MODELLING COCOA HAULAGE AS A TRANSSHIPMENT PROBLEM

CASE STUDY: KUAPA KOKOO COMPANY LIMITED

By

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DECLARATION

I hereby declare that this submission is my own work towards the Master of Science degree and that, to the best of my knowledge it contains no material previously published by another person nor material which has been accepted for award of any other degree of the University except where due acknowledgement has been made in the text.

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ABSTRACT

The transportation problem is a special class of the linear programming problem. It deals with the situation in which a commodity is transported from Sources to Destinations. The transshipment problem is an expansion of the transportation where intermediate nodes which are also referred to as transshipment node are added to account for locations such as warehouses. Our main objective is to model Kuapa cocoa transportation as transshipment problems and also minimize the cost of transportation of cocoa in the Kuapa Company. We will formulate the Transshipment problem as a Transportation problem and use the Transportation algorithm to solve it. The Quantitative Method (QM) Software will be use to analyze the data. We conclude that if Kuapa adapt this method, the cost of transporting Cocoa will be minimized.

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DEDICATION

I dedicate this work to my family.

ACKNOWLEDGEMENT

O worship the king All glorious above; O gratefully sing His power and His love: Our shield and defender, The ancient of days, pavilioned in splendour, And girded with praise for giving me His strength and wisdom throughout this work.

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CHAPTER ONE

INTRODUCTION

1.1 Introduction

Though many people are becoming familiar with the numerous health benefits derived from the use of cocoa beans, it is also important to realize the history of this important “superfood”.

The cocoa bean is a product of the “cacao tree”, which produces cacao pods. Inside each cacao pod can be found the cocoa beans ranging from 30 to 50 beans. In addition to this, there is a sweet pulp surrounding the cocoa beans, which is called “baba de cacao” by some cocoa bean harvesters. The appearance of the cocoa bean ranges from pink, brown to purple, and the texture of the cocoa bean is fairly soft.

It is speculated that the cacao tree was first introduced to Central America in ancient times, by the Mayas. In Mexico, the cacao tree was grown and harvested by the Olmecs, and eventually became a common form of currency throughout the Americas. This was, of course, prior to the Spanish conquest of the area. The cacao tree is considered to be a native species to the Americas.

When Hernan Cortes first began the conquest of Mexico, he came into contact with Montezuma II, who was the then emperor over the Aztecs. In the chronicles of his journey, it is recorded that Montezuma would not approve of any other beverage at his meals except chocolate. When dining on chocolate, Montezuma reportedly ate with a golden spoon, out of a golden goblet. At this time, powdered cocoa beans were combined with spices, vanilla, and other ingredients, and then whipped into foam. Reportedly, 200 portions of this chocolate beverage were consumed by Montezuma's court of nobles on a daily basis, while Montezuma consumed 50 chocolate beverages each day.

It is recorded that Chocolate was first introduced in the European area during the 1600's, most likely by the Spaniards. In addition to this, the Spaniards began cultivating the cacao tree plantation, expanding to areas such as the Philippines, as well as the West Indies. The botanical name of the cacao plant itself is "Theobroma Cacao", which, loosely translated, means "food of the gods". Cocoa beans were a staple of society in many areas around the world, and have rapidly grown in popularity in today's society.

In Ghana, Cocoa was introduced after Tetteh Quarshie travelled to Fernando Po (now Bioko in Equatorial Guinea). His introduction of cocoa beans on his return transformed the economy of the Gold Coast. Tetteh Quashie was in fact the first blacksmith to establish at Akwapim-Mampong. His hobby was farming. Hitherto, palm-oil and rubber were the main staple industries in Ghana.

In 1879 Tetteh Quarshie planted the seeds at Mampong with some success. Friends and relatives also undertook the planting of cocoa when pods were distributed to them. Soon other farmers also engaged in cocoa farming. It was only at this point that the Basel Missionaries stepped into the picture by importing large quantities of the crop into the country. From the Gold Coast (Ghana) cocoa beans or cuttings were sent to other countries like Nigeria and Sierra leone.

The export of cocoa from Ghana began in 1891, (two bags exported). Ghana once provided almost half of world output. Between 1910 and 1980 Ghana was the world's largest exporter.

This position was ceded due to bush fires etc. However Ghana's cocoa is still of the highest quality and the country earns hundreds of millions of dollars annually from the export of the beans and processed materials.

1.1.1 Cocoa-based farming system

The cocoa crop covers almost 30 percent of the arable land. The main growing areas are in central and southwest Ghana. The best conditions for cocoa are a permeable soil with a good structure, annual rainfall of between 1250 and1500 mm and a soil pH of between 5.6 and 6.5. The average cocoa farm covers 1.2 ha but there are a few large plantations. Mineral fertilizer and manure inputs go to annual crops such as maize, plantains and yams. Failure of these crops means that farmers lose the whole investment (seeds, fertilizer, pesticides, etc), while cocoa as a permanent crop provides a harvest each year.

In the early stages of the cocoa plants, plantain grows fast and provides shade. After five years, the cocoa plants would have developed a closed canopy and farmers would then maintain the crop as a monoculture. Yields decrease after 20 years, but production is possible for up to 50 years. The farmers usually maintain between 300 and 400 cocoa trees per hectare. Crig (2001) advises leaving a minimum of 6 and a maximum of 8 large forest trees per hectare to shade the cocoa trees. These forest trees (preferably leguminous) need to be selected during forest clearing. Where the canopy is not closed, farmers sometimes plant other leguminous trees such as Gliricidia.

The farmers normally remove the lower branches of the cocoa trees to improve air circulation and to facilitate harvesting. These branches are normally left on the ground, together with all the leaves that fall off. This results in a thick litter layer, which is important for nutrient cycling, but decomposition is rapid because of the high temperatures and rainfall (Ofori-Frimpong & Rowell, 1999). The litter layer also protects the soil against erosion and prevents weed growth.

1.1.2 Economic importance

The cocoa industry has been the driving force of Ghana's economic development and expansion through employment of rural labour, development of trade and commerce, savings, investment, and growth of the money economy (Asante, 1997).

Between 1990 and 1999, the industry contributed an average of 31 percent of total foreign exchange earnings annually and an average of 12 percent of total annual government revenue. It is the source of income and livelihood for about 25 percent of the population (ISSER, 2000).

Small-scale farmers dominate the cocoa industry in Ghana. The indications are that the industry will continue to play a significant role in the national economy. Efforts to place the industry on a firm footing have been ongoing. Successive governments have supported cocoa cultivation through producer price stabilization, the provision of research and extension services for the control of cocoa pests and diseases, and the dissemination of improved agronomic practices.

There is no doubt that cocoa occupies a centre stage in our economy and the indications are that it will continue to assume such increasing importance for a long time to come. This reinforces the fact that the Ghanaian economy rests to a large extent on the fortunes of this golden pod. The government, realizing the importance of agriculture to alleviating poverty in

Ghana, has identified cocoa as a priority sub-sector. It therefore attaches great importance to this sector. In doing this, the Government is committed to ensuring that all the needed assistance is given to the cocoa sector. As a result of this, Government has come up with various policy initiatives which undeniably have led to tremendous successes."

Cocoa has been the back bone of the country so far as income is concern, however, due to the high rate of Urbanization that have allowed infrastructure such as Schools, Hospitals, Markets, Stadia, Buildings etc to be built anywhere in the country, the farming areas have also shifted from cities and towns to far distant areas. Even though farming areas are been shifted to far places the government cannot overlook farming especially cocoa farming since the country depends so much on it. Its significance to the nation is emphasised by the huge amount of money located to this sector. Among these initiatives vigorously pursued by the Government include: increased producer prices and payment of bonuses; effective diseases and pest control exercise; improving the agronomic practices on our cocoa farms; increased value addition to cocoa and introduction of new and innovative methods of cocoa farming on pilot basis in selected districts in all cocoa growing regions etc.

However, after spending so much on cocoa production, the dried cocoa beans need to be conveyed to the port for export so that the government will get its foreign exchange. It is therefore necessary that the government considers the best way to convey cocoa at a low cost so that maximum profits can be realized by the government. The process of sending goods and people from one location to another is known as transportation.

1.2 BACKGROUND

1.2.1 History of Transportation

Ever since mankind inhabited earth, he has always been on the move, in search of safer places or water, initially on foot. Walking is the earliest and most dependable mode of transport.

People learned to tame animals for food and to ride them for hunting and further movement. Around 3500 B.C the wheel was invented, the discovery of which revolutionized forms of transport. It remains till today the most beneficial discovery in the field of transport. In their search for safer lands, man encountered rivers and streams that had to be crossed. Necessity gave rise to dugouts transportation, raft transportation and canoe transportation often made of hollowed tree trunks. Thus began the age of water transport. The Phoenicians are considered the best sailors and forerunners of all ships that sail on sea. Slowly well-laid roads made their appearance and by 1662, a carriage drawn by horses was being used as public transport complete with scheduled stops and fares.

The discovery of the steam engine in 1769 soon led to steam boats in 1787 and later to steam powered road vehicles. In 1790 the bicycle made its first hesitant appearance and throughout the succeeding decades it underwent many transformations to become the bicycle, as we know it today.

The provision of infrastructure and operations in all modes of transport in Ghana are dominated by the state. Except in the case of road transport, the public sector has been heavily involved in operations in all modes and has monopoly over rail and inland water transport.

Road

Road transport is very important to the Ghanaian economy. It is estimated that road transport accounts for 94% of freight ton-miles and about 97% of passenger miles in the country.

Road transport in Ghana may be categorized into 4 main segments, namely urban, express services, rural-urban and rural. The demand for urban passenger transport is mainly by residents commuting to work, school, and other economic, social and leisure activities. Most urban transportation in Ghana is by road and provided by private transport including taxis, mini-buses and state/private-supported bus services. Buses are the main mode of transport accounting for about 60% of passenger movement. Taxis account for only 14.5% with the remaining accounted for by private cars.

One important trend in road transport (especially inter-city) is that there has been a shift from mini-buses towards medium and large cars with capacities of 30-70 seats. There has been a growing preference for good buses as the sector continues to offer more options to passenger in tons of quality of vehicles used.

Ghana's road transport infrastructure is made up of 50,620km of road network linking the entire country. These are under the control of the Ghana Highways Authority (14,047 km), Department of Urban Roads (4,063 km) and the Department of Feeder Roads (32,594 km). About 15.7% of the total road network is paved.

On the whole, traffic densities are low, except in the large cities of Accra and Kumasi, where peak hour densities are relatively high. The intention is to have many of the existing highways tolled and private-sector participation in road construction and ownership.

Railways

A triangular rail network (of 950km) links the three cities of Kumasi in the heart of the country, Takoradi in the west and Accra-Tema in the east. The network connects the main agricultural and mining regions to the ports of Tema and Takoradi. It has mainly served the purpose of hauling minerals, cocoa and timber. Considerable passenger traffic is also carried on the network.

There are firm plans by the Government to develop the rail network more extensively to handle up to 60% of solid and liquid bulk cargo haulage between the ports and the interior and /or the landlocked neighbouring countries to the north of Ghana and elsewhere. The government has set out seeking the necessary investment to restore the network, improve speed and axle load capacity and replace worn-out rolling stock. Plans are far advanced to privatize the State-owned Ghana Railways Corporation (GRC) through concession and to provide much greater capacity for rail haulage of containers and petroleum products.

Air

The country is at the hub of an extensive international (and national) airline network that connects Ghana to Africa and the rest of the world. Most major international carriers fly regularly to Kotoka International Airport (KIA) in Accra, the main entry point to Ghana by air. This is the result of Ghana's open skies policy, which frees an air space regulator from the constraints on capacity, frequency, route, structure and other air operational restrictions. In effect, the policy allows the Ghana Civil Aviation Authority (GCAA) to operate with minimal restrictions from aviation authorities, except in cases of safety and standards and/or dominant position to distort market conditions.

Ghana is working to position herself as the gateway to West Africa. KIA remains the leading and preferred airport in the sub-region, having attained Category One status by the US Federal Aviation Administration (FAA) audit as part of their International Aviation Safety Audit (IASA) programme. As at now, Ghana is one of the four countries in sub-Saharan Africa in this category. The others are Egypt, South Africa and Morocco. It handles the highest volume of cargo in the sub-region and has all the requisite safety facilities, recommended practices and security standards.

A rehabilitation programme embarked upon since 1996 has brought about an expansion and refurbishment and upbringing of facilities at the international terminal building, as well as the domestic terminal. These terminals now have significantly increased traveler and cargo capacity. The airport's runway has been extended to cater for all types of aircraft allowing direct flights from Ghana at maximum take-off weight without the need for technical stops en-route.

Harbours

Ghana has two (2) commercial ports at Tema and Takoradi. An inland port is under construction at Boankra, near Kumasi. The port of Tema covers 166 hectares of water area enclosed by 2 breakwaters. There are 2 quays housing 12 multi-purpose berths. Quay 1 houses berth 6-12, while Quay 2 houses berths 1-5. These berths are operated as common-user and a wide range of cargo including dry bulks, steel products, bagged cargo, newspapers, vehicles and containers. There is a terminal for handling crude and other liquid petroleum products. The oil berth can accommodate tanker of up to 244 metres in length with a maximum draught of 9.7 metres.

Recent years have seen a rapid increase in cargo through Tema, owing to trans-shipment and transit traffic to land-locked Burkina Faso, Mali and Niger. Indications are that traffic will continue to grow in the foreseeable future.

The Takoradi port, a much smaller one, was commissioned in 1928, but underwent major rehabilitation in the 1990s. It is slated for another massive refurbishment under the Ghana Gateway Project in the near future. Currently, it handles about 60% of Ghana's total exports, which mainly includes minerals (manganese, bauxite and gold), timber and cocoa.

A new centrally located "inland port" is being constructed at Boankra near Kumasi in the heart of the country. This is expected to be an important staging post for goods in transit to and from the landlocked lying north of Ghana. This will be a multi-modal facility handling both road and rail traffic. When the facility enters service in 2005, cargo owners to the northern part of Ghana were able to use Boankra as their trans-shipment instead of Tema and Takoradi.

Water

The Volta Lake was created in the early 1960's by building a dam at Akosombo and flooding the long valley of the River Volta. It is the largest man-made lake in the world stretching 415km from Akosombo, 101km north of Accra, to Buipe in northern Ghana, about 200km from Ghana's border with Burkina Faso.

As a waterway, the Volta Lake plays a key role in the "Ghana Corridor" programme by providing a useful and low cost alternative to road and rail transport between the north and the south. Ghana is in an advantageous position, by virtue of her seaports and inland lake transport system, to service the maritime needs of land-locked countries to the north of Ghana.

Volta Lake Transport Company (VLTC) uses a fleet of pusher tugs and assorted barges to provide regular north-south services for general cargo and liquid bulks, and tramping service for local traders. VLTC carries 88,000 tonnes of cargo annually.

Northbound, one of the most important cargoes is diesel oil, which is piped to Akosombo from the Tema Oil Refinery and taken on to final destination (Buipe) by barge. Other cargo includes alumina, sulphate, cement, and fertilizer all of which are conveyed to Akosombo by truck.

Southbound, the barges carry a range of agricultural produce including cassava chips, cotton lint, cottonseed and sheanuts. All these items are trucked south (from Akosombo) to Accra and Tema, from where cottonseeds and sheanuts are exported.

VLTC also operates a 300-passenger capacity vessel between Akosombo and Yeji in Northern Ghana (293km). This vessel is designed to carry cargo as well as passengers.

Even though the Government is doing his best to produce and buy more cocoa for export, the demand has become excessively high that the government cannot only do this job. This brought about more private firms and companies like Amajaro, Kuapa, and GOC etc to the scene to help the government. Among these firms is the Kuapa Company limited.

1.2.2 Kuapa Company Limited

In 1993 the Government of Ghana initiated the partial liberalization of its most significant economic export, cocoa beans. Having resisted World Bank pressure to liberalize fully, the

Cocoa Marketing Board retained its monopoly on exports through the Cocoa Marketing Company. It thus sustained its farm-to-port quality control system of every sack and its authority to determine the terms of trade from farmer to free on board (fob). This was an attempt to keep Ghana's premium status as the second largest cocoa supplier in the world and as a reliable exporter. In contrast to the situation in neighbouring Côte d'Ivoire, the largest supplier, it also left a dependable export channel for farmers in place (Ronchi, 2002).

In common with other liberalizations of the period, however, farmers – particularly the considerable number of women cocoa farmers in Ghana – were considered not as 'protagonists' in the exercise but as subjects. This assumption is epitomized by the terminology of the liberalizations itself, which granted trade licenses to 'buying companies', ignoring the fact that what farmers want is to 'sell', not 'buy' cocoa.

In 1993, just over 2,000 farmers in 22 villages were therefore assisted by Twin, a UK NGO, and the Netherlands development organization SNV to establish a co-operatively owned company to 'buy' its own cocoa and then 'sell' it to the Cocoa Marketing Company. From those modest beginnings, Kuapa Kokoo has evolved to become a complex, multifaceted institution working in five of the six growing regions of Ghana, with an active membership of more than 45,000 farmers in more than 1,300 villages or Kuapa Kokoo societies.

The organisation is often cited as a success story in the field of fair trade, its products being used in many Fair-trade labelled products. It is the largest cooperative in Ghana, and counts 45,000 cocoa growers as members. Day Chocolate Company sales rose to over £5m in 2004. Between 1993 and 2004 Kuapa received over $2m in extra Fair-trade premiums. Part of the money was paid to the farmers; the rest went to projects such as the construction of four new schools.

There is a visible and positive trend in women's involvement at all levels of the organization. Between 1998 and 2006 female representation increased at society executive level from 29 to 32 per cent, at area level from 29 to 45 per cent and on the National Executive Council from 15 to 60 per cent. This exceeded the target set in 2001 for 30 per cent female participation at all levels of decision-making (Ronchi, 2002). In addition, Kuapa Kokoo farmers have a direct and meaningful stake in the Divine chocolate brand marketed in the UK, Ireland and the USA and in several other countries. In this period, their equity stake in the UK Company rose from 33 to 45 per cent.

At the heart of the growth of the Kuapa Kokoo project has been its transparency and its democratic process. It has seen the orderly arrival and departure of a number of leaders and, as noted above, a growing number of elected women. This structure distinguishes Kuapa Kokoo from its competitors, both at home in a now highly competitive cocoa trading environment (where a number of the major cocoa multinationals also operate), and overseas in the performance and impact of the two chocolate companies in which Kuapa Kokoo has a significant equity stake: The Day Chocolate Company (renamed Divine in 2006) in the UK and Divine Chocolate Inc., set up in 2007 in the USA.

Sub-groups

Kuapa Kokoo comprises the following sub-groups:

- Kuapa Kokoo Farmers' Union (KKU) or (KKFU), which aims to empower small-scale cocoa producers, enhance female participation in the decision-making process, and encourage environmentally sustainable production.
- Kuapa Kokoo Limited (KKL), the commercial trading wing of the Farmers' Union.

- Kuapa Kokoo Farmers Trust (KKFT), a trust fund which receives fair trade premiums and other funds intended for farmers and their communities, and uses these for to provide social infrastructure and income generation for farmers.

Kuapa Kokoo Credit Union (KKCU), which promotes savings schemes and enables members to access credit at competitive rates.

The cocoa industry in Ghana

Within Ghana the logic of partial liberalization has proceeded, with more buying companies competing, including several transnational corporations. Tightening global supply due to climatic changes and more unpredictable harvests, together with stable demand, have led to rising prices for cocoa beans from below the fair trade 'minimum' level of US$1,600, reaching the highest level for 30 years in 2009. A continued global shortfall has persisted for four consecutive years, adding to incentives for buying companies and sharpening competitive practices at village level.

Independent research shows that Kuapa Kokoo has played an important role in shaping the expectations of all farmers familiar with their model, to the extent that there are now few licensed buying companies in Ghana who do not at least pay lip-service to social benefits. This usually means giving out small, discretionary rewards – salt, soap, pens, notebooks – and minor bonuses to cocoa agents or collectors at the point of purchase. However, only Kuapa Kokoo stresses local management and ownership of weighing scales – a vital tool and one of the main ways for buyers to cheat farmers in the villages.

The Cocoa Marketing Board continues to find Kuapa Kokoo a model that gives significant financial and other returns to farmers. It particularly noted that Kuapa Kokoo was the only buying company that accounted to farmers by reporting in public each year to its membership. Kuapa Kokoo's segregated export channel – essential for their small but growing proportion of fair trade cocoa sales – remains the same as when it launched its trading in 1993. Around 8 per cent of its cocoa ends up in Fair-trade certified products. However, pressure is growing for more 'traceability', organic beans and semi-processed products (in one of the several cocoa processing facilities now built in Ghana with foreign direct investment). Concessions are being made, especially to transnational and their end clients, which are putting the future of this professional, third party mechanism in question. The cocoa trading world is a small one, with just a few intensely competing players. Being forced to enter this world directly could prove a significant new barrier to Kuapa Kokoo accessing conventional cocoa export markets in its own right. It could directly inhibit the entry of many new women's or farmers' groups in Ghana; indeed, most of the new farmer-centered initiatives are sponsored by transnational cocoa and chocolate corporations.

1.3 STATEMENT OF PROBLEM

Kuapa is among the few Non- Governmental Organizations (NGO's) which have been helping people with bole holes, toilets, hospitals etc from its little profit. A company like this needs to be sustained to continue its good works and development. Unfortunately the Kuapa Company has not researched into an efficient way of transporting Cocoa so as to minimize the cost of transporting Cocoa from their Societies (Sources) to the Harbour (Destination). It is against this background that we research on the possible ways to minimize the cost of transshipping cocoa in the Kuapa Company limited.

1.4 OBJECTIVES

The main objectives of this study are:

- To model Kuapa cocoa transport as transshipment problems.
- To minimise cost of transportation of cocoa in Kuapa Company.

1.5 METHODOLOGY

The problem of carting cocoa by Kuapa Kokoo limited will be modelled as a transshipment problem. This problem would be solved by using the transshipment model with intermediate destinations between the sources and the destinations. The transshipment problem will be converted to a transportation problem and the transportation algorithm will be used to solve it. The Quantitative Methods (QM) software will be used to analyse the data.

The Internet and the Main library at KNUST and the Department of Mathematics library will be consulted in the course of this work.

1.6 JUSTIFICATION OF THE PROBLEM

Looking at the various benefits the country derive from Kuapa Company limited such as bole holes, toilets, hospitals and other services, reduced cost of cocoa Transshipment is one of the major way to sustain the social responsibility of this company. Additionally the research work will serve as a reference material to students for future research work.

1.7 ORGANISATION OF THE STUDY

This study consists of five chapters. Chapter one is the introduction, Chapter two is on the related literature reviewed. Chapter three also talks about the methodology we used. Chapter four deals with the data collected and its analysis whereas chapter five talks about conclusions and recommendations.

CHAPTER TWO

LITERATURE REVIEW

The literature on pickup and delivery problems has grown enormously during the last 30 years, and there is a clear need to develop a classification scheme for all their variants. The need for such a scheme exits because there are many connections and dependencies among the many variants of these problems and it is conceivable of such a scheme (or taxonomy) (Psaraftis, 2007).

Mues *et al*., (2005) stated that the transshipment Problems and Vehicle Routing Problems with Time Windows (VRPTW) are common network flow problems and well studied. Combinations of both are known as intermodal transportation problems. This concept describes some real world transportation problems more precisely and can lead to better solutions, but they are examined rarely as mathematical optimization problems.

According to White, (1972) the movement of vehicles and goods in a transportation system can be represented as flows through a time-dependent transshipment network. An inductive out-of-kilter type of algorithm is presented which utilizes the basic underlying properties of the dynamic transshipment network to optimize the flow of a homogeneous commodity through the network, given a linear cost function.

Ozdemir *et al.,* (2006) gave a literature review on transshipment theory but limited it to deterministic cases. A more recent review covering stochastic and some non - linear facility location problems was discussed by Sydney, (2006). In particular, this survey considers some classical problems including the P-median problem.

According to Chou, (2007) transshipment of cargo means that the direct handling cost per ton will be doubled. This is a severe disadvantage even for unitized cargo. Advocates of a shuttle-service/sea-feeder transportation system seem to believe that this disadvantage will be offset by savings of the very expensive time of big trunk liners.

Kuo and Chu (2000) constructed a decision-making model for the selection of calling container port using the mathematical programming approach. Chou (2002) analyzed some important factors that influence the selection of container port.

The multi-product inventory problem with one-way substitution and zero setup costs was considered by Bassok *et al.*, (1999); they demonstrated that myopic base-stock policies were optimal.

Hsu and Bassok (1999) considered a single period problem with one input resulting in a random yield of multiple, downward substitutable products. They showed how the network structure of the problem can be used to devise an efficient algorithm.

McGillivray and Silver (1978) considered a case where products had identical costs and there is a fixed probability that a customer demand for a stocked-out product can be substituted by another available product.

Pasternack and Drezner (1991) compared the optimal stocking levels to the corresponding inventory levels without substitution for the case where the substitution probability is one.

Herer and Rashit (1997) have shown that even for the two-product, one period special case, the optimal ordering policy is complex and cannot be characterized using extensions of the single product (s, S) policy. This suggests that the optimal solution to the multi-product problem is also likely to be difficult to characterize, which necessitates use of effective heuristics.

Boffey, (1995) dealt with the selection of optimal routes for the transportation of hazardous materials in a realistic environment. The routes were selected to minimize the expected damage effects on population in case of an accident.

Gilbert *et al., (*1997) identified some of the main issues in freight transportation planning and operations, and presented appropriate Operations Research models and methods, as well as computer-based planning tools.

Ratick *et al.*,(1998) proposed two approaches for analyzing the types of dynamic location problems, focussing on situations where the total number of facilities to be located is uncertain. They termed this type of location problem Number Of Facilities Uncertain (NOFUN) and analyzed the NOFUN problem using two well-established decision criteria: the minimization of expected opportunity loss (EOL), and the minimization of maximum regret.

Koning, (2009) focussed on strategies to improve the performances of the different links of the intermodal transport chain: the barge transport services, the transshipment at terminals and pre- and post-truck haulage operations. In his paper he considered coordination among facilities through replenishment strategies that took into consideration transshipments, that is, movement of a product between locations at the same echelon level.

The dynamic transshipment problem was introduced by Herer and Tzur (2001). In their paper two locations were considered and location-dependent holding costs were allowed, giving rise to another reason for using transshipments. In their paper they studied the analysis to multiple locations with identical holding costs.

The most traditional quantitative framework for distribution network design problem is the cost of minimization approach (Hansen *et al.*, 1992).

'In the profit maximization framework the costs of the distribution network are deducted from the customer's profits', said Hakimi *et al.*, (1996). According to the authors, no attention is paid to the customer's wishes hence they are not necessarily satisfied. They concluded that the cross-section method is poor because it does not provide details of port performance, whereas the panel data with window analysis reflect a variation of the absolute performance of a port over time, and the relative performance of that port in comparison to the others at the same time.

Bird and Bland (1988) voice the widespread belief that frequency of shipping service is a main reason for choice of seaport in cargo movement.

Chou (2007) proposed five important dimensions for evaluating and selecting an appropriate hub transshipment location, including the port location dimension, hinterland economic dimension, port physical dimension, port efficiency dimension, and cost dimension.

Allahviranloo and Afandizadeh (2008) formulated a model to determine the optimum investment on port development from a national investment prospective. On the other hand, costs and benefits are calculated from consumer and investor's view point.

Brook (2000) suggested that coast and coverage are not the only drivers of the network configuration decision. A carrier's optimal port call structure is not only a function of voyage distance, steaming time, or port time, but also a complicated interplay of these operational factors with shippers' needs for transit time, service frequency, special equipment, or other service elements.

Dong and Rudi (2004) examine a different aspect by looking at the benefits of lateral transshipments for a manufacturer that supplies a number of retailers. They compare the case where the manufacturer is the price leader to the case of exogenous prices. For exogenous prices, it is found that retailers benefit more when demand across the network is uncorrelated.

Granot and Sosic, (2003) also identified a class of allocation rules that resulted in complete pooling, but that is not in the core of the corresponding transshipment game. It can be shown that this allocation rule leads to a farsighted stable grand coalition for symmetric retailers Sosic (2006)).

Kutanoglu and Mahajan (2009) considered the time-based service levels. They discussed models to examine cost and service levels in this setting within two and three location networks. This allows time-based service levels to be achieved while it is noted that there is particular sensitivity to changes in demand. They also considered how suitable stocking levels can be obtained so as to minimize cost. This is achieved in the form of an enumeration based algorithm.

2.1 SUPPLY CHAIN MANAGEMENT

Reyes *et al*., (2006) described an approach for improving the operational performance in the reverse supply chain which is in a non-profit environment. They presented a model based on risk pooling through preventive lateral transshipment as a method for improving the responsiveness of not-for-profit core business practice of redistributing donated products in order to increase revenues.

Supply chain management (SCM) has been extensively studied in recent years. The logistical network consists of facilities and distribution options that perform the functions of procurement of materials, transformation of these materials into intermediate and finished products, and the distribution of these finished products to customers (Simchi *et al.*, 2003).

The issues of cost, customer service, and quality have become significant objective in the development of logistic network strategies by many firms seeking competitive advantage. Beamon, (1999) presented an overview and evaluation of the performance measures used in supply chain models. These performance measures are summarized as high level of effectiveness, high level of customer service, and the ability to respond to a changing environment where either of these must correspond to the firms strategic goals.

The second stream studies a vertically decentralized supply chain with a single manufacturer and a chain store retailer assumed a normal demand distribution. Dong and Rudi (2004) showed that under mild assumptions, the manufacturer is better off from transshipment. Zhang (2005) generalizes the results of Dong and Rudi (2004) to an arbitrary demand distribution. Their work differs from the existing literature as it examines transshipment in a completely decentralized supply chain taking into consideration both the downstream retail competition (in inventory) and the upstream manufacturer's decisions.

Huang *et al*.,(2009) studied a newsvendor game with transshipments, in which n retailers face a stochastic demand for an identical product. Before the demand was realized, each retailer independently orders her initial inventory. After the demand was realized, the retailers selected an optimal transshipment pattern and ship residual inventories in order to meet residual demands. Unsold inventories were salvaged at the end of the period.

Traditionally, network flow problems have been studied extensively for analyzing systems. Beginning with the work of (Ford *et al.,* 1962) a great number of algorithms have been directed for various versions of flow problems.

Urban, (2000) modeled and analyzed supply contracts with periodical commitment, in which the order quantities are fixed and stationary, with limited flexibility to change the order quantity at a cost to the buyer. The problem was formulated as a mixed-integer linear programme and as a network flow problem and the solution methodology provided for the general, stochastic problem with consideration given to specific demand distributions.

Dynamic flow problems originate in many applications, such as production distribution systems, communication systems, and logistic transportation scheduling. The research approach on dynamic flow problems can be modelled either as networks with discrete time steps or as networks with time continuously (Reyes, 2005).

The minimum cost for transshipment problems has been simplified as linear cost problems which are not realistic when applying it in real life situations. Other researchers also developed algorithms that can directly solve concave cost bipartite network problems, but all of them seem not to be applicable in solving most transshipment problems. Shangyao *et al.*, (2005) proposed a global search algorithm for solving concave cost transshipment problems. Efficient methods for encoding, generating initial populations, selection, crossover and mutation were proposed, according to the problem characteristics.

Practicable methods for optimizing concave-cost, uncapacitated transshipment networks are non – exact. Bazlamacci, (1996) discussed one of such effective methods and that of adjacent extreme point search, is further developed to enhance its overall computational efficiency. The enhanced search algorithm is then embedded in a tabu search scheme which proved capable of finding better solutions, by a wide margin in some instances.

A new approach to investigating public decision problems was suggested by Chernykh.,*et al.*, (1992). The use of the approach was illustrated via analysis of long-term development strategies for a national economy. The approach presented was based on the Generalized Reachable Sets (GRS) method developed by one of the authors.

According to Shahabuddin *et al.*, (2002) they used data from 1996/97 through 1998/99 to examine the relative efficiency of production of crops in Bangladesh and their comparative advantage in international trade as measured by net economic profitability (the profitability using economic, rather than financial costs and prices), and the domestic resource cost ratio, (the amount of value of non-tradable domestic resources used in production divided by the value of tradable products). The economic profitability analysis demonstrates that

Bangladesh has a comparative advantage in domestic production of rice for import substitution.

Ugarte *et al.,* (2003) in response to energy security concerns, substitute energy programs such as biomass energy systems that are being developed to provide energy in the 21st century. For the biomass industry to expand, a variety of feedstock will need to be utilized. Large scale production of bioenergy crops could have significant impacts on the United States agricultural sector in terms of quantities, prices and production location of traditional crops as well as farm income. Borbora *et al.,* (2007) stated that the diversification of agriculture is considered as an important strategy for agricultural development in India and importance of horticulture crops as a means of diversification and creation of employment opportunities in rural areas is recognized.

Turner *et al.,* (1995) describes the relative size of the green industry within the U.S. economy and how it is linked to supporting industries through the volume of transactions and economic impact multipliers.

2.2 DECENTRALIZED SYSTEMS

A decentralized system is one in which each stocking point operates to meet its own goals. Chang and Lin, (1991) considered when it is beneficial for such a system to actually operate as a more centralized system by using transshipments. They compared a decentralized model with a centralized model and deduced some properties that, if met, showed that costs will be reduced if the operation shares resources.

In Rudi *et al*. (2001) transshipment prices are determined in advance by an accepted authority, for example by the manufacturer who would like to stimulate stock sharing and is also willing to invest in an information system to provide accurate stock level data. Rudi *et al*. (2001) show that there exists a Nash equilibrium for the ordering quantities, and that the joint profit is generally not maximized at this equilibrium.

2.3 COMPLETE POOLING

Complete pooling is often applied in a spare parts environment, where holding and backordering costs are typically large compared to transshipment costs. The basic model for repairable spare parts are called METRIC, developed by Sherbrooke (1968). In his model, he said items could be repaired at central base-Depots which supply the individual locations with the repaired items. These locations use a one-for-one ordering system to replenish their stocks.

Lee (1987) considered lateral transshipments using the same model. He divided the stock locations into pooling groups, and focused on one such group. All locations were identical and faced Poisson demand. Failed parts were repaired at the central repair facility, which has innate repair capacity but repair times are positive and probabilistic. Lee tested three rules for selecting from where to tranship: random selection, maximum stock on hand, and smallest number of outstanding orders.

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CHAPTER THREE

METHODOLOGY

3.1 INTRODUCTION

In this chapter we shall put forward the transportation and the transshipment problems.

3.1.1 The Transportation Problem

The transportation problem seeks the determination of a shipping plan of a single commodity from a number of sources, *m*, say, to a number of destinations, *n*, say, at a minimum total cost, while satisfying the demand at all destination.

The standard scenario where a transportation problem arises is that of sending units of a product across a network of highways that connect a given set of cities. Each city is considered either as a "source," (supply route) or a "sink," (demand route). Each source has a given supply, each sink has a given demand, and each highway that connects a source-sink pair has a given transportation cost per unit of shipment. This can be visualized in the form of a network, as depicted in fig 3.1.

Shipment from sources to sinks

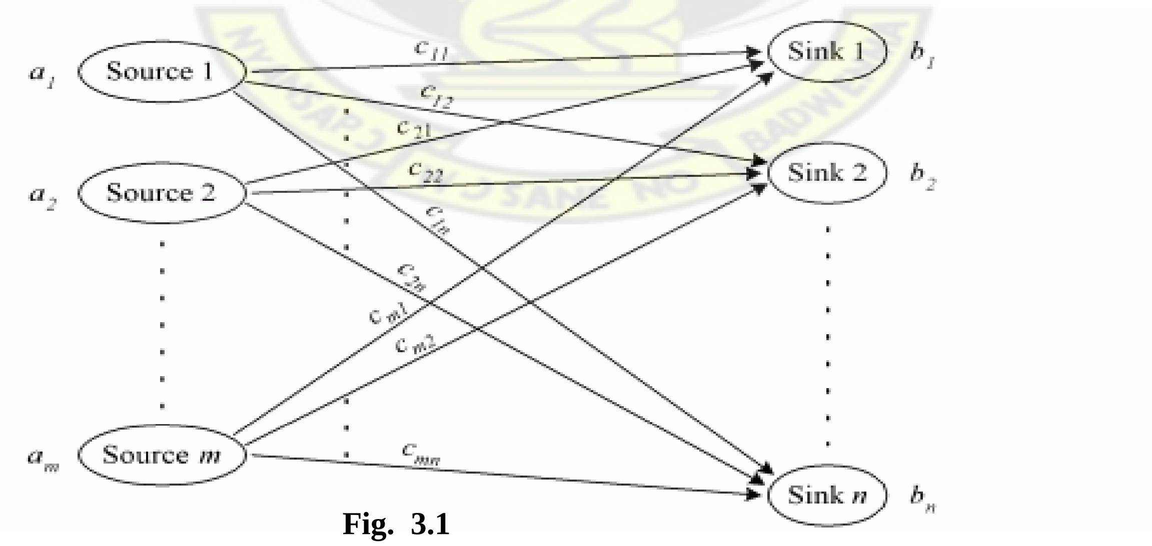

Fig. 3.1

Given such a network, the problem of interest is to determine an optimal transportation scheme that minimizes the total cost of shipments, subject to supply and demand constraints.

Problems with this structure arise in many real-life situations. The transportation problem is a linear programming problem, which can be solved by the regular simplex method but due to its special structure a technique called the transportation technique is used to solve the transportation problem.

It got its name from its application to problems involving transporting products from several sources to several destinations, although the formation can be used to represent more general assignment and scheduling problems as well as transportation and distribution problems. The two common objectives of such problems are either to:

- minimize the total transportation cost of shipping a single commodity from *m* sources to *n* destinations, or
- maximize the profit of shipping from *m* sources to *n* destinations.

3.1.2 Characteristics of a Transportation Problem

i. Objective function is to reduce the transportation cost to the minimum.
ii. Maximum quantity available at the sources is limited. This is a constraint.
iii. Maximum quantity required at the destination is specified. This cannot be exceeded, this is another constraint.
iv. Transportation cost is specified for each item.
v. Sum of the products available from all sources is equal to sum of the products distributed at various destinations

1. Maximum quantity available at the source, maximum quantity required at the destination and the cost of transportation, all refer to a single product.

3.1.3 Uses of Transportation Techniques

i. To reduce distribution and transportation cost
ii. To improve competitiveness of products
iii. To assist in locating ware – houses properly
iv. To assist proper location of new factories or plants being planned
v. To close down ware – houses which found costly and uneconomical

3.1.4 Degeneracy in Transportation Problem

Transportation with *m*-origins and *n*-destinations can have (m+n-1) positive basic variables, otherwise the basic solution degenerates. So whenever the number of basic cells is less than (m + n-1), the transportation problem is degenerate.

3.1.5 How to resolve degeneracy in transportation problem

To resolve the degeneracy, the positive variables are augmented by as many zero-valued variables as is necessary to complete (m +n –1) basic variables.

3.2 MATHEMATICAL FORMULATION

Let the cost of transporting one unit of goods form ith origin to *jth* destination be C_{ij} , $i= 1,2, \ldots m$, $j=1,2,\ldots n$. If $x_{ij} \geq 0$ be the amount of goods to be transported from i^{th} origin to *jth* destination , then the problem is to determine x_{ij} so as to

Minimize

$$z = \sum_{i=1}^{m} \sum_{j=1}^{n} x_{ij} c_{ij}$$

Subject to the constraint

and $x_{ij} \geq 0$, for all i and j.

$$\sum_{j=1}^{n} x_{ij} = a_i, (i = 1,2,\ldots m)$$

$$\sum_{i=1}^{m} x_{ij} = b_j, (j = 1,2,\ldots n.)$$

3.2.1 Feasible Solution

A set of non-negative allocations, x_{ij} which satisfies the row and column restrictions is known as feasible solution.

3.2.2 Basic Feasible Solution

A feasible solution to an *m*-origin and *n*-destination problem is said to be basic feasible solution if the number of positive allocations are (m+n–1).

3.2.3 Non – Degenerate Basic Feasible Solution

A basic feasible solution of an ($m \times n$) transportation problem is said to be non-Degenerate if it has following two properties:

(a) Initial basic feasible solution must contain exactly (m+n–1) number of individual allocations.

(b) These allocations must be in independent positions. Independent positions of a set of allocations means that it is always impossible to form any closed loop through these allocations.

Definition (Loop). In a transportation table, an ordered set of four or more cells is said to form a loop if:

i. Any two adjacent cells in the ordered set lie in the same row or in the same column.
ii. Any three or more adjacent cells in the ordered set do not lie in the same row or in the same column.

3.2.4 Degenerate Basic Feasible Solution

A basic feasible solution that contains less than (m + n – 1) non – negative allocations is said to be degenerate basic feasible solutions.

3.3 BALANCED TRANSPORTATION PROBLEM

If total supply equals total demand, the problem is said to be a balanced transportation problem: that is

$$\sum_{i=1}^{i=m} a_i = \sum_{j=1}^{j=n} b_j \qquad (4)$$

3.3.1 Unbalanced Transportation Problem

$$\sum_{i=1}^{m} a_i \neq \sum_{j=1}^{n} b_j \qquad (5)$$

If the transportation problem is known as an unbalanced transportation problem then, there are two cases.

$$\sum_{i=1}^{m} a_i > \sum_{j=1}^{n} b_j \qquad (6)$$

Case (1).

Introduce a dummy destination in the transportation table. The cost of transporting to this destination is all set equal to zero. The requirement at this destination is assumed to be equal

to

$$\sum_{i=1}^{m} a_i - \sum_{j=1}^{n} b_{j.} \qquad (7)$$

$$\sum_{i=1}^{m} a_i < \sum_{j=1}^{n} b_j \qquad (8)$$

Case (2) .

Introduce a dummy origin in the transportation table; the costs associated with are set equal to zero. The availability is

$$\sum_{j=1}^{n} b_j - \sum_{i=1}^{m} a_i \qquad (9)$$

3.3.2 Converting unbalanced problem to a Balanced Transportation Problem

An unbalanced transportation problem can be converted to a balanced one by adding a dummy row (source) with cost zero and the excess demand is entered as a requirement if total supply is less than the total demand. On the other hand if the total supply is greater than the total demand, then introduce a dummy column (destination) with cost zero and the excess supply is entered as the requirement for dummy destination.

3.4 THE TRANSPORTATION TABLE:

Table 3.1

	D1	D2	D3	D4	SUPPLY
S1	C_{11} X_{11}	C_{12} X_{12}	…….	C_{1n} X_{1n}	$S_1 = a_1$
S2	C_{21} X_{21}	C_{22} X_{22}	…….	C_{2n} X_{2n}	$S_2 = a_2$
-----	…….	…….	…….	…….	…….
S_n	C_{m1} X_{m1}	C_{m2} X_{m2}	…….	C_{mn} X_{mn}	$S_n = a_m$
DEMAND	d1 ⋮ b1	d2 ⋮ b2	…….	dn ⋮ bn	

3.5 METHODS OF FINDING INITIAL BASIC FEASIBLE SOLUTION FOR A BALANCED TRANSPORTATION PROBLEM

There are three basic methods:

- The Northwest Corner Method
- The Least Cost Method
- The Vogel's Approximation Method

3.5.1Northwest-Corner Method

The steps below are used in the Northwest- Corner method

Step (1). The first assignment is made in the cell occupying the upper left-hand (North West) corner of the transportation table. The maximum feasible amount is allocated there, i.e; x_{11} = min(a_1, b_1) .

Step (2). If $b_1 > a_1$, the capacity of origin O_1 is exhausted but the requirement at D_1 is not satisfied. So move downs to the second row, and make the second allocation:

$x_{21} = \min (a_2 , b_1 - x_{11})$ in the cell (2,1).

If $a_1 > b_1$, allocate $x_{12} = \min (a_1 - x_{11} , b_2)$ in the cell (1,2) .

Continue this until all the requirements and supplies are satisfied.

3.5.2 Least-Cost Method

The least cost method uses shipping costs in order to come up with a basic feasible solution that has a lower cost. To begin the minimum cost method, first we find the decision variable with the smallest shipping cost x_{ij}. Then assign x_{ij} its largest possible value, which is the minimum of s_i and d_j .

After that, as in the Northwest Corner Method we should cross out row i and column j and reduce the supply or demand of the noncrossed-out row or column by the value of x_{ij}, then we will choose the cell with the minimum cost of shipping from the cells that do not lie in a crossed-out row or column and we will repeat the procedure.

3.5.3 Vogel'S Approximation Method (VAM)

Step 1. For each row of the transportation table, identify the smallest and the next to-smallest costs. Determine the difference between them for each row. Display them alongside the transportation table by enclosing them in parenthesis against the respective rows. Similarly compute the differences for each column.

Step 2. Identify the row or column with the largest difference among all the rows and columns. If a tie occurs, use any arbitrary tie breaking choice. Let the greatest difference correspond to i^{th} row and the minimum cost be C_{ij} . Allocate a maximum feasible amount $x_{ij} = min\ (a_i\ , b_j\ )$ in the $(i, j)^{th}$ cell, and cross off the i^{th} row or j^{th} column.

Step 3. Re compute the column and row differences for the reduced transportation table and go to step 2. Repeat the procedure until all the rim requirements are satisfied.

3.6 OPTIMAL SOLUTION

A feasible solution (not necessarily basic) is said to be optimal if it minimizes the total transportation cost.

3.6.1 Theorem for Testing Optimality.

If we have a B.F.S. consisting of m+n–1 independent positive allocations and a set of arbitrary number u_i and v_j (i=1,2,...m; j=1,2,...n) such that $c_{rs} = u_r+v_s$ for all occupied cells (r,s) then the evaluation d_{ij} corresponding to each empty cell (i, j) is given by

$d_{ij} = c_{ij} – (u_i+vj)$

3.6.2 Solution to Optimality

As mentioned above, the solution method for transportation problems is a streamlined version of the Simplex algorithm. As such, the solution method also has two phases. In the first phase, the aim is to construct an initial basic feasible solution; and in the second phase, to iterate to an optimal solution.

For optimality, we need a method, like the simplex method, to check and obtain the optimal solution. The two methods used are:

i. Stepping-stone method

ii. Modified distributed method (MODI)

3.6.3 Stepping Stone

i. Consider an initial tableau

ii. Introduce a non-basic variable into basic variable

iii. Add the minimum value of all the negative cells into cells that has " positive sign", and subtracts the same value to the "negative" cells

iv. Repeat this process to all possible non-basic cells in the tableau until one has the minimum cost. If it does not give the optimal solution or yield a good results, Introduce the MODI method for optimality

3.6.4 Modified distributed method (MODI)

It is a modified version of the stepping stone method

- MODI has two important elements:

  i. It determines if a tableau is the optimal one

  ii. It tells you which non-basic variable should be firstly considered as an entry variable

  iii. It makes use of stepping-stone to get its answer of next iteration

Procedure (MODI)

Step 0: let $u_{i,}$ v , c_{ij} variables represent rows, columns, and cost in the transportation tableau, respectively

Step 1: (a) form a set of equations that uses to represent all basic variables $u_i + vj = c_{ij}$

(b) solve variables by assign one variable = 0

Step2: (a) form a set of equations use to represent non-basic variable (or empty cell) as such

$$c_{ij} - u_i - vj = k_{ij}$$

(b) solve variables by using step 1b information

Step 3: Select the cell that has the most negative value in 2b

Step 4: Use stepping-stone method to allocate resource to cell in Step 3

Step 5: Repeat the above steps until all cells in 2a has no negative Value.

3.7 THE TRANSSHIPMENT PROBLEM

The transshipment problem is an extension of the framework of the transportation problem. The extension is in allowing the presence of a set of transshipment points that can serve as intermediate stops for shipments, possibly with a net gain or loss in units. Any given transshipment problem can be converted into an equivalent transportation problem. Hence, the procedure for solving the transportation problems can be applied to the solution of transshipment problem as well.

A transshipment problem (or network flow problem) consists of finding the cheapest way of shipping goods through a network of routes so that all given demands at all points of the network is satisfied.

Given:

• a network of routes as a graph

• a set of nodes which act as sources (supplies)

• a set of nodes which act as sinks (demands)

• the amount of supply and demand at each node

• the cost of each transport route (edge)

The transshipment problem is similar to the transportation problem except that in the transshipment problem it is possible to ship both into and out of the same node (point). It is an extension of the transportation problem in which intermediate nodes, referred to as transshipment nodes, are added to source as well as sink nodes to account for locations such as warehouses. In this more general type of distribution problem, shipments may be made between any pair of the three general types of nodes: origin nodes, transshipment nodes and destination nodes. For example

(i) transshipment problems permits shipments of goods from origins to transshipment nodes and on to destinations,

(ii) From one origin to another origin,

(iii) From one transshipment location to another,

(iv) from one destination location to another and

(v) directly from origins to destinations.

MODEL

The general linear programming model of a transshipment problem is

$$Min \sum_{allarcs} c_{ij} x_{ij} \qquad (10)$$

Subject to

$$\sum_{arcout} x_{ij} - \sum_{arcin} x_{ij} = s_i \qquad \text{Origin nodes } i$$

$$\sum_{arcout} x_{ij} - \sum_{arcin} x_{ij} = 0 \qquad \text{Transshipment nodes}$$

$$\sum_{arcin} x_{ij} - \sum_{arcout} x_{ij} = d_j \qquad \text{Destination nodes } j$$

Where

x_{ij} = amount of units shipped from the node i to node j

c_{ij} = cost per unit of shipping from node i to node j

s_i = supply at origin node i

d_{ij} = demand at the origin node j

The following steps describe how the optimal solution to a transshipment problem can be found by solving a transportation problem.

Step1: If necessary, add a dummy to a demand point or supply points (with a supply of 0 and a demand equal to the problem's excess supply) to balance the problem. Shipments to the dummy and from a point to itself will be zero. Let *s*= total available supply and d= total demand.

Step2: Construct a transportation tableau as follows: A row in the tableau will be needed for each supply point and transshipment point, and a column will be needed for each demand point and transshipment point.

Each supply point will have a supply equal to its original supply, and each demand point will have a demand to its original demand.

Let s = total available supply and d = demand. Then each transshipment point will have a supply equal to (point's original supply)+s and a demand equal to (point's original demand)+s. This ensures that any transshipment point that is a net supplier will have a net outflow equal to point's original supply and a net demander will have a net inflow equal to point's original demand. Although we don't know how much will be shipped through each transshipment point, we can be sure that the total amount will not exceed s.

Step 3: Solve the transportation table of step 2 by the transportation technique

CHAPTER FOUR

DATA COLLECTION AND ANALYSIS

This chapter deals with data collection and data analysis. The data was obtained from the Kuapa Kokoo Company Limited. The data was collected from the various depots in the Ashanti Region. They have fifteen depots in the Ashanti Region. The data collected was from October 2009 to October 2010. The data collected was a quantitative type of data.

Table 4.1 is the summary of the distances from the various sources to the destinations. Column 1 is the various sources. Column 2 up to Column 16 is the summary of the distances from the sources to the various destinations. The last column is the supply and the last row is the demand.

Data for Distances from Sources to Destinations

Table 4.1

	D1	D2	D3	D4	-	D15	D16	SUPPLY
S1	29	99	126.9	96.6	-	78.5	364	2338
S2	32.2	102.2	130.1	99.8	-	81.7	367.2	566
S3	64.4	134.4	162.3	132	-	113.9	399.4	2160
S4	51.5	121.5	149.4	119.1	-	101	386.5	5277
-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-
S71	127	131.5	138	108	152	111	244	150000
S72	49.5	65.5	79.5	59.1	73.5	-	328.5	150000
DEMAND	150000	150000	150000	150000	150000	150000		2377776

The table above which was the distances from sources to destination was later converted to the unit cost of shipment of cocoa from sources to destination. Table 4.2 is the table for the unit cost of shipment cocoa from sources to destinations. Column 1 is the sources whiles Column 2 – 16 is the unit cost of shipment from the various sources to the destinations. The last column is the supply and the last row is the demand.

Unit Cost of Shipment of Cocoa from sources to Destinations

Table 4.2

SOURCES	D1	D2	D3	-	-	D15	D16	SUPPLY
S1	0.20	0.69	0.89	-	-	0.55	2.548	2338
S2	0.23	0.72	0.91	-	-	0.57	2.5704	566
S3	0.45	0.94	1.14	-	-	0.80	2.7958	2160
S4	0.36	0.85	1.05	-	-	0.71	2.7055	5277
S5	0.27	0.76	0.96	-	-	0.62	2.6152	91
S6	0.49	0.75	0.85	-	-	0.61	2.499	2673
-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-
S70	0.83	0.94	1.04	0.91	1.00	0.80	2.784	150000
S71	0.88	0.92	0.97	0.76	1.06	0.78	1.708	150000
S72	0.35	0.46	0.56	0.41	0.51	-	2.2995	150000
DEMAND	150000	150000	150000	150000	150000	150000		127776

Mathematical formulation

$$Min\ \ z =$$

$$0.2x_{11} + 0.7x_{12} + 0.9x_{13} + 0.7x_{14} \quad + - - - + \quad 0.6x_{115} + 2.5x_{116}$$

$$+ 0.2x_{21} + 0.7x_{22} + 0.9x_{23} + 0.7x_{24} + - - - + \quad 0.6x_{215} + 2.6x_{216}$$

$$+ 0.5x_{31} + 0.9x_{32} + 1.1x_{33} + 0.9x_{34} \ + - - - + \quad 0.8x_{315} + 2.8x_{316}$$

....

....

....

$$+ 0.35x_{721} + 0.46x_{722} + 0.56x_{723} + 0.41x_{724} + - - - + 2.30\,x_{7216}$$

Subject to :

$$x_{11} + x_{12} + x_{13} + x_{14} + - - - \ + x_{116} \leq 2338$$

$$x_{21} + x_{22} + x_{23} + x_{24} + - - - + x_{216} \leq 566$$

$$- -$$

$$- -$$

$$x_{721} + x_{722} + x_{723} + x_{724} + - - - + x_{7216} \leq 150000$$

$$x_{11} + x_{21} + x_{31} + x_{41} + - - - + x_{16} = 150000$$

$$x_{12} + x_{22} + x_{32} + x_{42} + - - - + x_{216} = 150000$$

$$x_{13} + x_{23} + x_{33} + x_{43} + - - - + x_{316} = 150000$$

$$x_{14} + x_{24} + x_{34} + x_{44} + - - - + x_{416} = 1500000$$

$$- -$$

$$- -$$

$$- -$$

$$x_{172} + - - - + x_{7216} = 150000$$

Computational Procedure

The computer used for the computation was Toshiba Intel Core 2 Duo T6500 with 320GB as Hard disk size and 3GB DDR2 RAM size. The QM software was used for the data analysis. There were five trials before conclusion was made for the minimum cost of shipment and each of them gave me the same minimum cost.

Table 4.3 is the summary of the data analyzed using the QM software. Column gives the sources and allocates it to a right destination in column 2. The number of shipment made from each source to its destination is displayed in column 3. Column 4 talks about the unit cost of shipment from each source to a destination. The last column talks about the total shipment cost from each source to its destination.

SUMMARY OF RESULTS OF DATA ANALYSED

TABLE 4.3

From	To	Shipment	Cost per unit	Shipment cost
Source 1	Destination 4	2,338.	0.6762	1,580.956
Source 2	Destination 4	566.	0.6986	395.4076
Source 3	Destination 1	2,160.	0.4508	973.728
Source 3	Destination 13	0.	1.2817	0.
Source 4	Destination 4	5,277.	0.8337	4,399.435
Source 5	Destination 4	91.	0.7434	67.6494
Source 6	Destination 4	2,673.	0.721	1,927.233
Source 6	Destination 7	0.	0.056	0.
Source 7	Destination 4	4,053.	0.833	3,376.149
Source 8	Destination 4	5,933.	0.805	4,776.065
Source 9	Destination 5	1,318.	0.35	461.3
-	-	-	-	-
-	-	-	-	-
-	-	-	-	-
Source 71	Destination 16	7,742	1.708	13,223.34
Source 72	Destination 15	150,000	0.	0.
Demand	Destination 16	2,122,224	0.	0.

4.1 DISCUSSIONS

From Table 4.3, the allocations made from various sources to destinations are shown with the cost of each in Ghana cedi.

It could be observed that, Sources 3 and 58 were allocated to Destination 1 with a total shipment of 2160 at 0.45 per unit cost and 147,840 respectively. Sources 33 and 59 were allocated to Destination 2. Sources 12, 13, 14, 15, 16, 17 and 60 were also allocated to Destination 3. Again, Sources 1, 2, 4, 5, 6, 7, 8, 28, 29, 31, 32, 33, 34, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 58, 61, 65 were allocated to Destination 4.

Destination 5 was satisfied by sources 9, 10 and 11. Sources 42 and 63 were allocated to Destination 6. Sources 6 and 64 were allocated to destination 7. Sources 27, 30 and 65 were allocated to destination 8. Destination 9 was fed by sources 18, 19, 20, 21, 22 and 66. Source 49, 50 and 67 were allocated to Destination 10. Sources 35, 36, 37 and 68 were allocated to destination 11. Sources 23, 24, 25, 26, 51, 52, 53, 54, 69 were allocated to Destination 12. Source 70 was allocated to Destination 13. Sources 55, 56, 57 and 69 were allocated to Destination 14. Sources 47 and 72 were allocated to Destination 15. Sources 60, 61, 62, 67, 68, 69 and 71 were allocated to Destination 16.

The results revealed the various allocations where units were shipped from various sources to various destinations and each showing us the unit cost for each shipment.

The cost of transporting Cocoa from the sources to the destinations reduced drastically as compared to the original expenditure from the Kuapa Company. Their original expenditure was GH¢477,596.45 and the minimum cost or the optimal cost from the QM analyses was GH¢298,823.10. This shows that the transshipment nodes were very helpful.

The shipment from source 61 – destination 16 recorded the highest shipment of GH¢66482 at a unit cost of GH¢1.869 and the total shipment cost was GH¢124254.9 whiles the shipment from source 21 – 9 recorded the low shipment of 342 at a unit GH¢0.0791 cost of and the total shipment cost was GH¢27.05. The detail for the rest of the data is in table 4.3 in appendix c.

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATION

5.1 CONCLUSIONS

The cocoa transportation in the Kuapa Company was modeled into a transshipment problem. The Quantitative Method (QM 32) software was used to analyze the data collected from the Kuapa Kokoo Company Limited. It comprises of the cost of transporting goods from supply points (Societies and Depots) to demand points (Depots and Harbours). The optimal cost was GH ¢298,823.10. It was revealed that some societies should be move from their current depots to associate with different depots to minimize cost.

It also came to light that the fixed amount of money paid now for transporting one bag of cocoa from the various societies to their depots was costing the company so much because some societies were very closer to their depots and therefore the cost of transporting cocoa from those areas were not up to the price they charge now. Most of them too were far away from their depots and they were also charge below reality causing financial loss to the company. This came to light when we compared their annual expenditure to the minimum cost we got following the QM. Theirs was GH ¢477,596.45 whiles the suggested route by QM gave us GH ¢298,823.10.

5.2 RECOMMENDATION

We shall recommend that the Kuapa Company Limited adapt this result of transporting goods giving by the Quantitative Methods Software so that their cost of transporting cocoa from the Societies through the various Depots to the Harbour will be minimal.

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APENDICES

APENDIX A

Table 4.1 **DATA FOR DISTANCES FROM SOURCES TO DESTINATIONS**

SOURCES	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	D11	D12	D13	D14	D15	D16	SUPPLY
S1	29	99	126.9	96.6	110	120	91	116	68.5	123	91	150	148	156	79	364	2338
S2	32.2	102	130.1	99.8	113	124	94.2	119	71.7	126	94.2	153	151	159	82	367.2	566
S3	64.4	134	162.3	132	146	156	126	151	103.9	158	126	185	183	191	114	399.4	2160
S4	51.5	122	149.4	119	133	143	114	138	91	145	114	173	170	179	101	386.5	5277
S5	38.6	109	136.5	106	120	130	101	125	78.1	132	101	160	157	166	88	373.6	91
S6	70	107	121.4	103	115	129	8	124	98.2	128	93.4	156	156	153	87	7E+10	2673
S7	86	123	137.4	119	131	145	24	140	114.2	144	109	172	172	169	103	7E+10	4053
S8	82	119	133.4	115	127	141	20	136	110.2	140	105	168	168	165	99	7E+10	5933
S9	131	144	133.3	109	50	165	157	160	103.6	64.2	137	139	193	202	124	7E+10	1318
S10	146	159	148.3	124	65	180	172	175	118.6	79.2	152	154	208	217	139	7E+10	3024
S11	126	139	128.3	104	45	160	152	155	98.6	59.2	132	134	188	197	119	7E+10	1270
S12	124	126	25.7	71.4	109	147	139	142	130.7	123	125	71	174	164	105	7E+10	1074
S13	138	140	40.2	85.9	124	162	154	157	145.2	138	139	85	189	178	120	7E+10	901
S14	143	145	45.1	90.8	128	167	159	162	150.1	143	144	90	194	183	125	7E+10	582

S15	140	142	41.8	87.5	125	163	155	158	146.8	139	141	87	191	180	121	7E+10	95
S16	154	156	56.3	102	140	178	170	173	161.3	154	155	101	205	194	136	7E+10	1404
S17	170	172	72.4	118	156	194	186	189	177.4	170	171	118	221	210	152	7E+10	505
S18	65.2	103	130.7	87	79.3	124	116	119	25.7	91.9	107	139	139	172	82	426.9	3420
S19	78.1	115	143.6	99.9	92.2	137	129	132	38.6	105	120	152	152	185	95	439.8	866
S20	65.2	103	130.7	87	79.3	124	116	119	25.7	91.9	107	139	139	172	82	426.9	1020
S21	50.8	88.1	116.3	72.6	64.9	110	102	105	11.3	77.5	92.2	124	124	157	68	412.5	342
S22	63.5	101	129	85.3	77.6	122	114	117	24	90.2	105	137	137	170	80	425.2	1464
S23	136	149	59.6	67.5	104	171	163	166	127.5	117	137	15	198	176	129	384.9	3621
S24	150	164	74.1	82	118	185	177	180	142	131	151	29	212	190	143	399.4	1870
S25	163	177	86.9	94.8	131	198	190	193	154.8	144	164	42	225	203	156	412.2	2550
S26	193	207	117.1	125	161	228	220	223	185	174	194	72	255	233	186	442.4	1851
S27	99.4	115	129.3	111	123	137	129	12.9	106.2	136	101	164	164	161	95	378.4	514
S28	109	125	138.4	120	132	146	138	22	115.3	145	111	173	173	170	104	387.5	4055
S29	124	140	153.4	135	147	161	153	37	130.3	160	126	188	188	185	119	402.5	10338
S30	92.9	109	122.8	105	117	130	122	6.4	99.7	130	94.9	158	158	154	88	371.9	1552
S31	109	38.6	138.6	120	133	146	138	141	115.4	145	111	173	173	170	104	7E+10	3995
S32	109	38.6	138.6	120	133	146	138	141	115.4	145	111	173	173	170	104	7E+10	2348
S33	95	25	125	107	119	132	124	128	101.8	132	97	160	160	157	91	7E+10	2339
S34	142	72	172	154	166	179	171	175	148.8	179	144	207	207	204	138	7E+10	695
S35	94.2	104	131.2	101	119	126	118	121	113.1	132	32.2	154	154	145	84	7E+10	3011
S36	120	130	157	127	145	151	143	147	138.9	158	58	180	180	171	110	7E+1	459

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S37	102	112	139.2	109	127	134	126	129	121.1	140	40.2	162	162	153	92	7E+10	1838
S38	79.6	93.6	57.7	12	70.6	115	107	110	73.3	83.2	80.7	65	142	120	71	7E+10	1153
S39	97.6	112	75.7	30	88.6	133	125	128	91.3	101	98.7	83	160	138	89	7E+10	2107
S40	103	117	80.7	35	93.6	138	130	133	96.3	106	104	88	165	143	94	7E+10	5330
S41	132	148	162.4	144	156	41	162	165	139.2	169	134	197	197	194	128	411.4	930
S42	105	121	134.9	117	129	13.5	134	137	111.7	142	107	170	170	166	100	383.9	1217
S43	110	126	140.4	122	134	19	140	143	117.2	147	112	175	175	172	106	389.4	1121
S44	97.9	114	127.9	110	122	6.5	127	130	104.7	135	99.9	163	163	159	93	376.9	136
S45	78.5	94.5	108.5	88.1	103	116	108	111	85.3	115	80.5	143	144	140	29	357.6	517
S46	88.5	105	118.5	98.1	113	126	118	121	95.3	125	90.5	153	154	150	39	367.6	713
S47	107	123	136.5	116	131	144	136	139	113.3	143	109	171	172	168	57	385.6	2402
S48	78.1	94.1	108.1	87.7	102	116	108	111	84.9	115	80.1	143	143	140	29	357.2	1929
S49	122	135	125.5	99.2	42.2	156	148	151	94.2	28	128	130	130	193	114	344	2693
S50	115	128	118.5	92.2	35.2	149	141	144	87.2	21	121	123	123	186	107	337	1357
S51	151	165	75.1	83	119	186	178	181	143	132	152	30	213	191	144	611.1	4169
S52	145	159	69.1	77	113	180	172	175	137	126	146	24	207	185	138	605.1	5360
S53	140	154	64.1	72	108	175	167	170	132	121	141	19	202	180	133	600.1	4271
S54	148	162	72.1	80	116	183	175	178	140	129	149	19	210	188	141	608.1	3217
S55	146	151	157	127	171	172	164	167	165	184	132	180	199	19	130	263	2603
S56	149	154	160	130	174	175	167	170	168	187	135	183	202	22	133	266	2525
S57	142	147	153	123	167	168	160	163	161	180	128	176	195	15	126	259	2614
S58	0	70	97.9	67.6	81.1	91.4	62	86.5	39.5	93.7	62	121	119	127	50	335	150000
S59	70	0	100	81.6	94	107	99.4	103	76.8	107	72	135	135	132	66	349	150000

S60	97.9	100	0	45.7	83.3	121	113	116	105	97.5	99	45	149	138	80	259	150000
S61	67.6	81.6	45.7	0	58.6	103	95	98.1	61.3	71.2	68.7	53	130	108	59	267	150000
S62	81.1	94	83.3	58.6	0	115	107	110	53.6	14.2	87	89	143	152	74	303	150000
S63	91.4	107	121.4	103	115	0	121	124	98.2	128	93.4	156	156	153	87	370.4	150000
S64	62	99.4	113.4	95	107	121	0	116	90.2	120	85.4	148	148	145	79	362.4	150000
S65	86.5	103	116.4	98.1	110	124	116	0	93.3	123	88.5	151	151	148	82	365.5	150000
S66	39.5	76.8	105	61.3	53.6	98.2	90.2	93.3	0	66.2	80.9	113	113	146	56	327	150000
S67	93.7	107	97.5	71.2	14.2	128	120	123	66.2	0	99.6	102	102	165	86	316	150000
S68	62	72	99	68.7	87	93.4	85.4	88.5	80.9	99.6	0	122	122	113	52	335	150000
S69	121	135	45.1	53	89.1	156	148	151	113	102	122	0	183	161	114	214	150000
S70	119	135	148.7	130	142	156	148	151	113	102	122	183	0	180	115	397.7	150000
S71	127	132	138	108	152	153	145	148	146	165	113	161	180	0	111	244	150000
S72	49.5	65.5	79.5	59.1	73.5	86.9	78.9	82	56.3	86.1	51.5	114	115	111	0	328.5	150000
Demand	150000	150000	150000	150000	150000	150000	150000	150000	150000	150000	150000	150000	150000	150000	150000	150000	

APENDIX B

Table4.2 **DATA FOR UNIT COST OF TRANSPORTATION OF COCOA FROM SOURCES TO DESTINATION**

SORCES	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	D11	D12	D13	D14	D15	D16	SUPPLY
S1	0.2	0.7	0.89	0.68	0.77	0.84	0.64	0.81	0.48	0.86	0.64	1.05	1.03	1.09	0.55	2.548	2338
S2	0.2	0.7	0.91	0.7	0.79	0.87	0.66	0.83	0.5	0.88	0.66	1.07	1.06	1.11	0.57	2.5704	566
S3	0.5	0.9	1.14	0.92	1.02	1.09	0.88	1.06	0.73	1.11	0.88	1.3	1.28	1.34	0.8	2.7958	2160
S4	0.4	0.9	1.05	0.83	0.93	1	0.79	0.97	0.64	1.02	0.79	1.21	1.19	1.25	0.71	2.7055	5277
S5	0.3	0.8	0.96	0.74	0.84	0.91	0.7	0.88	0.55	0.93	0.7	1.12	1.1	1.16	0.62	2.6152	91
S6	0.5	0.8	0.85	0.72	0.81	0.9	0.06	0.87	0.69	0.9	0.65	1.09	1.09	1.07	0.61	5E+08	2673
S7	0.6	0.9	0.96	0.83	0.92	1.01	0.17	0.98	0.8	1.01	0.77	1.2	1.2	1.18	0.72	5E+08	4053
S8	0.6	0.8	0.93	0.81	0.89	0.99	0.14	0.95	0.77	0.98	0.74	1.18	1.18	1.15	0.69	5E+08	5933
S9	0.9	1	0.93	0.76	0.35	1.16	1.1	1.12	0.73	0.45	0.96	0.97	1.35	1.41	0.86	5E+08	1318
S10	1	1.1	1.04	0.87	0.46	1.26	1.21	1.23	0.83	0.55	1.06	1.08	1.45	1.52	0.97	5E+08	3024
S11	0.9	1	0.9	0.73	0.32	1.12	1.07	1.09	0.69	0.41	0.92	0.94	1.31	1.38	0.83	5E+08	1270
S12	0.9	0.9	0.18	0.5	0.76	1.03	0.97	0.99	0.91	0.86	0.87	0.5	1.22	1.15	0.74	5E+08	1074
S13	1	1	0.28	0.6	0.86	1.13	1.08	1.1	1.02	0.96	0.97	0.6	1.32	1.25	0.84	5E+	901

																08	
S14	1	1	0.32	0.64	0.9	1.17	1.11	1.13	1.05	1	1.01	0.63	1.36	1.28	0.87	5E+08	582
S15	1	1	0.29	0.61	0.88	1.14	1.09	1.11	1.03	0.98	0.99	0.61	1.33	1.26	0.85	5E+08	95
S16	1.1	1.1	0.39	0.71	0.98	1.24	1.19	1.21	1.13	1.08	1.09	0.71	1.44	1.36	0.95	5E+08	1404
S17	1.2	1.2	0.51	0.83	1.09	1.36	1.3	1.32	1.24	1.19	1.2	0.82	1.55	1.47	1.06	5E+08	505
S18	0.5	0.7	0.91	0.61	0.56	0.87	0.81	0.83	0.18	0.64	0.75	0.97	0.97	1.2	0.57	2.9883	3420
S19	0.5	0.8	1.01	0.7	0.65	0.96	0.9	0.92	0.27	0.73	0.84	1.06	1.06	1.29	0.66	3.0786	866
S20	0.5	0.7	0.91	0.61	0.56	0.87	0.81	0.83	0.18	0.64	0.75	0.97	0.97	1.2	0.57	2.9883	1020
S21	0.4	0.6	0.81	0.51	0.45	0.77	0.71	0.73	0.08	0.54	0.65	0.87	0.87	1.1	0.47	2.8875	342
S22	0.4	0.7	0.9	0.6	0.54	0.86	0.8	0.82	0.17	0.63	0.73	0.96	0.96	1.19	0.56	2.9764	1464
S23	0.9	1	0.42	0.47	0.73	1.19	1.14	1.16	0.89	0.82	0.96	0.1	1.39	1.23	0.9	2.6943	3621
S24	1.1	1.1	0.52	0.57	0.83	1.3	1.24	1.26	0.99	0.92	1.06	0.2	1.49	1.33	1	2.7958	1870
S25	1.1	1.2	0.61	0.66	0.92	1.39	1.33	1.35	1.08	1.01	1.15	0.29	1.58	1.42	1.09	2.8854	2550
S26	1.4	1.4	0.82	0.88	1.13	1.6	1.54	1.56	1.3	1.22	1.36	0.5	1.79	1.63	1.3	3.0968	1851
S27	0.7	0.8	0.91	0.78	0.86	0.96	0.9	0.09	0.74	0.95	0.71	1.15	1.15	1.13	0.66	2.6488	514
S28	0.8	0.9	0.97	0.84	0.93	1.02	0.97	0.15	0.81	1.02	0.77	1.21	1.21	1.19	0.73	2.7125	4055

S29	0.9	1	1.07	0.95	1.03	1.13	1.07	0.26	0.91	1.12	0.88	1.32	1.32	1.3	0.83	2.8175	10338
S30	0.7	0.8	0.86	0.73	0.82	0.91	0.86	0.04	0.7	0.91	0.66	1.1	1.1	1.08	0.62	2.6033	1552
S31	0.8	0.3	0.97	0.84	0.93	1.02	0.97	0.99	0.81	1.02	0.77	1.21	1.21	1.19	0.73	5E+08	3995
S32	0.8	0.3	0.97	0.84	0.93	1.02	0.97	0.99	0.81	1.02	0.77	1.21	1.21	1.19	0.73	5E+08	2348
S33	0.7	0.2	0.88	0.75	0.83	0.93	0.87	0.89	0.71	0.92	0.68	1.12	1.12	1.1	0.63	5E+08	2339
S34	1	0.5	1.2	1.08	1.16	1.26	1.2	1.22	1.04	1.25	1.01	1.45	1.45	1.42	0.96	5E+08	695
S35	0.7	0.7	0.92	0.71	0.83	0.88	0.82	0.84	0.79	0.92	0.23	1.08	1.08	1.02	0.59	5E+08	3011
S36	0.8	0.9	1.1	0.89	1.02	1.06	1	1.03	0.97	1.1	0.41	1.26	1.26	1.2	0.77	5E+08	459
S37	0.7	0.8	0.97	0.76	0.89	0.94	0.88	0.9	0.85	0.98	0.28	1.14	1.14	1.07	0.64	5E+08	1838
S38	0.6	0.7	0.4	0.08	0.49	0.81	0.75	0.77	0.51	0.58	0.56	0.46	1	0.84	0.5	5E+08	1153
S39	0.7	0.8	0.53	0.21	0.62	0.93	0.88	0.9	0.64	0.71	0.69	0.58	1.12	0.97	0.62	5E+08	2107
S40	0.7	0.8	0.56	0.25	0.66	0.97	0.91	0.93	0.67	0.74	0.73	0.62	1.16	1	0.66	5E+08	5330
S41	0.9	1	1.14	1.01	1.09	0.29	1.13	1.15	0.97	1.18	0.94	1.38	1.38	1.36	0.9	2.88	930
S42	0.7	0.8	0.94	0.82	0.9	0.09	0.94	0.96	0.78	0.99	0.75	1.19	1.19	1.16	0.7	2.6875	1217
S43	0.8	0.9	0.98	0.85	0.94	0.13	0.98	1	0.82	1.03	0.79	1.23	1.23	1.2	0.74	2.726	1121
S44	0.7	0.8	0.9	0.77	0.85	0.05	0.89	0.91	0.73	0.94	0.7	1.14	1.14	1.12	0.65	2.6385	136

S45	0.5	0.7	0.76	0.62	0.72	0.81	0.76	0.78	0.6	0.81	0.56	1	1	0.98	0.2	2.503	517
S46	0.6	0.7	0.83	0.69	0.79	0.88	0.83	0.85	0.67	0.88	0.63	1.07	1.07	1.05	0.27	2.573	713
S47	0.7	0.9	0.96	0.81	0.91	1.01	0.95	0.97	0.79	1	0.76	1.2	1.2	1.18	0.4	2.699	2402
S48	0.5	0.7	0.76	0.61	0.71	0.81	0.75	0.77	0.59	0.8	0.56	1	1	0.98	0.2	2.5002	1929
S49	0.9	0.9	0.88	0.69	0.3	1.09	1.04	1.06	0.66	0.2	0.89	0.91	0.91	1.35	0.8	2.408	2693
S50	0.8	0.9	0.83	0.65	0.25	1.04	0.99	1.01	0.61	0.15	0.84	0.86	0.86	1.3	0.75	2.359	1357
S51	1.1	1.2	0.53	0.58	0.83	1.3	1.25	1.27	1	0.92	1.06	0.21	1.49	1.34	1.01	4.2778	4169
S52	1	1.1	0.48	0.54	0.79	1.26	1.2	1.23	0.96	0.88	1.02	0.17	1.45	1.3	0.97	4.2358	5360
S53	1	1.1	0.45	0.5	0.76	1.23	1.17	1.19	0.92	0.85	0.99	0.13	1.42	1.26	0.93	4.2008	4271
S54	1	1.1	0.5	0.56	0.81	1.28	1.23	1.25	0.98	0.9	1.04	0.13	1.47	1.32	0.99	4.2568	3217
S55	1	1.1	1.1	0.89	1.2	1.2	1.15	1.17	1.16	1.29	0.92	1.26	1.39	0.13	0.91	1.841	2603
S56	1	1.1	1.12	0.91	1.22	1.22	1.17	1.19	1.18	1.31	0.95	1.28	1.42	0.15	0.93	1.862	2525
S57	1	1	1.07	0.86	1.17	1.18	1.12	1.14	1.13	1.26	0.9	1.23	1.37	0.11	0.88	1.813	2614
S58	0	0.5	0.69	0.47	0.57	0.64	0.43	0.61	0.28	0.66	0.43	0.85	0.83	0.89	0.35	2.345	150000
S59	0.5	0	0.7	0.57	0.66	0.75	0.7	0.72	0.54	0.75	0.5	0.94	0.94	0.92	0.46	2.443	150000
S60	0.7	0.7	0	0.32	0.58	0.85	0.79	0.81	0.74	0.68	0.69	0.32	1.04	0.97	0.56	1.81	15000

																3	0
S61	0.5	0.6	0.32	0	0.41	0.72	0.67	0.69	0.43	0.5	0.48	0.37	0.91	0.76	0.41	1.869	150000
S62	0.6	0.7	0.58	0.41	0	0.81	0.75	0.77	0.38	0.1	0.61	0.62	1	1.06	0.51	2.121	150000
S63	0.6	0.7	0.85	0.72	0.81	0	0.85	0.87	0.69	0.9	0.65	1.09	1.09	1.07	0.61	2.5928	150000
S64	0.4	0.7	0.79	0.67	0.75	0.85	0	0.81	0.63	0.84	0.6	1.04	1.04	1.01	0.55	2.5368	150000
S65	0.6	0.7	0.81	0.69	0.77	0.87	0.81	0	0.65	0.86	0.62	1.06	1.06	1.04	0.57	2.5585	150000
S66	0.3	0.5	0.74	0.43	0.38	0.69	0.63	0.65	0	0.46	0.57	0.79	0.79	1.02	0.39	2.289	150000
S67	0.7	0.7	0.68	0.5	0.1	0.9	0.84	0.86	0.46	0	0.7	0.71	0.71	1.16	0.6	2.212	150000
S68	0.4	0.5	0.69	0.48	0.61	0.65	0.6	0.62	0.57	0.7	0	0.85	0.85	0.79	0.36	2.345	150000
S69	0.8	0.9	0.32	0.37	0.62	1.09	1.04	1.06	0.79	0.71	0.85	0	1.28	1.13	0.8	1.498	150000
S70	0.8	0.9	1.04	0.91	0.99	1.09	1.04	1.06	0.79	0.71	0.85	1.28	0	1.26	0.8	2.7839	150000
S71	0.9	0.9	0.97	0.76	1.06	1.07	1.01	1.04	1.02	1.16	0.79	1.13	1.26	0	0.78	1.708	150000
S72	0.3	0.5	0.56	0.41	0.51	0.61	0.55	0.57	0.39	0.6	0.36	0.8	0.8	0.78	0	2.2995	150000
Demand	150000	150000	150000	150000	150000	150000	150000	150000	150000	150000	150000	150000	150000	150000	150000	150000	

APENDIX C

SUMMARY OF RESULTS OF DATA ANALYSED

Table 4.3

From	To	Shipment	Cost per unit	Shipment cost
Source 1	Destination 4	2,338.	0.6762	1,580.956
Source 2	Destination 4	566.	0.6986	395.4076
Source 3	Destination 1	2,160.	0.4508	973.728
Source 3	Destination 13	0.	1.2817	0.
Source 4	Destination 4	5,277.	0.8337	4,399.435
Source 5	Destination 4	91.	0.7434	67.6494
Source 6	Destination 4	2,673.	0.721	1,927.233
Source 6	Destination 7	0.	0.056	0.
Source 7	Destination 4	4,053.	0.833	3,376.149
Source 8	Destination 4	5,933.	0.805	4,776.065
Source 9	Destination 5	1,318.	0.35	461.3
Source 10	Destination 5	3,024.	0.455	1,375.92
Source 11	Destination 5	1,270.	0.315	400.05
Source 12	Destination 3	1,074.	0.1799	193.2126
Source 13	Destination 3	901.	0.2814	253.5414
Source 14	Destination 3	582.	0.3157	183.7374
Source 15	Destination 3	95.	0.2926	27.797
Source 16	Destination 3	1,404.	0.3941	553.3164
Source 17	Destination 3	505.	0.5068	255.934
Source 18	Destination 9	3,420.	0.1799	615.258
Source 19	Destination 9	866.	0.2702	233.9932
Source 20	Destination 9	1,020.	0.1799	183.498
Source 21	Destination 9	342.	0.0791	27.0522
Source 22	Destination 9	1,464.	0.168	245.952
Source 23	Destination 12	3,621.	0.1015	367.5315
Source 24	Destination 12	1,870.	0.203	379.61
Source 25	Destination 12	2,550.	0.2926	746.13
Source 26	Destination 12	1,851.	0.504	932.904
Source 27	Destination 8	514.	0.0903	46.4142
Source 28	Destination 4	4,055.	0.8407	3,409.038
Source 29	Destination 4	10,338.	0.9457	9,776.646

Source 30	Destination 8	1,552.	0.0448	69.5296
Source 31	Destination 4	3,995.	0.8414	3,361.393
Source 32	Destination 4	2,348.	0.8414	1,975.607
Source 33	Destination 2	0.	0.175	0.
Source 33	Destination 4	2,339.	0.7462	1,745.362
Source 34	Destination 4	695.	1.0752	747.264
Source 35	Destination 11	3,011.	0.2254	678.6794
Source 36	Destination 11	459.	0.406	186.354
Source 37	Destination 11	1,838.	0.2814	517.2132
Source 38	Destination 4	1,153.	0.084	96.852
Source 39	Destination 4	2,107.	0.21	442.47
Source 40	Destination 4	5,330.	0.245	1,305.85
Source 41	Destination 4	930.	1.008	937.44
Source 42	Destination 4	1,217.	0.8155	992.4635
Source 42	Destination 6	0.	0.0945	0.
Source 43	Destination 4	1,121.	0.854	957.334
Source 44	Destination 4	136.	0.7665	104.244
Source 45	Destination 4	517.	0.6167	318.8339
Source 46	Destination 4	713.	0.6867	489.6171
Source 47	Destination 4	2,402.	0.8127	1,952.105
Source 47	Destination 15	0.	0.399	0.
Source 48	Destination 4	1,929.	0.6139	1,184.213
Source 49	Destination 10	2,693.	0.196	527.828
Source 50	Destination 10	1,357.	0.147	199.479
Source 51	Destination 12	4,169.	0.21	875.49
Source 52	Destination 12	5,360.	0.168	900.48
Source 53	Destination 12	4,271.	0.133	568.043
Source 54	Destination 12	3,217.	0.133	427.861
Source 55	Destination 14	2,603.	0.133	346.199
Source 56	Destination 14	2,525.	0.154	388.85
Source 57	Destination 14	2,614.	0.105	274.47
Source 58	Destination 1	147,840.	0.	0.
Source 58	Destination 4	2,160.	0.4732	1,022.112
Source 59	Destination 2	150,000.	0.	0.
Source 60	Destination 3	145,439.	0.	0.

Source 60	Destination 16	4,561.	1.813	8,269.093
Source 61	Destination 4	83,518.	0.	0.
Source 61	Destination 16	66,482.	1.869	124,254.9
Source 62	Destination 5	144,388.	0.	0.
Source 62	Destination 16	5,612.	2.121	11,903.05
Source 63	Destination 6	150,000.	0.	0.
Source 64	Destination 7	150,000.	0.	0.
Source 65	Destination 4	2,066.	0.6867	1,418.722
Source 65	Destination 8	147,934.	0.	0.
Source 66	Destination 9	142,888.	0.	0.
Source 66	Destination 16	7,112.	2.289	16,279.37
Source 67	Destination 10	145,950.	0.	0.
Source 67	Destination 16	4,050.	2.212	8,958.6
Source 68	Destination 11	144,692.	0.	0.
Source 68	Destination 16	5,308.	2.345	12,447.26
Source 69	Destination 12	123,091.	0.	0.
Source 69	Destination 16	26,909.	1.498	40,309.68
Source 70	Destination 13	150,000.	0.	0.
Source 71	Destination 14	142,258.	0.	0.
Source 71	Destination 16	7,742.	1.708	13,223.34
Source 72	Destination 15	150,000.	0.	0.
Demand	Destination 16	2,122,224.	0.	0.

APPENDIX D

Table 4.4 **Names of towns used as sources and towns used as Destinations.**

Source 1	Abroma
Source 2	Barekuma
Source 3	Akomadan
Source 4	Baniekrom
Source 5	Gambia
Source 6	Kwaakrom
Source 7	Aboaboso
Source 8	Mam nkwanta
Source 9	Bobiam
Source 10	Kubease
Source 11	Achiasse No 1
Source 12	Yaadome
Source 13	Kube nkwanta
Source 14	Kwadwo kwapia
Source 15	Kokotenten
Source 16	Ampuyase
Source 17	Adansi Grumisa
Source 18	Nkwa Kwanua
Source 19	Onaa
Source 20	Mennam
Source 21	Dadease
Source 22	Abasua
Source 23	Dzovie
Source 24	Odumase
Source 25	Hwediem
Source 26	Mpirekyere
Source 27	Achiase No 2
Source 28	Marfokrom
Source 29	Kyirabaa
Source 30	Bogoso
Source 31	Mooso
Source 32	Yonso
Source 33	Fufuni Dabang
Source 34	Kwaman
Source 35	Asakra
Source 36	Apenimade
Source 37	Dotiem
Source 38	Pekyi No. 1
Source 39	Asisiriwa
Source 40	Fiamoso
Source 41	Nsokote
Source 42	Akromaso
Source 43	Tebeso
Source 44	Akwasrem
Source 45	Jamaica

Source 46	Amadaa
Source 47	Moseaso
Source 48	Akaniase
Source 49	Konkonma Bronyakrom
Source 50	Teshie Praso
Source 51	Ayinasaso
Source 53	Katapei
Source 53	Nyameadom
Source 54	Yamfo
Source 55	Bayerebon No. 3
Source 56	Kwabenakwa
Source 57	Obosikrom
Source 58	Ofinso
Source 59	Agona
Source 60	Obuasi
Source 61	Bekwai
Source 62	Konongo
Source 63	Nsokote
Source 64	Antoakrom
Source 65	Nyinahin
Source 66	Effiduase
Source 67	Juaso
Source 68	Mankranso
Source 69	New Edubiase
Source 70	Tepa
Source 71	Bibiani
Source 72	Nkawie
Destination 1	Ofinso
Destination 2	Agona
Destination 3	Obuasi
Destination 4	Bekwai
Destination 5	Konongo
Destination 6	Nsokote
Destination 7	Antoakrom
Destination 8	Nyinahin
Destination 9	Effiduase
Destination 10	Juaso
Destination 11	Mankranso
Destination 12	New Edubiase
Destination 13	Tepa
Destination 14	Bibiani
Destination 15	Nkawie
Destination 16	Tema