0861	0.1340	0.1300	0.0018	0,0082	0.1457	0.9123	0.0775
0.4056	0.0110	0.0147	0.0861	0.1340	0.1300	0.0018	0,0082	0.1457	0.9289	0.0775
0.4107	0.0112	0.0786	0.0635	0.1964	0.3340	0.0018	0,0082	0.1457	1.2418	0.0600
0.4429	0.0120	0.0786	0.0816	0.2357	0.3340	0.0018	0,0082	0.1457	1.3323	0.0886
0.6324	0.0172	0.0773	0.1011	0.2295	0.2429	0.0018	0,0082	0.1457	1.4478	0.0932
0.1138	0.0031	0.0773	0.0262	0.0775	0.1857	0.0018	0,0082	0.1457	0.6312	0.1190
0.3290	0.0089	0.0786	0.0544	0.1422	0.2429	0.0018	0,0082	0.1457	1.0035	0.0765
0.5970	0.0162	0.0877	0.0635	0.8381	0.5924	0.0018	0,0082	0.1457	2.3424	0.0843
0.3010	0.0082	0.0843	0.0466	0.4105	0.4271	0.0018	0,0082	0.1457	1.4253	0.0843
0.6389	0.0174	0.1357	0.1415	0.2191	0.1981	0.0018	0,0082	0.1457	1.4983	0.1209
0.6389	0.0174	0.1167	0.1415	0.2191	0.3436	0.0018	0,0082	0.1457	1.6247	0.1290

0.4307	0.0117	0.0348	0.1172	0.1289	0.2514	0.0018	0,0082	0.1057	1.0623	0.0325
0.3608	0.0098	0.0833	0.0547	0.0321	0.1371	0.0018	0,0082	0.1457	0.8253	0.0633
0.4421	0.0120	0.1006	0.0752	0.0882	0.1314	0.0018	0,0082	0.1457	0.9971	0.0674
0.4900	0.0133	0.1006	0.0564	0.0662	0.1424	0.0018	0,0082	0.1457	1.0164	0.0674
0.3739	0.0102	0.0381	0.0569	0.0525	0.1420	0.0018	0,0082	0.1457	0.8212	0.0557
0.4570	0.0124	0.0381	0.0569	0.1074	0.1420	0.0018	0,0082	0.1457	0.9614	0.0557
0.3157	0.0086	0.0381	0.0569	0.0537	0.1420	0.0018	0,0082	0.1457	0.7626	0.0557
0.5179	0.0141	0.0702	0.0952	0.1729	0.1204	0.0018	0,0082	0.1457	1.1381	0.0662
0.4643	0.0126	0.0702	0.0952	0.1729	0.1264	0.0018	0,0082	0.1457	1.0891	0.0726
0.4643	0.0126	0.0702	0.0952	0.1729	0.1264	0.0018	0,0082	0.1457	1.0891	0.0703
0.5408	0.0147	0.4444	0.0218	0.1746	0.1321	0.0018	0,0082	0.1457	1.4760	0.0767
0.3936	0.0107	0.2357	0.0170	0.1425	0.2039	0.0018	0,0082	0.1457	1.1509	0.0729
0.5268	0.0143	0.4888	0.0335	0.1964	0.1321	0.0018	0,0082	0.1457	1.5395	0.0795
0.5089	0.0138	0.0540	0.0635	0.0982	0.1327	0.0018	0,0082	0.1457	1.0186	0.0694
0.4741	0.0129	0.0589	0.0635	0.0982	0.1161	0.0018	0,0082	0.1457	0.9712	0.0833
0.3863	0.0105	0.1270	0.0397	0.1440	0.1571	0.0018	0,0082	0.1457	1.0122	0.0847
0.3863	0.0105	0.1365	0.0397	0.0917	0.1429	0.0018	0,0082	0.1457	0.9550	0.0847
0.3863	0.0105	0.1830	0.0595	0.2161	0.1310	0.0018	0,0082	0.1457	1.1339	0.0847
0.3863	0.0105	0.1830	0.0397	0.0917	0.1310	0.0018	0,0082	0.1457	0.9897	0.0847
0.4214	0.0115	0.0988	0.0476	0.1729	0.1429	0.0018	0,0082	0.1457	1.0425	0.0847
0.4214	0.0115	0.1131	0.0476	0.1729	0.1310	0.0018	0,0082	0.1457	1.0449	0.0847
0.4214	0.0115	0.1036	0.0476	0.1729	0.1310	0.0018	0,0082	0.1457	1.0354	0.0847
0.4214	0.0115	0.1131	0.0476	0.1729	0.1429	0.0018	0,0082	0.1457	1.0568	0.0847
0.8571	0.0233	0.0925	0.0298	0.0576	0.1981	0.0018	0,0082	0.1457	1.4059	0.0857
0.8571	0.0233	0.0925	0.0298	0.0576	0.1981	0.0018	0,0082	0.1457	1.4059	0.0857
0.8571	0.0233	0.0925	0.0298	0.0576	0.1981	0.0018	0,0082	0.1457	1.4059	0.0857
0.8571	0.0233	0.0925	0.0298	0.0576	0.1981	0.0018	0,0082	0.1457	1.4059	0.0857
0.4341	0.0118	0.0643	0.0346	0.0471	0.1257	0.0018	0,0082	0.1457	0.8652	0.0742
0.4479	0.0122	0.0643	0.0456	0.0471	0.1123	0.0018	0,0082	0.1457	0.8768	0.0707
0.4479	0.0122	0.0643	0.0456	0.0471	0.1123	0.0018	0,0082	0.1457	0.8768	0.0707

0.4557	0.0124	0.0643	0.0489	0.0471	0.1163	0.0018	0,0082	0.1457	0.8923	0.0861
0.4051	0.0110	0.0643	0.0346	0.0471	0.1163	0.0018	0,0082	0.1457	0.8259	0.0742
0.4300	0.0117	0.0643	0.0456	0.0471	0.0980	0.0018	0,0082	0.1457	0.8442	0.1020
0.4917	0.0134	0.0587	0.0828	0.0982	0.1538	0.0018	0,0082	0.1457	1.0461	0.0694
0.4741	0.0129	0.0968	0.0762	0.0982	0.1461	0.0018	0,0082	0.1457	1.0518	0.0806
0.4821	0.0131	0.0258	0.0476	0.0746	0.1164	0.0018	0,0082	0.1457	0.9072	0.0833
0.5179	0.0141	0.0258	0.0476	0.0746	0.1381	0.0018	0,0082	0.1457	0.9656	0.0707
0.4821	0.0131	0.0258	0.0476	0.0746	0.1381	0.0018	0,0082	0.1457	0.9289	0.0703
0.4821	0.0131	0.0258	0.0476	0.0746	0.1177	0.0018	0,0082	0.1457	0.9085	0.0808
0.4821	0.0131	0.0258	0.0476	0.0746	0.1381	0.0018	0,0082	0.1457	0.9289	0.0729
0.4875	0.0133	0.0971	0.1190	0.0655	0.2971	0.0018	0,0082	0.1457	1.2271	0.0649
0.5510	0.0150	0.1000	0.1166	0.1603	0.2971	0.0018	0,0082	0.1457	1.3876	0.0530
0.5333	0.0145	0.0952	0.0979	0.0582	0.2971	0.0018	0,0082	0.1457	1.2438	0.0609
0.3214	0.0087	0.0500	0.0476	0.0982	0.0891	0.0018	0,0082	0.1457	0.7626	0.0560
0.3214	0.0087	0.0500	0.0476	0.0982	0.0891	0.0018	0,0082	0.1457	0.7626	0.0784
0.3895	0.0106	0.0147	0.0861	0.1340	0.1300	0.0018	0,0082	0.1457	0.9123	0.0775
0.4056	0.0110	0.0147	0.0861	0.1340	0.1300	0.0018	0,0082	0.1457	0.9289	0.0775
0.3895	0.0106	0.0147	0.0861	0.1340	0.1300	0.0018	0,0082	0.1457	0.9123	0.0775
0.4056	0.0110	0.0147	0.0861	0.1340	0.1300	0.0018	0,0082	0.1457	0.9289	0.0775

Appendix D:

Summary of the established FTCPM variables

Distance to Destination (km)	Truck Model	Cargo Factor	Time Allowed	Return Cargo	Total VOCs (US$/v-km)	Freight Rate (US$/ton-km)
490	5	0.50	2.0	0	0.7959	0.3555
490	5	0.50	2.0	0	0.8116	0.3555
490	5	0.50	2.0	0	0.8273	0.3555
490	5	0.50	2.0	0	0.8336	0.3555
490	4	0.47	2.0	1	0.3320	1.0412
270	6	0.47	2.0	1	0.4957	1.8896
75	5	0.53	2.0	1	0.8793	2.2676
240	3	0.42	2.0	0	1.0420	1.5337
155	3	0.85	1.0	0	0.9405	0.5576
155	3	0.60	1.0	0	0.8417	1.0241
240	5	0.42	2.0	0	1.0458	1.4286
490	5	0.50	2.0	0	0.7959	0.3555
490	5	0.50	2.0	0	0.8116	0.3555
490	5	0.50	2.0	0	0.8273	0.3555
490	5	0.50	2.0	0	0.8336	0.3555
490	4	0.47	2.0	1	0.3320	1.0412
270	6	0.47	2.0	1	0.4957	1.8896
75	5	0.53	2.0	1	0.8793	2.2676

240	3	0.42	2.0	0	1.0420	1.5337
155	3	0.85	1.0	0	0.9405	0.5576
155	3	0.60	1.0	0	0.8417	1.0241
240	5	0.42	2.0	0	1.0458	1.4286
195	2	0.73	2.0	0	0.9927	0.3125
195	2	0.73	2.0	0	0.9927	0.3125
490	5	0.50	2.0	0	0.7959	0.3555
490	5	0.50	2.0	0	0.8116	0.3555
490	5	0.50	2.0	0	0.8273	0.3555
490	5	0.50	2.0	0	0.8336	0.3555
490	4	0.47	2.0	1	0.3320	1.0412
270	6	0.47	2.0	1	0.4957	1.8896
75	5	0.53	2.0	1	0.8793	2.2676
240	3	0.42	2.0	0	1.0420	1.5337
155	3	0.85	1.0	0	0.9405	0.5576
155	3	0.60	1.0	0	0.8417	1.0241
240	5	0.42	2.0	0	1.0458	1.4286
490	5	0.50	2.0	0	0.7959	0.3555
490	5	0.50	2.0	0	0.8116	0.3555
490	5	0.50	2.0	0	0.8273	0.3555
490	5	0.50	2.0	0	0.8336	0.3555
490	4	0.47	2.0	1	0.3320	1.0412
270	6	0.47	2.0	1	0.4957	1.8896
75	5	0.53	2.0	1	0.8793	2.2676
240	3	0.42	2.0	0	1.0420	1.5337
155	3	0.85	1.0	0	0.9405	0.5576

155	3	0.60	1.0	0	0.8417	1.0241
240	5	0.42	2.0	0	1.0458	1.4286
195	2	0.73	2.0	0	0.9927	0.3125
195	2	0.73	2.0	0	0.9927	0.3125
490	2	0.59	2.0	1	1.0243	0.0661
1,200	2	0.60	7.0	1	1.2418	0.0600
700	2	0.60	6.0	1	1.3323	0.0886
1,130	2	0.61	6.0	1	1.4478	0.0932
1,245	2	0.58	3.0	1	0.6312	0.1190
700	2	0.62	4.0	1	1.0035	0.0765
240	2	0.59	2.0	1	2.3424	0.0843
490	2	0.59	3.0	1	1.4253	0.0843
545	2	0.58	5.0	1	1.4983	0.1209
545	6	0.55	5.0	1	1.6247	0.1290
195	3	0.59	2.0	0	1.0823	0.0345
490	2	0.57	3.0	1	0.8253	0.0633
950	6	0.60	7.0	0	0.9971	0.0674
950	4	0.57	7.0	0	1.0164	0.0674
490	1	0.63	2.0	1	0.8212	0.0557
490	2	0.63	2.0	0	0.9614	0.0557
490	2	0.63	2.0	1	0.7626	0.0557
1,200	2	0.76	7.0	0	1.1381	0.0662
1,200	2	0.69	7.0	0	1.0891	0.0726
1,200	2	0.59	7.0	0	1.0891	0.0703
1,200	2	0.71	7.0	0	1.4760	0.0767
490	2	0.71	2.0	0	1.1509	0.0729

1,600	2	0.73	12.0	1	1.5395	0.0795
1,200	2	0.56	7.0	0	1.0186	0.0694
1,200	2	0.56	7.0	1	0.9712	0.0833
1,200	2	0.58	6.0	0	1.0122	0.0847
1,200	2	0.58	6.0	1	0.9550	0.0847
1,200	2	0.58	6.0	0	1.1339	0.0847
1,200	2	0.58	6.0	1	0.9697	0.0847
1,200	2	0.65	8.0	0	1.0425	0.0847
1,200	2	0.65	8.0	0	1.0449	0.0847
1,200	2	0.65	8.0	1	1.0354	0.0847
1,200	2	0.65	8.0	1	1.0568	0.0847
1,200	2	0.80	6.0	1	1.4059	0.0857
1,200	6	0.80	6.0	1	1.4059	0.0857
1,200	6	0.80	6.0	1	1.4059	0.0857
1,200	2	0.80	6.0	1	1.4059	0.0857
645	2	0.61	3.0	1	0.8652	0.0742
490	2	0.61	2.0	1	0.8768	0.0707
490	2	0.61	2.0	1	0.8768	0.0707
730	2	0.57	4.0	0	0.8923	0.0861
645	6	0.59	3.0	1	0.8259	0.0742
490	6	0.56	2.0	1	0.8442	0.1020
1,200	1	0.56	7.0	0	1.0461	0.0694
1,200	4	0.57	7.0	0	1.0518	0.0806
1,200	2	0.54	9.0	0	0.9072	0.0833
1,200	2	0.59	10.0	0	0.9656	0.0707
1,200	2	0.59	10.0	0	0.9289	0.0703

1,200	2	0.52	10.0	0	0.9085	0.0808
1,200	2	0.59	10.0	0	0.9289	0.0729
1,200	2	0.61	7.0	1	1.2271	0.0649
490	2	0.61	3.0	1	1.3876	0.0530
1,350	6	0.61	8.0	1	1.2438	0.0609
1,200	6	0.63	6.0	1	0.7626	0.0560
1,200	6	0.63	6.0	0	0.7626	0.0784
1,200	2	0.59	8.0	1	0.9123	0.0775
1,200	6	0.59	8.0	1	0.9289	0.0775
1,200	2	0.59	8.0	1	0.9123	0.0775
1,200	6	0.59	8.0	1	0.9289	0.0775
490	2	0.59	2.0	1	1.0243	0.0661
1,200	2	0.60	7.0	1	1.2418	0.0600
700	2	0.60	6.0	1	1.3323	0.0886
1,130	2	0.61	6.0	1	1.4478	0.0932
1,245	2	0.58	3.0	1	0.6312	0.1190
700	2	0.62	4.0	1	1.0035	0.0765
240	2	0.59	2.0	1	2.3424	0.0843
490	2	0.59	3.0	1	1.4253	0.0843
545	2	0.58	5.0	1	1.4983	0.1209
545	6	0.55	5.0	1	1.6247	0.1290
195	3	0.59	2.0	0	1.0823	0.0325
490	2	0.57	3.0	1	0.8253	0.0633
950	6	0.60	7.0	0	0.9971	0.0674
950	4	0.57	7.0	0	1.0164	0.0674
490	1	0.63	2.0	1	0.8212	0.0557

490	2	0.63	2.0	0	0.9614	0.0557
490	2	0.63	2.0	1	0.7626	0.0557
1,200	2	0.76	7.0	0	1.1381	0.0662
1,200	2	0.69	7.0	0	1.0891	0.0726
1,200	2	0.59	7.0	0	1.0891	0.0703
1,200	2	0.71	7.0	0	1.4760	0.0767
490	2	0.71	2.0	0	1.1509	0.0729
1,600	2	0.73	12.0	1	1.5395	0.0795
1,200	2	0.56	7.0	0	1.0186	0.0694
1,200	2	0.56	7.0	1	0.9712	0.0833
1,200	2	0.58	6.0	0	1.0122	0.0847
1,200	2	0.58	6.0	1	0.9550	0.0847
1,200	2	0.58	6.0	0	1.1339	0.0847
1,200	2	0.58	6.0	1	0.9897	0.0847
1,200	2	0.65	8.0	0	1.0425	0.0847
1,200	2	0.65	8.0	0	1.0449	0.0847
1,200	2	0.65	8.0	1	1.0354	0.0847
1,200	2	0.65	8.0	1	1.0568	0.0847
1,200	2	0.80	6.0	1	1.4059	0.0857
1,200	6	0.80	6.0	1	1.4059	0.0857
1,200	6	0.80	6.0	1	1.4059	0.0857
1,200	2	0.80	6.0	1	1.4059	0.0857
645	2	0.61	3.0	1	0.8652	0.0742
490	2	0.61	2.0	1	0.8768	0.0707
490	2	0.61	2.0	1	0.8768	0.0707
730	2	0.57	4.0	0	0.8923	0.0861

645	6	0.59	3.0	1	0.8259	0.0742
490	6	0.56	2.0	1	0.8442	0.1020
1,200	1	0.56	7.0	0	1.0461	0.0694
1,200	4	0.57	7.0	0	1.0518	0.0806
1,200	2	0.54	9.0	0	0.9072	0.0833
1,200	2	0.59	10.0	0	0.9656	0.0707
1,200	2	0.59	10.0	0	0.9289	0.0703
1,200	2	0.52	10.0	0	0.9085	0.0808
1,200	2	0.59	10.0	0	0.9289	0.0729
1,200	2	0.61	7.0	1	1.2271	0.0649
490	2	0.61	3.0	1	1.3876	0.0530
1,350	6	0.61	8.0	1	1.2438	0.0609
1,200	6	0.63	6.0	1	0.7626	0.0560
1,200	6	0.63	6.0	0	0.7626	0.0784
1,200	2	0.59	8.0	1	0.9123	0.0775
1,200	6	0.59	8.0	1	0.9289	0.0775
1,200	2	0.59	8.0	1	0.9123	0.0775
1,200	6	0.59	8.0	1	0.9289	0.0775

Appendix E:

Freight Rates Sensitivity to VOCs (Exponential Function)

VOCs(US$/v-km	$VOCs^2$(US$/v-km)	$VOCs^3$(US$/v-km)	Freight Rates(US$/ton-km)	*Predicted Freight Rates(US$/ton-km)*
1.0243	1.0491	1.0746	0.0661	0.071060921
1.2418	1.5422	1.9151	0.0600	0.076757382
1.3323	1.7750	2.3648	0.0886	0.081598841
1.4478	2.0961	3.0347	0.0932	0.088873769
0.6312	0.3984	0.2514	0.1190	0.099118613
1.0035	1.0069	1.0104	0.0765	0.071121692
2.3424	5.4870	12.8531	0.0843	0.086051563
1.4253	2.0314	2.8954	0.0843	0.087399638
1.4983	2.2449	3.3635	0.1209	0.092222459
1.6247	2.6397	4.2888	0.1290	0.100389426
1.0823	1.1713	1.2677	0.0345	0.071523504
0.8253	0.6811	0.5621	0.0633	0.077462763
0.9971	0.9942	0.9914	0.0674	0.071165474
1.0164	1.0331	1.0500	0.0674	0.071069108
0.8212	0.6743	0.5537	0.0557	0.077749713
0.9614	0.9244	0.8887	0.0557	0.071641547
0.7626	0.5816	0.4435	0.0557	0.082573093
1.1381	1.2954	1.4743	0.0662	0.072761916

1.0891	1.1862	1.2920	0.0726	0.071635976
1.0891	1.1862	1.2920	0.0703	0.071635976
1.4760	2.1787	3.2159	0.0767	0.090744292
1.1509	1.3246	1.5245	0.0729	0.073142884
1.5395	2.3700	3.6485	0.0795	0.094948697
1.0186	1.0375	1.0568	0.0694	0.071065056
0.9712	0.9432	0.9161	0.0833	0.071471586
1.0122	1.0245	1.0370	0.0847	0.071080911
0.9550	0.9121	0.8711	0.0847	0.071769693
1.1339	1.2857	1.4579	0.0847	0.072642834
0.9897	0.9794	0.9693	0.0847	0.071232498
1.0425	1.0869	1.1331	0.0847	0.071109125
1.0449	1.0918	1.1409	0.0847	0.071122195
1.0354	1.0720	1.1100	0.0847	0.071079231
1.0568	1.1169	1.1803	0.0847	0.071210461
1.4059	1.9765	2.7788	0.0857	0.086144407
1.4059	1.9765	2.7788	0.0857	0.086144407
1.4059	1.9765	2.7788	0.0857	0.086144407
1.4059	1.9765	2.7788	0.0857	0.086144407
0.8652	0.7485	0.6476	0.0742	0.075050613
0.8768	0.7688	0.6741	0.0707	0.074459965
0.8768	0.7688	0.6741	0.0707	0.074459965
0.8923	0.7962	0.7104	0.0861	0.073756203
0.8259	0.6821	0.5634	0.0742	0.077421242

0.8442	0.7126	0.6016	0.1020	0.076243037
1.0461	1.0943	1.1448	0.0694	0.071129329
1.0518	1.1063	1.1636	0.0806	0.071168647
0.9072	0.8230	0.7466	0.0833	0.073161023
0.9656	0.9324	0.9004	0.0707	0.071564852
0.9289	0.8629	0.8016	0.0703	0.07243115
0.9085	0.8254	0.7499	0.0808	0.073110547
0.9289	0.8629	0.8016	0.0729	0.07243115
1.2271	1.5057	1.8476	0.0649	0.0760725
1.3876	1.9255	2.6718	0.0530	0.084980108
1.2438	1.5470	1.9242	0.0609	0.076850696
0.7626	0.5816	0.4436	0.0560	0.082571138
0.7626	0.5816	0.4436	0.0784	0.082571138
0.9123	0.8323	0.7594	0.0775	0.072973294
0.9289	0.8629	0.8016	0.0775	0.072431954
0.9123	0.8323	0.7594	0.0775	0.072973294
0.9289	0.8629	0.8016	0.0775	0.072431954
1.0243	1.0491	1.0746	0.0661	0.071060921
1.2418	1.5422	1.9151	0.0600	0.076757382
1.3323	1.7750	2.3648	0.0886	0.081598841
1.4478	2.0961	3.0347	0.0932	0.088873769
0.6312	0.3984	0.2514	0.1190	0.099118613
1.0035	1.0069	1.0104	0.0765	0.071121692
2.3424	5.4870	12.8531	0.0843	0.086051563

1.4253	2.0314	2.8954	0.0843	0.087399638
1.4983	2.2449	3.3635	0.1209	0.092222459
1.6247	2.6397	4.2888	0.1290	0.100389426
1.0823	1.1713	1.2677	0.0325	0.071523504
0.8253	0.6811	0.5621	0.0633	0.077462763
0.9971	0.9942	0.9914	0.0674	0.071165474
1.0164	1.0331	1.0500	0.0674	0.071069108
0.8212	0.6743	0.5537	0.0557	0.077749713
0.9614	0.9244	0.8887	0.0557	0.071641547
0.7626	0.5816	0.4435	0.0557	0.082573093
1.1381	1.2954	1.4743	0.0662	0.072761916
1.0891	1.1862	1.2920	0.0726	0.071635976
1.0891	1.1862	1.2920	0.0703	0.071635976
1.4760	2.1787	3.2159	0.0767	0.090744292
1.1509	1.3246	1.5245	0.0729	0.073142884
1.5395	2.3700	3.6485	0.0795	0.094948697
1.0186	1.0375	1.0568	0.0694	0.071065056
0.9712	0.9432	0.9161	0.0833	0.071471586
1.0122	1.0245	1.0370	0.0847	0.071080911
0.9550	0.9121	0.8711	0.0847	0.071769693
1.1339	1.2857	1.4579	0.0847	0.072642834
0.9897	0.9794	0.9693	0.0847	0.071232498
1.0425	1.0869	1.1331	0.0847	0.071109125
1.0449	1.0918	1.1409	0.0847	0.071122195

1.0354	1.0720	1.1100	0.0847	0.071079231
1.0568	1.1169	1.1803	0.0847	0.071210461
1.4059	1.9765	2.7788	0.0857	0.086144407
1.4059	1.9765	2.7788	0.0857	0.086144407
1.4059	1.9765	2.7788	0.0857	0.086144407
1.4059	1.9765	2.7788	0.0857	0.086144407
0.8652	0.7485	0.6476	0.0742	0.075050613
0.8768	0.7688	0.6741	0.0707	0.074459965
0.8768	0.7688	0.6741	0.0707	0.074459965
0.8923	0.7962	0.7104	0.0861	0.073756203
0.8259	0.6821	0.5634	0.0742	0.077421242
0.8442	0.7126	0.6016	0.1020	0.076243037
1.0461	1.0943	1.1448	0.0694	0.071129329
1.0518	1.1063	1.1636	0.0806	0.071168647
0.9072	0.8230	0.7466	0.0833	0.073161023
0.9656	0.9324	0.9004	0.0707	0.071564852
0.9289	0.8629	0.8016	0.0703	0.07243115
0.9085	0.8254	0.7499	0.0808	0.073110547
0.9289	0.8629	0.8016	0.0729	0.07243115
1.2271	1.5057	1.8476	0.0649	0.0760725
1.3876	1.9255	2.6718	0.0530	0.084980108
1.2438	1.5470	1.9242	0.0609	0.076850696
0.7626	0.5816	0.4436	0.0560	0.082571138
0.7626	0.5816	0.4436	0.0784	0.082571138

0.9123	0.8323	0.7594	0.0775	0.072973294
0.9289	0.8629	0.8016	0.0775	0.072431954
0.9123	0.8323	0.7594	0.0775	0.072973294
0.9289	0.8629	0.8016	0.0775	0.072431954

Appendix F:

Characteristics of Vehicles Plying the Northern Corridor Road

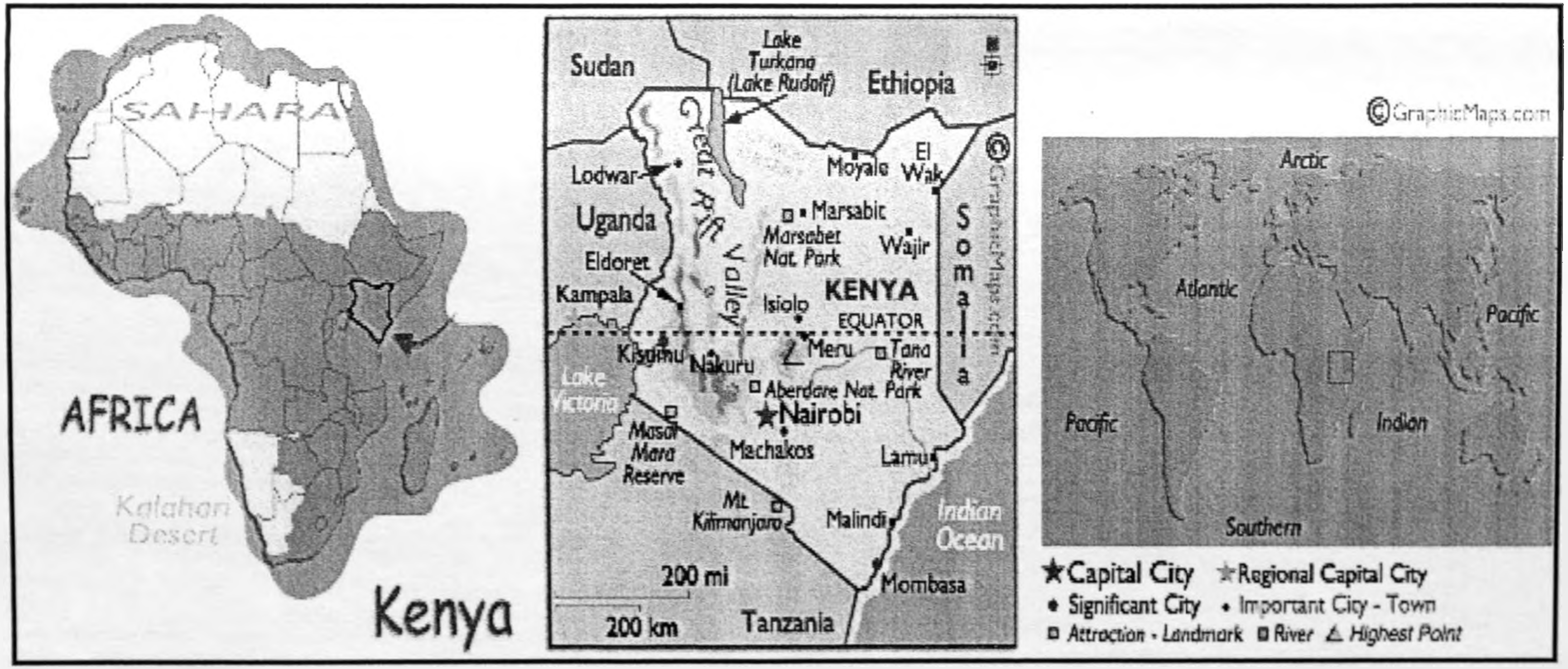
Item	HGV-1	HGV-2	HGV-3	HGV-4	HGV-5
Axles	7	7	7	6	7
wheels	28	26	24	22	24
Average life	6	7	7	8	6
GVW	54	50	50	50	54
Price of new truck	12000000	9970455	6375000	7266667	3196000
Maintenance frequency (km)	66000	184043	14000	44333	10000
Maintenance cost	120000	250405	33750	107667	45000
Fuel type	Diesel	Diesel	Diesel	Diesel	Diesel
Breaking power	255kw	255kw	255kw	220kw	255kw
Frontal area	9	8.5	8.5	6.6	8.5
PCSE	2.2	2.0	2.0	1.5	1.8
Driving power	227kw	227kw	227kw	100kw	227kw
Rated engine power	300kw	288kw	288kw	87kw	288kw
Dimensions	(6x4)	(6x4)	(6x2)	(6x2)	(6x4)

Source: Field survey, 2007

HGV-1 to HGV-5 is equivalent to Renault, Mercedes, Isuzu, Mitsubishi and Nissan
All prices are indicative as obtained from field survey.
Dealers confirmed some of the figures.
GVW: Gross Vehicle Weight and PCSE: Passenger Car Space Equivalent

No.	Description	Cars		Pick-ups		Mini bus		Bus		Head	
1	Vehicle make	Chevrolet Aveo		TFR32		NKR (25 pass)		FRR (41 / 51 pass)		FVX (6x2)	
		Chevrolet Optra		TFR54		NPR (29 pass)		MV123 (62 pass)		FVZ (6x4)	
				TFS77 S/C & D/C		NQR (33 / 37)					
2	Passenger capacity	4		4		25 / 29 / 37 respectively		41 / 62 respectively		0	
3	Vehicle price (US $)	Aveo	19,890	TFR32	20,233.20	NKR	30,178.33	FRR	56,488.34	FVX	90,535
				TFR54	21,262.00	NPR	37,037.04				
		Optra	25,034	TFS77 S/C	26,748.97	NQR	43,689.99	MV123	97,393.69	FVZ	102,881
				TFS77 D/C	37,722.91						
4	Type of tyre used	Aveo - Firestone F570 175/70R14		TFR32 TFR54 TFS77S/C	YANA MORAN (225/75R15)	NKR	Mitchelin XZA 7.00R16	FRR	Goodyear Omni truck 265/70R19.5	Mitchelin XZY 12R22.5	
		Optra Hankook Optimo K406 195/55R15		TFS77 D/C	Pirelli Scorpion 245/70R16	NPR / NQR	Mitchelin XZY 9.5R17.5	MV123	Goodyear G286 295/80R22.5		
5	Tyre price (US $)	F 570	51	Moran	111.51	XZA	150.75	Omni truck	260.63	315.50	
		K 460	NA	Scorpion	137.17	XZY	219.34	G286	377.23		
6	Fuel used	Unleaded gasoline		TFR32	Unleaded gasoline	Automotive diesel		Automotive diesel		Automotive diesel	
				TFR54, TFS77S/C & TFS77 D/C	Automotive diesel						
7	Fuel price (US $ / L)	1.07		Gasoline	1.07	0.92		0.92		0.92	
				Diesel	0.92						
8	Type of lubricant used	Mobil Super XHP		TFR32	Mobil super 20W/50	Total Rubia XT 15W/40		Total Rubia XT 15W/40		Total Rubia XT	
				REST	AC Delco / Delvac 15W/40						
9	Lubricant price (US $ / L:)			Mobil super	1.54	1.70		1.70		1.70	
				Ac Delco	1.34						
10	Gross Vehicle Weight (Tons)			TFR32	2.55	NKR	5.7	FRR	10.4	22	
				TFR54	2.65	NPR	7.5				
				TFS77 S/C	2.75	NQR	8.5	MV123	16		
				TFS77 D/C	2.75						

Source: General Motors, 2007



Source: Kenewzmap