TRANSSHIPMENT PROBLEM IN SUPPLY CHAINSYSTEM

(CASE STUDY: JUABEN OIL MILLS LTD)

BY

AMMA ACHIAA (B. Ed Mathematics)

PG3005709

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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.

Amma Achiaa PG3005709	………………	………………
Student's Name & ID	Signature	Date

Certified By

Mr. K. F. Darkwah	…………….	……………
Supervisor's Name	Signature	Date

Certified by

Dr. S. K. Amponsah	………………….	……………………
Head of Department's Name	Signature	Date

Certified by

Prof. I. K. Dontwi	………………….	..………………..
Dean of Distance Learning's Name	Signature	Date

DEDICATION

I dedicate this to the Glory of God the Father, God the Son and God the Holy Spirit, and to my family. I am grateful.

ABSTRACT

Transportation is the physical distribution of resources from one place to the other, to meet a specific set of requirements. It is easy to express a transportation problem mathematically in terms of an LP model, which can be solved by the Simplex Method. Since transportation problem involves a large number of variables and constraints, it takes a very long time to solve it by simple Simplex Method. Simplex algorithms can be specialized to solve several linear programming models that arise from Network flow problems.

The transshipment problem is an extension of the framework of transportation problem in which intermediate nodes, referred to as transshipment nodes are added to account for locations such as warehouses. We will show that any given transshipment problem can be converted into an equivalent transportation problem. Hence our procedure for solving the latter problems can be applied to the solution of transshipment problems as well.

The transshipment problem is concerned with the allocating and routing flow from supply centers to destination centers via intermediate points. In addition to transshipment flow, supply centers generates a surplus that must be distributed and each destination generates a given deficit. Intermediate points (transshipment nodes) neither generate nor absorb flow. The total supply must equal the total demand, so dummy nodes should be added appropriately. No connection may have a capacity, and all costs should be nonnegative. This defines a transshipment problem. The problem of interest is to determine an optimal transportation scheme that minimizes the total cost of shipments, subject to supply and demand constraints.

The research presented in this paper applies the Quantitative method to reveal and analyse transshipment problems in manufacturing industries using data collected from Juaben Oil Mills Limited

The main objective of this research is to minimize the cost of transporting goods from origins to detstinations in a manufacturing industry.

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CHAPTER ONE

INTRODUCTION

Effective supply chain management is currently recognized as a key determinant of competitiveness and success for most manufacturing and retailing organizations, because the implementation of supply chain management has significant impact on cost, service level and quality. Numerous strategies for achieving these targets have been proposed and investigated in both practiced and academic order over the past decades.

One such strategy commonly practiced in multi-locations supply chain systems, facing stochastic demand, allows movement of stock between locations at the same echelon levels or even across different levels. These stock movements are termed lateral transshipment. Or simply transshipment. As a demand occurs under the implementation of transshipment strategies, there will be three possible activities—the demand is met from the stock on-hand or it is met through transshipment from another location in the system or it is back ordered.

Firstly, if on-hand inventory level is greater than the demand size, then the demand is met.

Secondly, if the on-hand inventory level is less than the demand size, then it is used to partially satisfy the demand and the remaining demand is met either through transshipment or is back ordered.

Thirdly, if on-hand inventory level is zero, the demand is met through transshipment or is back ordered under the assumption of no lost sale. (Open Access Database www.intehweb.com)

One of the prerequisite of successful implementation of transshipment is well-established information systems. At present many large modern companies connected by information systems can control the relationships of many branches, and thus they may be ready to reap cost reduction and service improvement associated with lateral transshipment.

This thesis mainly concentrates on an analysis of the operation of transshipment of products in an oil company (JUABEN OIL MILLS COMPANY LIMITED), at a semi-rural town. The techniques employed in determining an optimal solution to transshipment problem is the same employed under direct transportation model. However certain modifications in sources and destination points are reviewed to be made to counter the peculiarities of indirect transportation.

1.1 TRANSPORTATION AND MODE OF TRANSPORT

Transport is the movement of people and goods from one location to another. Modes of transport include air, rail, road, water, cable, pipeline, and space. The field can be divided into infrastructure, vehicles, and operations.

Transport infrastructure consists of the fixed installations necessary for transport, and may be roads, railways, airways, waterways, canals and pipelines, and terminals such as airports, railway stations, bus stations, warehouses, trucking terminals, refueling depots (including fueling docks and fuel stations), and seaports. Terminals may be used both for interchange of passengers and cargo and for maintenance.

Vehicles traveling on these networks may include automobiles, bicycles, buses, trains, trucks, people, helicopters, and aircraft. Operations deal with the way the vehicles are operated, and the procedures set for this purpose including financing, legalities and policies. In the transport industry, operations and ownership of infrastructure can be either public or private, depending on the country and mode.

Passenger transport may be public, where operators provide scheduled services, or private. Freight transport has become focused on containerization, although bulk transport is used for large volumes of durable items. Transport plays an important part in economic growth and globalization, but most types cause air pollution and use large amounts of land. While it is heavily subsidized by governments, good planning of transport is essential to make traffic flow and restrain urban sprawl.

Mode of transport

A mode of transport is a solution that makes use of a particular type of vehicle, infrastructure and operation. The transport of a person or of cargo may involve one mode or several modes, with the latter case being called intermodal or multimodal transport. Each mode has its advantages and disadvantages, and will be chosen for a trip on the basis of cost, capability, route, and speed.The modes of transport include human-powered, animal-powered, air, road, water, cable, pipeline, and space.

Human-powered transport

Human powered transport is the transport of people and/or goods using human muscle-power, in the form of walking, running and swimming. Modern technology has allowed machines to enhance human-power. Human-powered transport remains popular for reasons of cost-saving, leisure, physical exercise and environmentalism. Human-powered transport is sometimes the only type available, especially in underdeveloped or inaccessible regions. It is considered an ideal form of sustainable transportation.

Although humans are able to walk without infrastructure, the transport can be enhanced through the use of roads, especially when enforcing the human power with vehicles, such as bicycles and inline skates. Human-powered vehicles have also been developed for difficult environments, such as snow and water, by watercraft rowing and skiing; even the air can be entered with human-powered aircraft.

Animal-powered transport

Animal-powered transport is the use of working animals for the movement of people and goods. Humans may ride some of the animals directly, use them as pack animals for carrying goods, or harness them, alone or in teams, to pull sleds or wheeled vehicles. Animals are superior to people in their speed, endurance and carrying capacity; prior to the Industrial Revolution they were used for all land transport impracticable for people, and they remain an important mode of transport in less developed areas of the world.

Air transport

A fixed-wing aircraft, commonly called airplane, is a heavier-than-air craft where movement of the air in relation to the wings is used to generate lift. The term is used to distinguish from rotary-wing aircraft, where the movement of the lift surfaces relative to the air generates lift. A gyroplane is both fixed-wing and rotary-wing. Fixed-wing aircraft range from small trainers and recreational aircraft to large airliners and military cargo aircraft.

Two things necessary for aircraft are air flow over the wings for lift and an area for landing. The majority of aircraft also need an airport with the infrastructure to receive maintenance, restocking, refueling and for the loading and unloading of crew, cargo and passengers. While the vast majority of aircraft land and take off on land, some are capable of take off and landing on ice, snow and calm water. The aircraft is the second fastest method of transport, after the rocket. Commercial jets can reach up to 875 kilometers per hour (544 mph), single-engine aircraft 175 kilometers per hour (109 mph). Aviation is able to quickly transport people and limited amounts of cargo over longer distances, but incur high costs and energy use; for short distances or in inaccessible places helicopters can be used. WHO estimates that up to 500,000 people are on planes at any time.

Rail transport

Rail transport is where a train runs along a set of two parallel steel rails, known as a railway or railroad. The rails are anchored perpendicular to ties (or sleepers) of timber, concrete or steel, to maintain a consistent distance apart, or gauge. The rails and perpendicular beams are placed on a foundation made of concrete, or compressed earth and gravel in a bed of ballast. Alternative methods include monorail and maglev.

A train consists of one or more connected vehicles that run on the rails. Propulsion is commonly provided by a locomotive, that hauls a series of uncovered cars that can carry passengers or freight. The locomotive can be powered by steam, diesel or by electricity supplied by trackside systems. Alternatively, some or all the cars can be powered, known as a multiple unit. Also, a train can be powered by horses, cables, gravity, pneumatics and gas turbines. Railed vehicles move with much less friction than rubber tires on paved roads, making trains more energy efficient, though not as efficient as ships.

Intercity trains are long-haul services connecting cities. modern high-speed rail is capable of speeds up to 350 km/h (220 mph), but this requires specially built track. Regional and commuter trains feed cities from suburbs and surrounding areas, while intra-urban transport is performed by high-capacity tramways and rapid transits, often making up the backbone of a city's public transport. Freight trains traditionally used box cars, requiring manual loading and unloading of the cargo. Since the 1960s, container trains have become the dominant solution for general freight, while large quantities of bulk are transported by dedicated trains.

Road transport

A road is an identifiable route, way or path between two or more places. Roads are typically smoothed, paved, or otherwise prepared to allow easy travel; though they need not be, and historically many roads were simply recognizable routes without any formal construction or maintenance. In urban areas, roads may pass through a city or village and be named as streets, serving a dual function as urban space easement and route.

The most common road vehicle is the automobile; a wheeled passenger vehicle that carries its own motor. Other users of roads include buses, trucks, motorcycles, bicycles and pedestrians. As of 2002, there were 590 million automobiles worldwide. Automobiles offer high flexibility and with low capacity, but are deemed with high energy and area use, and the main source of noise and air pollution in cities; buses allow for more efficient travel at the cost of reduced flexibility. Road transport by truck is often the initial and final stage of freight transport.

Water transport

Water transport is the process of transport a watercraft, such as a barge, boat, ship or

sailboat, makes over a body of water, such as a sea, ocean, lake, canal or river. The

need for buoyancy unites watercraft, and makes the hull a dominant aspect of its construction, maintenance and appearance.

In the 1800s the first steam ships were developed, using a steam engine to drive a paddle wheel or propeller to move the ship. The steam was produced using wood or coal. Now most ships have an engine using a slightly refined type of petroleum called bunker fuel. Some ships, such as submarines, use nuclear power to produce the steam. Recreational or educational craft still use wind power, while some smaller craft use internal combustion engines to drive one or more propellers, or in the case of jet boats, an inboard water jet. In shallow draft areas, hovercraft are propelled by large pusher-prop fans.

Although slow, modern sea transport is a highly effective method of transporting large quantities of non-perishable goods. Commercial vessels, nearly 35,000 in number, carried 7.4 billion tons of cargo in 2007, Transport by water is significantly less costly than air transport for trans-continental shipping; short sea shipping and ferries remain viable in coastal areas.

Others

Pipeline transport sends goods through a pipe, most commonly liquid and gases are sent, but pneumatic tubes can also send solid capsules using compressed air. For liquids/gases, any chemically stable liquid or gas can be sent through a pipeline. Short-distance systems exist for sewage, slurry, water and beer, while long-distance networks are used for petroleum and natural gas. Cable transport is a broad mode where vehicles are pulled by cables instead of an internal power source. It is most commonly used at steep gradient. Typical solutions include aerial tramway, elevators, escalator and ski lifts; some of these are also categorized as conveyor transport.

Spaceflight is transport out of Earth's atmosphere into outer space by means of a spacecraft. While large amounts of research have gone into technology, it is rarely used except to put satellites into orbit, and conduct scientific experiments. However, man has landed on the moon, and probes have been sent to all the planets of the Solar System.

Suborbital spaceflight is the fastest of the existing and planned transport systems from a place on Earth to a distant other place on Earth. Faster transport could be achieved through part of a Low Earth orbit, or following that trajectory even faster using the propulsion of the rocket to steer it.

1.1.1 ADVANTAGES AND DISADVANTAGES O F TRANSPORTATION

Environment

Transport is a major use of energy, and burns most of the world's petroleum. This creates air pollution, including nitrous oxides and particulates, and is a significant contributor to global warming through emission of carbon dioxide, for which transport is the fastest-growing emission sector. By subsector, road transport is the largest contributor to global warming. Environmental regulations in developed countries have reduced the individual vehicles emission; however, this has been offset by an increase in the number of vehicles, and more use of each vehicle. Some pathways to reduce the carbon emissions of road vehicles considerably have been studied. Energy use and emissions vary largely between modes, causing environmentalists to call for a transition from air and road to rail and human-powered transport, and increase transport electrification and energy efficiency.

Other environmental impacts of transport systems include traffic congestion and automobile-oriented urban sprawl, which can consume natural habitat and agricultural lands. By reducing transportation emissions globally, it is predicted that there will be significant positive effects on Earth's air quality, acid rain, smog and climate change.

Planning

Transport planning pave way for high utilization and less impact regarding new infrastructure. Models of transport forecasting help planners to predict future transport patterns. Logistics allows owners of cargo to plan transport as part of the supply chain on the level of operation.

Transport as a field is studied through transport economics, the backbone for the creation of regulation policy by authorities. Transport engineering, a sub-discipline of civil engineering, and must take into account trip generation, trip distribution, mode choice and route assignment, while the operative level is handles through

Because of the negative impacts made, transport often becomes the subject of controversy related to choice of mode, as well as increased capacity. Automotive transport can be seen as a tragedy of the commons, where the flexibility and comfort for the individual deteriorate the natural and urban environment for all. Density of development depends on mode of transport, with public transport allowing for better spacial utilization. Good land use keeps common activities close to peoples homes and places higher-density development closer to transport lines and hubs; minimize the need for transport. There are economies of agglomeration. Beyond transportation some land uses are more efficient when clustered. Transportation facilities consume land, and in cities, pavement (devoted to streets and parking) can easily exceed 20 percent of the total land use. An efficient transport system can reduce land waste.

Too much infrastructure and too much smoothing for maximum vehicle throughput means that in many cities there is too much traffic and many—if not all—of the negative impacts that come with it. It is only in recent years that traditional practices have started to be questioned in many places, and as a result of new types of analysis which bring in a much broader range of skills than those traditionally relied on—spanning such areas as environmental impact analysis, public health, sociologists as well as economists who increasingly are questioning the viability of the old mobility solutions. European cities are leading this transition.

Economics

Transport is a key necessity for specialization—allowing production and consumption of products to occur at different locations. Transport has throughout history been a spur to expansion; better transport allows more trade and a greater spread of people. Economic growth has always been dependent on increasing the capacity and rationality of transport. But the infrastructure and operation of transport has a great impact on the land and is the largest drainer of energy, making transport sustainability a major issue.

Modern society dictates a physical distinction between home and work, forcing people to transport themselves to places of work or study, as well as to temporarily relocate for other daily activities. Passenger transport is also the essence of tourism, a major part of recreational transport. Commerce requires the transport of people to conduct business, either to allow face-to-face communication for important decisions or to move specialists from their regular place of work to sites where they are needed.

1.2 THE JUABEN OIL MILLS COMPANY LIMITED

Juaben Oil Mills is a joint venture between the Juaben Oil Mills Limited and the Juaben Traditional Council. It used to be part of the state farms established by the Colonel Kutu Acheampong regime, but it was divested under the NDC government in 1994. The Juaben Traditional Council, which bought it, embarked on an expansion exercise to make it one of the leading oil mills in the country.

The industry was started in 1984 by Nana Otuo Serebour II. The industry started with the production of palm oil at a rate of 3 tonnes per day. In 1994, the company was expanded from 3 tonnes to 9 tonnes per day. The company became a family business after Nana had invited his nephews to partnership. Afterwards, palm fruits were planted for production. This provided jobs for the inhabitants of the Ejisu Juaben traditional area. After the expansion, palm kernel oil was produced

In 2000-2002, the company decided to generate their own power for production and to do away with the power from the Electricity Company of Ghana. The production of sheabutter was started in 2002. The company stopped producing the palm kernel oil when the production of the sheabutter started. In 2006, the company started to produce palm kernel oil again. In 2006-2008, the refinery was started to utilize the palm oil produce which is sold to Unilever Company and a soap production company in Togo. The refinery produces stearin and free fatty acids for the production of soap. The refinery gets the palm fruits from:

-Nucleus farm

-Outgrower system- farmers are given loans for cultivation of palm fruits.

-Private farms.

-Purchasing clerks-the company goes around the country to purchase fruits.

The government also helps to produce funds for the company. About 40-50% of the workers are from the Juaben Metropolis. The Juaben Oil Refining industry consists of four departments and they are:

1.The Out growers department.

2. The sheabutter department.

3.The operations department.

4. The refinery.

1.3 STATEMENT OF THE PROBLEM

The Juaben Oil Mills Company limited aims at producing refined oil to some companies and individuals nationwide. All the efforts put up by the company to transport raw materials from the farmers for the manufacturing of their products is experiencing a lot of transportation problems. It is in this light that the researcher seeks to investigate into transshipment as one of the numerous problems predisposing the problem mentioned above.

1.4 OBJECTIVES

The main objectives of this study are

i. Model palm fruit shipment from the farm gate to Juaben oil mills as transshipment.

ii. Minimize cost of transporting palm fruits from the farm gates to the production plant.

1.5 RESEARCH QUESTIONS

The following are the research questions the study seeks to answer

(i)What are the main transshipment problems facing manufacturing organizations in Ghana?

(ii)What are the various components of transshipment cost and how can they be reduced?

1.6 METHODOLOGY

This thesis focuses on transshipment problems in supply chain system. A primal-dual approach is proposed to solve the problem. This allows us to minimize the variable and fixed cost. There is a wide range experiment of problem test data by this heuristics. Quantitative Methods (Q. M.) for windows software will be used to analyze the data for the work.

1.7 SIGNIFICANCE OF THE STUDY

This thesis seeks to help manufacturing industries to reduce cost of transshipment of goods and maximize profit. It can also be used by the Juaben oil mills company limited to reduce the transportation problems facing them. Finally this thesis can be used for academic research.

1.8 ORGANISATION OF THE STUDY

The study consists of five chapters with chapter one being the introduction, chapter two consists of literature review. In chapter three the method used is discussed. Chapter four deals with data collection, analysis of data and results whilst the chapter five deals with conclusions and recommendations.

1.9 SUMMARY

In this chapter, I focused on transshipment problems in supply chain system as well as transportation and its related problems, objectives and justification of study.In the next chapter, we shall review some literature pertaining transportation and its variants.

CHAPTER TWO

LITERATURE REVIEW

There is a considerable amount of literature on supply chain management over the past decades. Some papers have provided literature survey for some specific topics. For example, (Ganeshan et al., 1998) provided a taxonomic review of the supply chain management research in three categories: competitive strategies, firm-focused tactics, and operational efficiency. (Tsay et al., 1998) reviewed the recent literature on supply chain contracts. (Tan, 2001) provided a review of the evolution of the supply chain management philosophy. (Sahin and Robinson, 2002) provided a review of the prior research on information and physical flow coordination. (Li and Wang, 2007) focused on coordination mechanisms that can align the objectives of individual supply chain members.

A significant part of the recent literature on supply chain system explores the decisions on controlling inventory, production, and distribution. That literature mostly considers a few aspects of supply chain production system: the ordering policy that applies to the suppliers, the delivery policy to the buyers and the system that must satisfy demand.

Literature abounds in assembly systems in view of optimal order policies, optimal materials control, production important costs minimizing, material requirements planning ordering philosophy, effect of Work-in-process inventory design. production system integrates a group of raw materials into finished product. Analysis of such integrated system may be complex when the raw materials are different and some need preprocessing before production work. Decision models involving inventory replenishment and transshipment are difficult to solve. A number of researchers have studied the special cases where there are only two retail locations or the multiple retail locations are identical in terms of their cost structure in which the transshipment decisions can be much simplified.

Krishnan and Rao (1965), studied the transshipment problems with multiple retail locations with identical cost structure. They showed that the optimal stocking quantities satisfy the equal fractile property. Tagaras (1989), extended Krishnan and Rao's two-location model to allow for different cost structures, and analyzed the pooling effect due to transshipment. His model can also allow for a service constraint on the minimum acceptable fill rates. Taragas and Cohen (1993), later extended the two-location model to allow for positive replenishment leadtimes. With positive replenishment leadtimes, it might be beneficial to hold back stock for future demands, and so it is not necessarily optimal to always transship from the other location (complete pooling) when shortages occur. However, their numerical results showed that complete pooling generally dominates partial pooling. Herer and Rashit (1999), studied the two-location transshipment problem to include fixed and joint replenishment costs, and derived several properties regarding the structure of the corresponding optimal replenishment and transshipment policies. Herer and Tzur (2001), considered a dynamic two-location transshipment problem where demands are deterministic and the objective is to minimize the total replenishment, holding and transshipment costs over a finite horizon. They derived some structural results on the optimal policy and provided a polynomial time algorithm for finding the optimal policy.

Rudi et al. (2001) ,studied a two location model with decentralized decision making. They analyzed the optimal transshipment prices to maximize the total profit. In a recent paper, Dong and Rudi (2004), analyzed how transshipment can benefit a manufacturer and multiple retailers in settings where the manufacturer can serve as a price setter or a price taking. In their model, the multiple retailers have the same cost structure and complete pooling among retailers is assumed. Zhang (2005), extended their results to general demand distributions.

When there are more than two locations in the system and the cost structures are non-identical, the optimal transshipment policy becomes more complex, as one need to determine from which location, in addition to how many, to transship when a shortage occurs at any location. In general, it is analytically intractable to determine the joint optimal replenishment and transshipment policy. A number of papers studied different heuristic decision rules for lateral transshipment and then evaluated the optimal replenishment policy under these decision rules. This line of research includes the work of Alfredsson and Verrijdt (1999), Archibald, et al. (1997), Axsater (1990, 2003), Dada (1992), Grahovac and Chakravarty (2001), Lee (1987), Minner et. al (2003), and Robinson (1990). Most recently, Wee and Dada (2005), studied the optimal policies for transshipping inventory in a retail network. They focused on the integrated transshipment decisions instead of the interactions among the retailers and the impact of the network structure.

There is a closely related literature where transshipment is allowed in a distribution system periodically as a way to rebalance stock at different locations rather than to cover shortage. This includes the work of Cohen, et al. (1986), Das (1975), Diks and de Kok (1996), Hoadley and Heyman (1977),Jonsson and Silver (1987), and Karmarker and Patel (1977).

Robust optimization has recently gained substantial popularity as a useful methodology for addressing optimization models under uncertainties. The methodology immunizes uncertain mathematical optimization against infeasibility while preserving the tractability of the model, Robust optimization models have recently been applied to tackle decision problems in dynamic settings where future decisions (recourse variables) depend on the realization of present data including inventory management, supply contracts and project management (Chen, et al., 2005).

The following sections review the literature related to the economic orders quantity (EOQ) model, just-in-time (JIT) system model, and the assembly of different components.

Most of the existing Economic order quantity (EOQ) models are focused on lot sizing and material shipping policies. An economic order quantity (EOQ) model considering joint vendor-buyer replenishment policy (JRP) is modeled by Goyal and Satir (1989). Miyazaki *et al.,* (1988), adapted the classical economic order quantity to obtain average inventory under the assumption of instantaneous replenishment. Parlar and Rempala (1992), have presented optimal order and production quantity model for a single-stage production system. Goswami and

Chaudhuri (1992), developed a deterministic inventory model allowing shortages and backlogged with two level of storage considering a linear trend in demand.

Dan (1995), developed an economic order quantity model where order quantity is set by the maximization of return on investment (ROI), so that the order quantity is fixed regardless of the demand. Drezner *et al.*, (1995), presented an economic order quantity model for two raw materials and substituted one for another, if necessary, within a given cost limit. He considered three cases: full substitution, partial substitution and no substitution. Banerjee (1992), developed production lot sizing model to satisfy periodic demand and included Work-in-process.

Hariga and Goyal (1995), dealt with the inventory lot-sizing problem with time varying demand having linear trend. Lu (1995), presented a one-vendor multi buyer integrated inventory model. Hill (1996), determined a purchasing and production schedule minimizing total cost for a system in which a single product is manufactured from a single raw material and shipped a fixed quantity to a single customer at fixed intervals.

Fazel *et al.,* (1998), discussed an analytical comparison of inventory costs on JIT purchasing vs. EOQ with a price discount. Hariga and Haouari (1999), presented inventory lot sizing model under EOQ framework and then showed the negligent cost penalty of using the EOQ lot size instead of uniform, exponential and truncated distributions. Hill (1996), presented a two-stage lot-sizing model where the production rate of the stages are independent of each other i.e., production at first stage may be higher or lower than the second stage and vice-versa and showed a similar results regardless of production rates between the stages.

Viswanathan (1996), considered an algorithm for the joint replenishment problem determining the optimal cyclic policy for all cycles. Viswanathan (1998), concerned an integrated vendor-buyer inventory model for two different strategies and analyzed the relative performance for both the strategies with various problem parameters. Raw material ordering policy and a fixed-interval, fixed-quantity delivery policy to multiple customers for an economic batch size of product was developed to minimize the total cost by Parija and Sarker

(1999). Hill (1997, 1999), considers a manufacturing system that produces products at a finite rate and delivers them in fixed intervals. Deriving a global-optimal solution to minimize the total cost that comprises a manufacturing set-up, stock transfer, and stock holding results from his investigation.

In Just in time model (JIT) philosophy, researchers investigate the benefit of reducing ordering and setup time to a minimum. Goyal and Gupta (1989), Goyal (1995), and Aderohunmu *et al.* (1995), presented models for joint vendor-buyer policy in a just-in-time environment. Chyr *et al*. (1990), compared between just-in-time system and EOQ system with a view of lot size based on setup times and damage rates. If damage cost is not considered, the unit total cost of JIT system is slightly higher than EOQ system for single stage case; otherwise, EOQ lot-size is equal to JIT lot-size under some conditions. His conclusion shows the lot-size of JIT system (with no damage cost) is better than EOQ system (included damage cost) for a specific range. Otherwise, the latter is better. Baker *et al.* (1994), suggested decision rules in determining the suitability of switching to a JIT model from EOQ model. A two-stage optimum order and fixed quantity model were developed by Ramasesh (1990).

In a fixed quantity, just-in-time delivery system, Golhar and Sarker (1992), tested a generalized inventory model where uptime and cycle time are integer multiples of the shipment interval and match shipment size. Total cost function is piecewise convex and under certain conditions; total cost decreases linearly with reduced shipment size. Jamal and Sarker (1993), estimated the finished product batch quantity in a just-in-time production system. The raw materials ordering policy and the batch size in a regular interval of time within the production cycle was developed in the model. Sarker and Parija (1994, 1996), extended Golhar and Sarker's (1992), model developing multi-order procurement policy for raw material within a single stage-manufacturing batch. The effect of setup cost on the total cost function and an approximate integer optimal solution was adopted. Nori and Sarker (1996), adapted Sarker and Parija's (1996), model including a two-situation case, fixed setup cost and variable setup cost, in a multi-product single facility system. Sarker and Balan (1996), proposed a single-stage two-station Kanban system for a varying (linear) demand pattern model where the Kanban transports the Work-in-processes from the first station to the second. The number of Kanbans, batch sizes of the Kanbans, the dispatching time, and the schedule for production are illustrated.

Sarker and Balan (1998,1999), modified the Sarker and Balan's (1996), model incorporating the optimal number of Kanbans required in two adjacent workstations for both single-stage and multi-stage production line under a just-in-time production system. Their models assumed the demand rate as linear with distinct phases (inception, maturation and declination) of a product's life cycle. Parija and Sarker (1999), addressed multi-ordering policy of procuring raw materials for a single manufacturing system.

The model obtained a closed-form solution for minimizing the total cost in a multiple customer system. Betts and Johnston (2001), presented a new analysis of inventory reduction decisions, either by adapting JIT replenishment or component substitutions in a deterministic batch-sizing model in which inventory investment capital is finite and a decision variable.

In supply chain assembly system model, most of the researchers discussed the impact of their inventory decisions on total cost function, and mathematical models are formulated to achieve the cost reductions by optimizing the system parameters and/or the operation sequences. Batch size, order rate, production lead-time, Work-in-process inventory, delivery lead times and development of suitable mathematical models for the solution are the major concern of the models.

Axsäter and Juntti (1996) ,presented the relative cost difference between the level stock or installation stock reorder policies in a multi-level inventory system for a constant demand. The echelon stock or installation stock policy may be advantageous depending on the structure of the system. Gurnani et al. (1996), considered an assembly problem of two critical components where demand of finished product is stochastic and delivery can be completed in the next cycle. A computational study is conducted to determine the effect of supplier costs and the probability of delivery on the optimal order policy. Rosenblatt and Lee (1996), considered assembly systems of highly expensive components (e. g. aerospace industry) with longer cycle time in which product's value increases the necessity to install additional parts and labor while moving along the assembly line. A branch-and-bound procedure is used to minimizes inventory holding cost and showed sequencing of ascending values of the ratios of the 'value added' to activity duration.

The number of series systems is proportional to, in the extreme case, the factorial of n nodes in the assembly system. The lower bound and the optimal lot-size frequency policy for assembly systems with backlogging are also illustrated. Fujiwara *et al.* (1998), considered a Kanban-controlled, multi-stage production assembly system where raw materials acquisition lead times, reorder points, number of Kanbans, production lead time and demand arrival are the design parameters and variables.

Mathematical model and simulation analyses are proposed to evaluate system performance measures. Powell and Pyke (1998), addressed unbalanced assembly systems with limited buffer capacity. Heuristic rules were developed to improve existing operations and to introduce new products. Wilhelm and Pradip (1998), considered the performance measureof a single-stage, single-product, and stochastic assembly system where raw materials are ordered under the material requirement planning (MRP) policy, and the inventory position process is a Markov renewal process and production lead-time is a random variable.

Sarker and Pan (1998), presented a mixed-model supply chain system with a close and open station assembly line format. The minimum total cost was found in the open-station system for a given line length and operation sequences.

De Kok and Ton (1999), proposed multi-echelon assembly systems where components are pre-allocated to finished product. The comparison of proposed pre-allocation policies with several commonly used allocation policies was demonstrated in their research. Park and Kim (1999), focused on a make-to order policy in an assembly system where delivery dates are constraints. A non-linear mathematical model was presented to minimize the holding costs of the inventories and the experimental results are tested.

Park and Kim (2000), extend Park and Kim's (1999), model developing a mixed integer linear programming model. They incorporated the 'branch and bound' (B&B) algorithm to find the integer solutions. Agrawal and Cohen (2001), analyzed the cost-service performance and component stocking policies due to shortages and delayed production completion rates of finished product.

In manufacturing systems, work-in-process (WIP) inventories are required due to the small delivery quantity of the finished product or due to space or capital constraint of the firm. If work-in-process inventory is restricted to zero, i.e., no work-in-process inventories, then the output of the plant will be severely affected. Any manufacturing plant or assembly plant should be designed to have minimal, but not zero, WIP buffer capacity. For example, Gurani *et at,* (1996), considered as assembly problem with stochastic demand of finished product where assembly stage is free, i.e., the firm produces raw materials but sells complete sets. The firm follows a make-to-order basis production policy, so that the production is restricted only to the order(s) from the buyers.

In multi-stage assembly production systems, such as Powel and Pike (1998), where a number of raw materials are acquired from various suppliers and assembled into a single product, procures raw materials once in one cycle period. If the frequency of the raw materials procurement is simplified to a single shipment in each cycle, the raw materials inventory cost are assumed to be greater than the multiple procurement of raw materials.

In many researches, conversion ratio between the raw materials and finished product are not considered. Fujiwara *et al.* (1998), considered an assembly system from a group of raw materials, but did not specify the quantity required for each type of raw materials to produce a single finished product. Agrawal and Cohan (2001), determined optimal stocking policies, but did not consider conversion ratio of raw materials with finished product. In real example, a finished product may require more than unique quantity of each type of raw material

Hoppe et al., (2000) ,gave the first polynomial-time algorithm for the quickest transshipment problem. Their algorithm provided an integral optimum flow. Previously, the quickest transshipment problem could only be solved efficiently in the special case of a single source and single sink.

An object-oriented model was proposed by Bullinger et al., (1997), on economic coercions within the automotive industry, the mechanical engineering or the electrical industry require cost reductions and means for prompter reaction due to a constantly altering market. The cooperation of several sites provides a solution of this challenge. Enterprises which show alternative as well as complementary production possibilities at several locations have to plan the coordination of interaction between sites. However, conventional planning systems are not designed adequately neither their functional nor their architectural basis in order to cover the requirements of multi-site production.

In recent years, supply chain optimisation has attracted attention that hitherto was focussed on more local issues such as optimisation of specific plant operations, individual logistic activities of distribution/routing and inventory management. Addressing this problem is a challenge not only from an optimisation perspective but also from the stand point of addressing and modeling important trade-offs. A supply chain problem consisting of production planning and distribution scheduling in two tiers was presented by Mokashi et al., (2003).

A decomposition of the overall problem into aggregate production planning and 2-echelon distribution scheduling is proposed. The two individual problems are solved by applying customised dispersion algorithms on graphs that represent their constraints and objectives in the form of connections between and weights of its vertices. Results are presented for an industrial case study making comparisons with ad-hoc methods for these individual problems.

“Transshipment” is a very popular and important issue in the present international trade container transportation market. In order to reduce the international trade container transportation operation cost, it is very important for shipping companies to choose the best transshipment container port. The aim of this paper was to present a new Fuzzy Multiple Criteria Decision Making Method (FMCDM) for solving the transshipment container port selection problem under fuzzy environment. Chien-Chang (2007), presented first the canonical representation of multiplication operation on three fuzzy numbers, and then this canonical representation was applied to the selection of transshipment container port. Based on the canonical representation, the decision maker of shipping company can determine quickly the ranking order of all candidate transshipment container ports and select easily the best one.

Weng (1999), studied coordination strategies for a two-echelon manufacturing and distribution system consisting of a manufacturing centre and n distribution centres. Models were developed and analysed for two alternative control systems: one employed coordination among the manufacturing centre and n distribution centres, the other did not. Three coordination strategies were studied: (1) coordinating production and distribution decisions at every production opportunity; (2) coordinating and deferring system-order allocation decisions; and (3) trans-shipment among distribution centres. The analysis yielded the following insights into the value of coordination. First, coordination could have a very significant impact on distribution centre safety stock needed to meet the required service level. Second, the three coordination strategies studied contribute very differently in reducing distribution centre safety stock. Third, the maximum reduction in a distribution centre's safety stock level resulted from coordination was achieved when the variance of end-of-cycle on-hand inventory was identical for all distribution centres.

The cash management program is concerned with optimally financing net cash outflows and investing net inflows of a firm while simultaneously determining payment schedules for incurred liabilities. The program was formulated by Srinivasan (1994), as a transshipment model to minimize the total cost of allocating sources of funds to different uses while retaining the possibility of transferring cash between sources. A numerical example was formulated using this model and its optimal solution was shown to be essentially the same as that of a linear programming formulation proposed by Orgler. Extensions of the methodology for examining the effects of different 'minimum cash balance' requirement and for incorporating others institutional constraints are also outlined. The transshipment formulation was useful in organizing data for financial control. It was intuitively appealing and computationally more efficient than linear programming formulation of the problem.

The transshipment is an important issue in the current marine transportation. Chien (2007), constructed a mathematical programming model to elaborate the transshipment port selection for the shipping company. This model was tested by the data collected from the ports of Hong Kong and Kaohsiung. The results showed that this model could be used to explain the transshipment competition relationship between the ports of Hong Kong and Kaohsiung well. A sensitivity analysis was also executed. The sensitivity analysis results showed that both the port of Hong Kong and Kaohsiung should decrease the charges of port and increase the efficiency of loading and discharging. Based on the sensitivity analysis results, some interesting conclusions and helpful suggestions were obtained for the managers of the ports of Hong Kong and Kaohsiung to improve their port management.

Moore (1978) et al., presented the formulation of a goal programming model for analysis of the transshipment problem, where multiple conflicting objectives must be considered. Included were the general G. P. model for the transshipment problem, and a representative application of goal programming to such a problem. Analysis and interpretation of the G.P. solution to the problem was presented.

One interpretation of the model considered in this paper was a single-echelon inventory system consisting of a number of local warehouses, which normally replenish from an outside supplier. In case of a stock out at a warehouse an emergency lateral transshipment from another warehouse may be possible. However, such transshipments are only allowed in one direction, i.e., the flow structure is unidirectional. Such policies can be of interest if the warehouses have very different shortage costs. Another interpretation is substitution in an inventory system. Sven (2001) then instead considered different items in a single warehouse. When a demand for a low quality item cannot be met directly, the item can be replaced by another high quality item. He provided a simple and efficient approximate technique for policy evaluation in such systems. The performance of this technique was evaluated in a simulation study. Although the errors were not always negligible, the suggested method gave a good picture of how the considered lateral transshipments or substitutions affect the inventory system.

Brandt A. et al (1978) ,wrote a paper which dealt with large transportation problems in which the number of destinations (n) was much larger than the number of origins (m), and in which some or many of the paths from origins to destinations may be inadmissible. Using a new approach, with certain auxiliary lists, it was proved that the ordinary simplex algorithm ("Most Negative Rule") can be performed in O(m2+ m log n) computer operations per iteration, as against O(mn) in the usual approach. A search-in-a-row simplex algorithm ("Row Most Negative Rule"), for which the total number of iterations was probably only somewhat larger, is shown to require just O(m + σm log n) operations per iteration, where σ was the density of the cost matrix (i.e. the proportion of admissible paths). For these rigorous results one needs computer storage which was not considerably larger than that required for storing the cost matrix. For smaller memory an efficient algorithm was also proposed. A general tentative rule for die amount of scanning per iteration was introduced and applied. Computer experiments are reported, confirming theoretical estimates.

Three generations of computers have elapsed since the first satisfactory method for solving transportation and transshipment problems was devised. During this time many computational advances have taken place in developing computer codes to solve these problems. For example, recent breakthroughs in the solution and human engineering aspects of transshipment problems have made it possible to solve problems in only a few minutes that require many hours of computing time with commercial LP packages. Additionally the computer memory requirements of new methods have enabled the solution of vastly larger problems than previously imagined possible (50,000 equations and 62 million variables). Enhancing the significance of these developments, new ways have been discovered for modelling broad classes of real world problems as transshipment or transshipment-related problems. The primary purpose by Charnes (2003), summarized these events and to do some crystal ball gazing to provide what we believe to be “best estimates” of future trends.

Kwak, et al., (1985), presented an application of goal programming as an aid in facility location analysis. Specifically, this paper illustrated the use of a goal programming model to resolve a site location problem. The results of this study showed that the goal programming model presented can be used to improve the site selection process over existing models. This was accomplished by allowing consideration of substitutable resources that exist in the decision environment.

Kumar et al., (1991), formulated a multistage multiobjective decision problem as a nonlinear goal programming model. The solution algorithm which used Box-Complex method was presented. The model formation and computational aspects were illustrated on the integrated grouping and loading problem of a flexible manufacturing system.

CHAPTER THREE

3.0 THE TRANSPORTATION PROBLEM

Transportation method is a simplified version of the simplex technique that may be used to solve a type of linear programming problem. Because of its major application in solving problems involving several product sources and several destinations of products, this type of problem is frequently called the transportation problem. It obtains its name from its application to problems involving transporting products from several sources to several destinations. The transportation model seeks the determination of transporting/shipping for a single commodity from a number, *m* of sources and a number, *n* of destinations. The formation can be used to represent more general assignment and scheduling objectives of such problems are either (1) minimize the cost of shipping *m* units to *n* destinations or (2) maximize the profit of shipping *m* units to *n* destinations.

Assuming there are *m* sources, each of which has available $a_i \left(i = 1, 2, \ldots, m \right)$ units of a homogeneous product supplying *n* destinations, each of which requires $b_j \left(j = 1, 2, \ldots, n \right)$ units of this product. The numbers a_i and b_j are positive integers. The cost c_{ij} of transporting one unit of product from the i^{th} source to the j^{th} destination is given for each i and j .

Source capacities, destinations requirements and costs of material shipping from each source to each destination are given constantly. Thus it is assumed that total supply and total demand are equal; that is

$$\sum_{i=1}^{m} a_i = \sum_{j=1}^{n} b_j$$

Let x_{ij} represent the (unknown) number of units to be shipped from source i to destination j.

Then the standard mathematical model for this problem is

Minimize:

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

Subject to:

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

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

$$x_{ij} \ge 0,\ 1 \le i \le m,\ 1 \le j \le n$$

where

m … number of sources

n … number of destinations

a_i … capacity of i-th source (in tons, cedis, liters, etc)

b_j … demand of j-th destination (in tons, cedis, liters, etc.)

c_{ij} … cost coefficients of material shipping (unit shipping cost) between i-th source and j-th destination (in C or as a distance in/kilometers, miles, etc.)

x_{ij} … amount of material shipped between i-th source and j-th destination (in tons, cedis, liters etc.)

3.1 THE TRANSPORTATION TABLEAU

The transportation tableau, where supply availability at each source is shown in the far right column and the destination requirements are shown in the bottom row. Each cell represents one route. The unit shipping cost is shown in the upper right corner of the cell, the amount of shipped material is shown in the center of the cell.

Table 3.1

	W_1	W_2	W_3	. . . . .	W_n	Supply
S_1	C_{11} X_{11}	C_{12} X_{12}	C_{13} X_{13}	. . . .	C_{1n} X_{1n}	a_1
S_2	C_{21} X_{21}	C_{22} X_{22}	C_{23} X_{23}	. . . .	C_{2n} X_{2n}	a_2
.						.
.						.
	C_{m1}	C_{m2}	C_{m3}		C_{mn}	

S_m	X_{m1}	X_{m2}	X_{m3}	.	.	.	.	X_{mn}	a_m
Demand	d_1	d_2	d_3	.	.	.	.	d_n	

3.2 BALANCED TRANSPORTATION PROBLEM

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

$$\sum_{i=1}^{m} a_i = \sum_{j=1}^{n} b_j$$

Methods to find the Balanced Transportation Problem

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

$$\sum_{i=1}^{m} a_i = \sum_{j=1}^{n} b_j$$

Balancing a Transportation Problem if total supply exceeds total demand

If total supply exceeds total demand, we can balance the problem by adding dummy fictitious demand point. Since shipments to the dummy demand point are not real, they are assigned a cost of zero.

Balancing a transportation problem if total supply is less than total demand

If a transportation problem has a total supply that is strictly less than total demand the problem has no feasible solution. There is no doubt that in such a case one or more of the demand will be left unmet. Generally in such situations a penalty cost is often associated with unmet demand and as one can guess this time the total penalty cost is desired to be minimum.

3.3 THE SOLUTION METHOD

The transportation problem can be described using linear programming mathematical model and usually it appears in a transportation tableau. There are three general steps in solving transportation problems.

At first, it is necessary to prepare an **initial feasible solution**, which may be done in several different ways; the only requirement is that the destination needs be met within the constraints of source supply. The transportation algorithm is the simplex method. It involves

i. finding an initial, basic feasible solution;
ii. testing the solution for optimality;
iii. improving the solution when it is not optimal
iv. repeating steps (ii) and (iii) until the optimal solution is obtained.

3.4 METHODS OF FINDING INITIAL BASIC FEASIBLE SOLUTION FOR TRANSPORTATION PROBLEM

Unlike other Linear Programming problems, a *balanced* Transportation Problem with m supply points and n demand points is easier to solve, although it has $m + n$ equality constraints. The reason for that is, if a set of decision variables (x_{ij}'s) satisfy all but one constraint, the values for x_{ij}'s will satisfy that remaining constraint automatically. Initial allocation entails assigning numbers to cells to satisfy supply and demand constraints.

Methods to find the 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 Approximatiion Method

3.4.1 The Northwest Corner Method

To find the initial basic feasible solution by the North West Corner method:

Step 1: Begin in the upper left (or northwest) corner of the transportation tableau and set x_{11} as large as possible. Clearly, x_{11} can be no larger than the smaller of s_1 and d_1.

Step 2: If $x_{11} = s_1$, cross out the first row of the transportation tableau; this indicates that no more basic variables will come from row 1. Also change d_1 to $d_1 - s_1$.

Step 3: If $x_{11} = d_1$, cross out the first column of the transportation tableau; this indicates no more basic variables will come from column 1. Also change s_1 to $s_1 - d_1$.

Step 4: If $x_{11} = s_1 - d_1$, cross out either row 1 or column 1 (but not both). If you cross out row 1, change d_1 to 0; if you cross out column 1, change s_1 to 0.

Step 5: Continue applying this procedure to the most northwest cell in the tableau that does not lie in a crossed-out row or column. Eventually, you will come to a point where there is only one cell that can be assigned a value. Assign this cell a value equal to its row or column demand, and cross out both the cell's row and column. A basic feasible solution has now been obtained.

3.4.2 The Least Cost Method

The Northwest Corner Method does not utilize shipping costs. It can yield an initial basic feasible solution easily but the total shipping cost may be very high. 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,

Step 1: 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.

Step 2: cross out row i and column j and reduce the supply or demand of the non-crossed-out row or column by the value of $x_{ij.}$.

Step 3: choose the cell with the minimum cost of shipping from the cells that do not lie in a crossed-out row or column.

Step 4: repeat the procedure in step 2 and step 3.

3.4.3 The Vogel's Approximation Method

Step 1: Begin with computing each row and column a penalty. The penalty will be equal to the difference between the two smallest shipping costs in the row or column.

Step 2: Identify the row or column with the largest penalty.

Step 3: Find the first basic variable which has the smallest shipping cost in that row or column.

Step 4: assign the highest possible value to that variable, and cross-out the row or column as in step 2.

Step 5: Compute new penalties and use the same procedure.

3.5 COMPUTING TO OPTIMALITY

there are two methods namely

- The stepping stone method
- The modified distribution method

These are initial basic feasible solution to compute to optimality.

3.5.1 The Steppingstone Method

Step 1: Pick any empty cell and identify the closed path leading to that cell. A closed path consists of horizontal and vertical lines leading from an empty cell back to itself (If assignments have been made correctly, the matrix has only one closed path for each empty cell.) In the closed path there can only be one empty cell that we are examining. The 90-degree turns must therefore occur at those places that meet this requirement.

Step 2: Move one unit into the empty cell from a filled cell at a corner of the closed path and modify the remaining filled cells at the other comers of the closed path to reflect this move. (More than one unit could be used to test the desirability of a shift. However, since the problem is linear, if it is desirable to shift one unit, it is desirable to shift more than one, and vice versa.) Modifying entails adding to and subtracting from filled cells in such a way that supply and demand constraints are not violated. This requires that one unit always be subtracted in a given row or column for each unit added to that row or column.

Step 3: Determine desirability of the move. This is easily done by (1) summing the cost values for the cell to which a unit has been added, (2) summing the cost values of the cells from which a unit has been subtracted, and (3) taking the difference between the two sums to determine if there is a cost reduction. If the cost is reduced by making the move, as many units as possible should be shifted out of the evaluated filled cells into the empty cell. If the cost is increased, no move should be made and the empty cell should be crossed.

Step 4: Repeat Steps 1 through 3 until all empty cells have been evaluated.

3.5.2 The Modified Distribution Method (MODI)

Modified method / Modi method / U-V method is the method for determining whether a basic feasible methods is optimal.

The steps involved in the method are as follows :

Step 1: Under this method we construct penalties for rows and columns by subtracting the least value of row / column from the next least value.

Step 2: We select the highest penalty constructed for both row and column. Enter that row / column and select the minimum cost and allocate min (a_i, b_j)

Step 3: Delete the row or column or both if the rim availability / requirements is met.

Step 4: We repeat steps 1 to 3 till all allocations are over.

Step 5: For all allocation form equation $u_i + v_j = c_j$, set one of the dual variable u_i / v_j to zero and solve for others.

Step 6: Use these values to find $k_{ij} = c_{ij} - u_i - v_j$. If all ij = 0, then it is the optimal solution.

Step 7: If any $k_{ij} =$ 0, select the most negative cell and form loop. Starting point of the loop is +ve and alternatively the other corners of the loop are –ve and +ve. Examine the quantities allocated at –ve places. Select the minimum. Add it at +ve places and subtract from –ve place.

Step 8: Form new table and repeat steps 5 to 7 till k ij = 0

Table 3.6

	W_1	W_2	W_3	. . . .	W_n	Supply
S_1	C_{11} X_{11}	C_{12} X_{12}	C_{13} X_{13}	. . . .	C_{1n} X_{1n}	a_1
S_2	C_{21} X_{21}	C_{22} X_{22}	C_{23} X_{23}	. . . .	C_{2n} X_{2n}	a_2
.						.
.						.
S_m	C_{m1} X_{m1}	C_{m2} X_{m2}	C_{m3} X_{m3}	. . . .	C_{mn} X_{mn}	a_m
Demand	d_1	d_2	d_3	. . . .	d_n	

m … number of sources

n … number of destinations

a_i … capacity of *i-th* source (in tons, cedis, liters, etc)

b_j … demand of *j-th* destination (in tons, cedis, liters, etc.)

c_{ij} … unit material shipping cost between *i*-th source and *j-th* destination (in cedis or as a distance in kilometers, miles, etc.)

x_{ij} … amount of material shipped between *i*-th source and *j-th* destination (in tons, cedis, liters etc.)

Let an initial basic feasible solution be available. Then (*m+n-1*) cells are occupied.

Test for optimality

For each occupied cell (i,j) of the transportation tableau, compute a row index ui and a column index v_j such that $c_{ij} = u_i + v_j$

Since there are *(m+n-1)* occupied cells, it follows that there are m + n -1 of these equations.

Since there are *(m + n)* row and column in dices altogether,it follows that by prescribing an arbitrary value for one of them,we say u=0,we then solve the equations for the remaining *(m+n -1)* unknowns u_i, v_j.

With all the u_i, v_j known,we compute for each unoccupied cell such that the evaluation factor e_{st} is computed as

$$e_{st} = c_{st} - u_s - v_j$$

It can be shown that the evaluation factors are the relative cost factors corresponding to the non-basic variables when the Simplex method is applied to the transportation problem. Hence the current basic feasible solution is optimal if and only if $e_{st} > 0$ for all unoccupied cells (s,t),since the transportation problem is a minimization problem. If there are unoccupied cells with negative evaluation factor, then current basic feasible solution is not optimal and needs to be improved.

Improvement to optimality

To improve upon the current basic feasible solution we find the unoccupied cell with the most negative evaluation factor, construct its circuit and adjust the value of the allocation in the cells of the circuit in exactly the same way as done in the steppingstone method. This yields a new basic feasible solution available, the whole process is repeated until optimality is attained.

Remarks

The fact that the circuit is not constructed for every unoccupied cell makes the modified distribution method more efficient than steppingstone method. In fact the MODI method is currently the most efficient method of solving the transportation problem.

If the total supply exceeds the total demand

If the total supply exceeds the total demand,we create a fictitious warehouse w_F whose demand is precisely the excess of supply over demand and such that the unit cost each source to the fictitious warehouse w_F is zero.

If the total demand exceeds total supply

if the total demand exceeds total supply, create a fictitious source Sf whose capacity is precisely the excess of demand over supply and such that the unit cost from source to every warehouse is 0.

How to Pivot a Transportation Problem

Based on the transportation tableau, the following steps should be performed.

Step 1. Determine (by a criterion to be developed shortly, for example northwest corner method) the variable that should enter the basis.

Step 2. Find the loop (it can be shown that there is only one loop) involving the entering variable and some of the basic variables.

Step 3. Counting the cells in the loop, label them as even cells or odd cells.

Step 4. Find the odd cells whose variable assumes the smallest value. Call this value θ. The variable corresponding to this odd cell will leave the basis. To perform the pivot, decrease the value of each odd cell by θ and increase the value of each even cell by θ. The variables that are not in the loop remain unchanged. The pivot is now complete. If $\theta=0$, the entering variable will equal 0, and an odd variable that has a current value of 0 will leave the basis. In this case a degenerate basic feasible solution existed before and will result after the pivot. If more than one odd cell in the loop equals θ, you may arbitrarily choose one of these odd cells to leave the basis; again a degenerate basic feasible solution will result.

3.6 DEGENERACY

Degeneracy exists in a transportation problem when the number of filled cells is less than the number of rows plus the number of columns minus one ($m + n - 1$). Degeneracy may be observed either during the initial allocation when the first entry in a row or column satisfies both the row and column requirements or during the Stepping stone method application, when the added and subtracted values are equal. Degeneracy requires some adjustment in the matrix to evaluate the solution achieved. The form of this adjustment involves inserting some value in an empty cell so a closed path can be developed to evaluate other empty cells. This value may be thought of as an infinitely small amount, having no direct bearing on the cost of the solution.

Procedurally, the value (often denoted by the Greek letter epsilon), is used in exactly the same manner as a real number except that it may initially be placed in any empty cell, even though row and column requirements have been met by real numbers.

Once has been inserted into the solution, it remains there until it is removed by subtraction or until a final solution is reached.

While the choice of where to put an ε is arbitrary, it saves time if it is placed where it may be used to evaluate as many cells as possible without being shifted.

How to Overcome Degeneracy

(i) Add zero(s) to make up the (m+n-1) basic variables.

(ii)Add zero(s) in such a way that no circuit is formed.

3.7 THE TRANSSHIPMENT PROBLEM

The transshipment problem is similar to the transportation problem except that in the transshipment problem it is possible to both ships 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 account for locations such as warehouses. In this more general type of distribution problem, shipments may be made between any three pairs of the three general types of nodes: origin nodes, transshipment nodes and destination nodes. for example transshipment problems permits shipments of goods from origins to transshipment nodes and on to destinations, from one origin to another origin, from one transshipment location to another, from one destination location to another and directly from origins to destinations.

The general linear programming model of a transshipment problem is

Minimize

$$\sum_{allarcs} c_{ij} x_{ij}$$

Subject to:

$$\sum_{arcout} x_{ij} = \sum_{arcin} x_{ij} \leq s_i$$

Origin nodes i …. …. (1)

$$\sum_{arcsout} x_{ij} - \sum_{arcin} x_{ij} = 0$$

Transshipment nodes …. ….(2)

$$\sum_{arcin} x_{ij} - \sum_{arcout} x_{ij} = d_j$$

Destination nodes j …. ….(3)

Where

x_{ij}

= number 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 origin node j

For the transportation problem, you can ship only from supply points to demand points. For the transshipment problem, you can ship from one supply point to another or from one demand point to another. Actually, designating nodes as supply points or demand points becomes confusing when you can ship both into and out of a node. You can make the designations clearer if you classify nodes by their net stock position-excess (+), shortage (-), or 0.

One reason to consider transshipping is that units can sometimes be shipped into one city at a very low cost and then transshipped to other cities. In some situations, this can be less expensive than direct shipment. The main objective in the transshipment problem is to determine how many units should be shipped over each arc in the network so that all destination demands are satisfied with the minimum possible transportation cost.

Model

There are two possible conversions to a transportation model. In the first conversion, make each excess node a supply point and each shortage node a demand point. Then, find the cheapest method of shipping from surplus nodes to shortage nodes considering all transshipment possibilities.

The second conversion of a transshipment problem to a transportation model does not require finding all of the cheapest routes from excess nodes to shortage nodes. The second conversion requires more supply and demand nodes than the first conversion, because the points where you can ship into and out of occur in the converted transportation problem twice – first as a supply point and second as a demand point.

3.8 CONCLUSION

The transportation problem is only a special topic of the linear programming problems. It would be a rare instance when a linear programming problem would actually be solved by hand. There are too many computers around and too many LP software programs to justify spending time for manual solution. Q. M. for windows software will be used to analyze the data. (There are also programs that assist in the construction of the LP or

TP model itself. Probably the best known is GAMS—General Algebraic Modeling System (GAMS-General, San Francisco, CA). This provides a high-level language for easy representation of complex problems.

3.9 SUMMARY

In this chapter, the transportation and transshipment problems were presented.In the next chapter, I shall put forward data collection and data analysis of my work

CHAPTER FOUR

DATA COLLECTION AND ANALYSIS

4.1 Introduction

This chapter deals with data collection, data analysis and discussion, the discussion of transshipment of raw materials from some farm gates to the industry. The data was obtained from Juaben Oil Mills Company; the cost of transporting goods involves fuel consumption of vehicle, cost of labour and maintenance. The sources of raw materials are called "farm gates", the warehouses are called "junctions", and the final destination is the industry. There are three main sources of raw materials, namely:

The Outgrower – land owners are assisted by the management of the company with palm seedlings and money to cultivate palm plantation to be supplied to the company for an agreed period of time.

Juaben Farms – the Juaben farms is own by the Juaben traditional council.

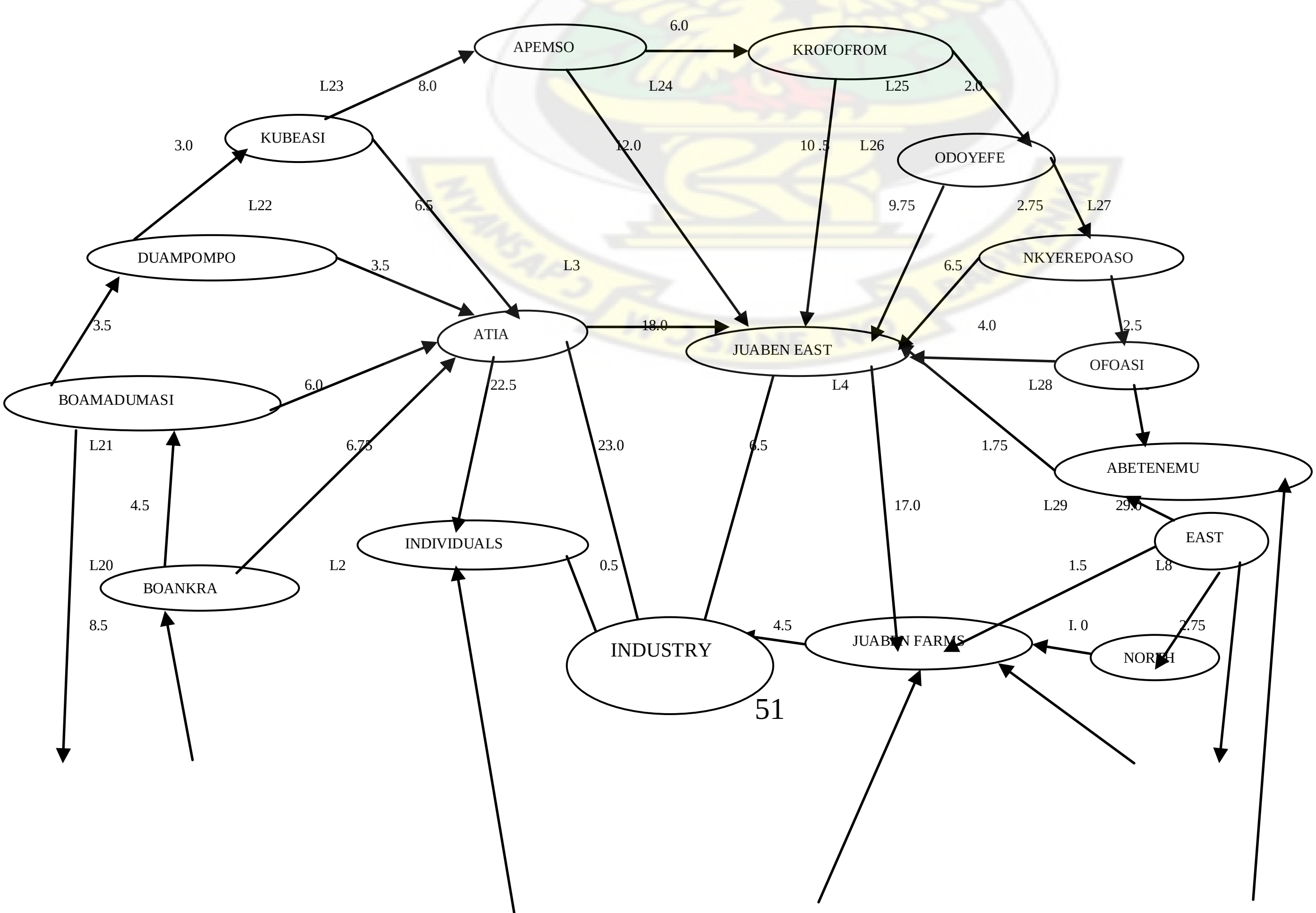
Individuals – private palm plantation owners.

Table 4.1, This table shows the farm gates, junctions and the industry

SOURCE (Si)	FARM GATE	JUNCTION	DESTINATION (Dj)
1	NORTH	JUABEN FARMS	INDUSTRY
2	EAST	JUABEN FARMS	INDUSTRY
3	WEST	JUABEN FARMS	INDUSTRY
4	KROFOFROM	JUABEN EAST	INDUSTRY
5	NKYEREPOASO	JUABEN EAST	INDUSTRY
6	ABETENIM	JUABEN EAST	INDUSTRY
7	ODOYEFE	JUABEN EAST	INDUSTRY
8	OFOASE	JUABEN EAST	INDUSTRY
9	APEMSO	JUABEN WEST	INDUSTRY
10	DUMAKWAI	JUABEN WEST	INDUSTRY
11	NTUMKUMSO	JUABEN WEST	INDUSTRY

12	ANKAASI	JUABEN WEST	INDUSTRY
13	KASAMU	JUABEN WEST	INDUSTRY
14	KOTEI	JUABEN WEST	INDUSTRY
15	ATIA	ATIA	INDUSTRY
16	KUBEASI	ATIA	INDUSTRY
17	DUAMPOMPO	ATIA	INDUSTRY
18	BOAMADUMASI	ATIA	INDUSTRY
19	BOANKRA	ATIA	INDUSTRY
20	NEW KOFORIDUA	ODUMASI	INDUSTRY
21	NNOBOAM	ODUMASI	INDUSTRY
22	BOMFA	ODUMASI	INDUSTRY
23	ODUMASI	ODUMASI	INDUSTRY
24	KONONGO	ODUMASI	INDUSTRY
25	INDIVIDUALS		INDUSTRY

NETWORK REPRESENTATION OF DATA SHOWING THE DISTANCES BETWEEN LOCATIONS (KM)



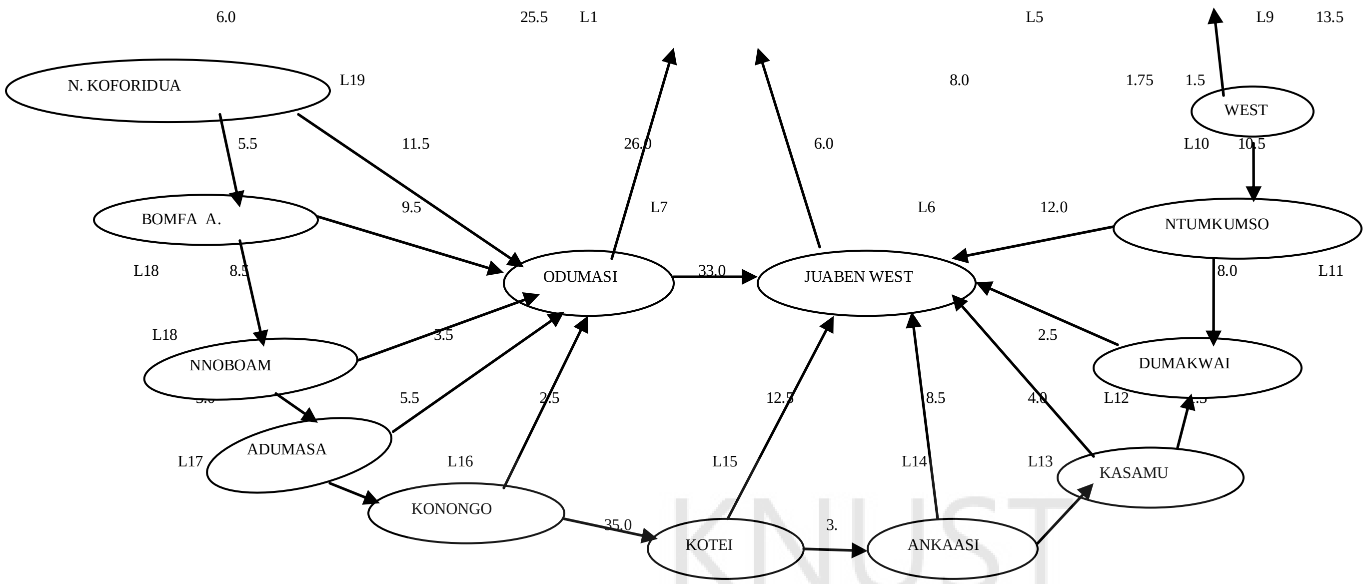


FIGURE 4. 1

4.2 DATA ANALYSIS

Consider the Network Representation of data of Juaben Oil Mills Limited in Figure 4.1. Location 1 serves as a pure destination, Location 2, 3, and 7 serve as both sources and junctions, Location 4, 5, and 6 serve as pure junctions. Locations 8 through to 29 serve as pure sources.

The table below shows the distances between locations in kilometers.

Table 4. 2 Table **of Data Showing The Distances Between Locations (KM)**

	ATI	ODU	JUE	JUW	JUF	IND	INDUSTRY
NOR	49.70	57.00	31.70	24.00	1.00	7.00	6.00
EAS	48.70	56.00	30.75	25.25	1.50	6.75	6.50
WES	51.50	55.50	33.50	22.50	1.75	7.50	7.00
KOT	49.75	37.50	31.75	12.50	28.75	18.00	18.50
ANK	46.75	40.50	28.75	8.50	25.75	13.50	14.50
APE	14.50	34.50	12.00	40.75	27.00	25.75	18.00

BOM	20.00	9.50	57.50	42.50	50.50	35.00	35.50
ADU	31.50	5.50	63.50	38.50	46.50	31.00	31.50
JUE	18.00	57.75	0	25.00	17.00	7.00	6.50
JUW	28.00	33.00	25.00	0	8.00	6.50	6.00
JUF	35.00	41.00	17.00	8.00	0	5.00	4.50
IND	22.50	25.50	7.00	6.50	5.00	0	0.50

The unit shipping costs per kilometer is obtained by dividing the costs of transportation per kilometer by the number of tones a truck can take at a time. The average number of tons of palm fruits a truck can take is six, and the costs of transportation per kilometer is GHC10, therefore the unit shipping cost per kilometer is 10 ÷ 6 = 1. 67, then the shipping cost per kilometer is multiplied by the number of kilometers from one point to another and that gives the total shipping cost for that distance.

Table 4. 3 below is the cost matrix showing the unit shipping cost at the locations.

THE COST MATRIX

	D1	D2	D3	D4	D5	D6	D7	Supply(S_i)
S1	83.08	95.19	53.02	40.08	1.67	11.69	10.02	387
S2	81.41	93.52	51.35	42.17	2.51	11.27	10.85	360
S3	86.01	92.69	55.95	37.58	2.92	12.53	11.69	378
S4	83.08	62.83	53.02	20.88	48.01	30.06	30.9	342
S5	78.07	67.13	48.01	14.2	43	22.55	24.21	279
S6	24.22	57.62	20.04	68.05	45.09	23.38	30.06	330

Table 4. 3

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.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.
S25	**52.61**	**9.19**	**106.05**	**64.3**	**77.66**	**51.77**	**52.61**	**308**
S26	**30.06**	**96.56**	**0**	**41.75**	**28.39**	**11.69**	**10.86**	**310**
S27	**46.76**	**55.11**	**41.75**	**0**	**13.36**	**10.86**	**10.02**	**305**
S28	**58.43**	**68.47**	**28.39**	**13.36**	**0**	**8.35**	**7.52**	**408**
S29	**37.58**	**42.53**	**11.69**	**10.86**	**8.35**	**0**	**0.84**	**242**
Demand(di)	**762**	**942**	**844**	**971**	**756**	**126**	**5000**	

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The cost Matrix

Table 4. 3 is the cost matrix, supply availability at each source is at the far right column and the warehouse demands are shown in the bottom row. The unit shipping costs

is at the north east corner within the cell.

Total supply = 9499.00 tones

Total demand = 9499.00 tones

Since the total supply is equal to the total demand, the transportation problem is a balanced one.

4. 3 MODEL

Algebraic Formulation

Let x_{ij} be the number of units palm fruit shipped from farm gate i to warehouse j for the raw material.

The objective is to minimize

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

Then the supply constrains are

$$\sum_{j=1}^{n} X_i \leq S_i, \quad i = 1,2,3, \dots \dots \dots n \qquad \dots\dots\dots\dots\dots\dots\dots (1)$$

The demand constrains are

$$\sum_{i=1}^{m} X_{ij} \geq d_j, \quad j = 1,2,3, \dots \dots \dots m \qquad \dots\dots\dots\dots\dots\dots\dots (2)$$

The transshipment constrains are

$$\sum_{j=1}^{n} X_{ij} - \sum_{i=1}^{m} X_{ij} = 0 \qquad \dots\dots\dots\dots\dots\dots\dots (3)$$

The balanced equation constrains are

$$\sum_{j=1}^{n} X_{ij} \leq S_i = \sum_{i=1}^{m} X_{ij} \geq d_j \qquad \dots\dots\dots\dots\dots\dots\dots (4)$$

And the non-negativity $x_{ij} \geq 0$, for all i, j

The c_{ij}'s are the unit shipping cost, the s_i's are the supply availability and the d_j's are the demand.

Computational Procedure

The computer used for the computation was Toshiba Intel with 250GB as Hard disk size and 2GB DDR2 RAM size.

Q. M. 32 for windows software was used to analyse the data to find solution to the problem.

It has a capacity of 760 bytes, approximately 4.00 KB, ie 4,096 bytes on disc.

The Q. M. 32 for windows start with an initial starting method to solve the problem, if an optimal solution is not provided; it then applies a method that would compute it to optimality to get an optimal solution. There were four iterations of which the final one gave an optimal transshipment cost of GHC 172,199.40.

The table below is the result of the data analysed.

Column 2 is the sources of raw materials, column 3 is the destinations, destinations 1, 2, 3, 4, 5 and 6 are junctions where the raw materials are transshipped to for onward transshipment to the industry for processing, column 4 is the shipment (the number of units shipped), column 5 is the unit cost per shipment, and column 6 is the total shipment cost.

4.4 RESULTS ANALYSIS

Table 4. 4 SUMMARY OF RESULTS OF DATA ANALYSED

	From	To	Shipment	Cost per unit	Shipment cost
1	Source 1	Destination 5	376	1.67	627.92
2	Source 1	Destination 7	11	10.02	110.22
3	Source 2	Destination 7	360	10.85	3906
4	Source 3	Destination 5	378	2.92	1103.76

5	**Source 4**	**Destination 4**	**342**	**20.88**	**7140.959**
6	**Source 5**	**Destination 7**	**279**	**24.21**	**6754.59**
7	**Source 6**	**Destination 6**	**126**	**23.38**	**2945.88**
8	**Source 6**	**Destination 7**	**204**	**30.06**	**6132.24**
9	**Source 7**	**Destination 4**	**249**	**6.68**	**1663.32**
10	**Source 8**	**Destination 4**	**304**	**4.18**	**1270.72**
11	**Source 9**	**Destination 7**	**317**	**27.97**	**8866.49**
12	**Source 10**	**Destination 3**	**228**	**2.92**	**665.76**
13	**Source 10**	**Destination 7**	**118**	**13.78**	**1626.04**
14	**Source 11**	**Destination 7**	**340**	**17.54**	**5963.6**
15	**Source 12**	**Destination 3**	**311**	**16.28**	**5063.08**
16	**Source 13**	**Destination 7**	**353**	**21.71**	**7663.63**
17	**Source 14**	**Destination 7**	**322**	**28.39**	**9141.58**
18	**Source 15**	**Destination 1**	**323**	**5.85**	**1889.55**
19	**Source 16**	**Destination 1**	**304**	**10.02**	**3046.08**
20	**Source 17**	**Destination 7**	**319**	**49.68**	**15847.92**
21	**Source 18**	**Destination 1**	**104**	**10.86**	**1129.44**
22	**Source 18**	**Destination 7**	**224**	**49.27**	**11036.48**
23	**Source 19**	**Destination 7**	**322**	**38.41**	**12368.02**
24	**Source 20**	**Destination 2**	**341**	**0**	**0**
25	**Source 21**	**Destination 3**	**305**	**10.04**	**3062.2**
26	**Source 22**	**Destination 1**	**31**	**24.22**	**750.82**
27	**Source 22**	**Destination 2**	**297**	**19.21**	**5705.37**
28	**Source 23**	**Destination 2**	**304**	**5.85**	**1778.4**
29	**Source 24**	**Destination 7**	**334**	**59.29**	**19802.86**
30	**Source 25**	**Destination 7**	**308**	**52.61**	**16203.88**
31	**Source 26**	**Destination 7**	**310**	**10.86**	**3366.6**
32	**Source 27**	**Destination 4**	**76**	**0**	**0**

33	**Source 27**	**Destination 7**	**229**	**10.02**	**2294.58**
34	**Source 28**	**Destination 7**	**408**	**7.52**	**3068.16**
35	**Source 29**	**Destination 7**	**242**	**0.84**	**203.28**

The maximum shipment is 408 tones, from source 28 to destination 7.

The minimum shipment is 11, from source 1 to destination 7.

The optimal transshipment cost for the area under study is GH₵172, 199.40

4. 5 DISCUSSION

From the result table (Table 4. 4), it could be seen that shipping goods from source to junctions then to the final destination was less costly than shipping straight from source to the final destination.

From row 1, 376 units were shipped from source 1 to destination 5, at a cost per unit of 1. 67, From row 34, 408 units were shipped from source 28 to destination 7, at a cost per unit of 7. 52, a total unit cost of 9. 19, whereas from row 2, 11 units were shipped from source 2 to destination 7 at a unit cost of 10.02.

It was also realized that the unit cost per shipment from sources within the district where the industry is located to the final destination was less costly than from sources on a different district.

From row 2, 360 units were shipped from source 2 to destination 7 at unit cost of 10. 85, whereas from row 29, 334 units were shipped from source 24 to destination 7 at a unit cost of 59.29.

From row 24 and 33, source 20 and destination 2, and source 27 and destination 4 respectively are the same locations hence the unit cost of 0.

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CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.1 CONCLUSIONS

Results of data collected from Juaben Oil Mills Limited consisting of cost of transporting raw materials (palm fruits) from the farm gates to the factory and the number of units being transported to each junction and destination were analysed by using Quantitative Method (QM 32). The minimum cost for the period under study was around GH C172, 199.40 used by Juaben oil mills Ltd.

Raw material shipment was moduled as a transshipment problem which was converted to a transportation problem, and subsequently solved using QM 32 for windows. Because some supply points and demand locations were on different district, the results made it clear that it is better to transport more palm fruits within the same district or locality for a less cost transportation. Based on my findings and analysis of the collated data, it was also realized that it was less costly to transport goods from sources to the industry through the intermediary points or junctions than directly from sources to the industry.

5.2 RECOMMENDATIONS

This research was conducted for only one year and results of this research provide some scope for further studies. It could be of interest to use data on the weekly basis, This will provide a more comprehensive view point about the cost of transporting the palm fruit.

I also recommend Q M for windows software to the supply chain management and the transport officer since it will help them to locate the shortest possible route that will lead to cost effective so far as carting the palm fruits to the production plant is concerened.

It is also recommended that Juaben oil mills should adopt the system of transporting goods through the intermediaries (junctions) since it is cost effective.

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APENDICES

APENDIX A

Table 3.2 shows a North-West Corner Assignment

To From	E	F	G	H	Factory Supply
A	10	30 3	25 6	15 5	14
B	20	15	20	10 10	10
C	10 9	30	20 6	20	15
D	30	40 12	35	45	12
Dummy	0 1	0	0	0	1
Destination Requirements	10	15	12	15	52 52

(Cell A-E was assigned first, A-F second, B-F third, and so forth.) Total cost:

10*10+30*4+15*10+30*1+20*12+20*2+45*12+0*1=1220(C)

Inspection of Table above indicates some high-cost cells were assigned and some low-cost cells bypassed by using the northwest-corner method. Indeed, this is to be expected since this method ignores costs in favour of following an easily programmable allocation algorithm.

Table 3.3 Least Cost Method Table

To From	E	F	G	H	Factory Supply
A	10 3	30	25 6	15 5	14
B	20	15	20	10 10	10
C	10 9	30	20 6	20	15
D	30	40 12	35	45	12
Dummy	0 1	0	0	0	1
Destination Requirement	10	15	12	15	52 52

(Cell Dummy-E was assigned first, C-E second, B-H third, A-H fourth and so on.) Total Cost=30*3+25*6+15*5+10*10+10*9+20*6+40*12 +0*1=1105(₵)

Table 3.4 shows the Vogel's Approximation Method Assignment

To From	E	F	G	H	Factory Supply
A	10	30 10	25	15 14	14
B	20	15	20	10 10	10
C	10 10	30	20 4	20 1	15
D	30	40 5	35 7	45	12
Dummy	0	0	0 1	0	1
Destination Requirement	10	15	12	15	52 52

(Cell Dummy-G was assigned first, B-F second, C-E third, A-H fourth, and so on.) Note that this starting solution is very close to the optimal solution obtained after making all possible improvements to the starting solution obtained using the northwest-corner method.

Total Cost: 15*14+15*10+10*10+20*4+20*1+40*5+35*7+0*1 = 1005(₵).

Table 3. 5 THE STEPPING STONE TABLEAU

To From	E	F	G	H	Factory Supply
A	10	30	25	15 14	14
B	25	15 10	20	10	10
C	10 10	30	20 4	20 1	15
D	30	40 4	35 8	45	12
Dummy	0	0 1	0	0	1
Destination Requirement	10	15	12	15	52 52

The table above indicates one marked cell B-H. This cell has closed path C-H, C-G, D-G, D-F and B-F.

APPENDIX B

Table 4. 2 Table **of Data Showing the Distances Between Locations (KM)**

	ATI	ODU	JUE	JUW	JUF	IND	INDUSTRY

NOR	49.70	57	31.70	24.00	1.00	7.00	6.00
EAS	48.70	56.00	30.75	25.25	1.5	6.75	6.5
WES	51.50	55.50	33.50	22.50	1.75	7.5	7.00
KOT	49.75	37.50	31.75	12.50	28.75	18.00	18.50
ANK	46.75	40.50	28.75	8.50	25.75	13.50	14.50
APE	14.50	34.50	12.00	40.75	27.00	25.75	18.00
KAS	32.00	36.00	24.75	4.00	12.00	9.50	8.50
DUM	30.00	34.90	23.25	2.50	10.00	8.00	8.50
NTU	40.00	43.50	15.25	12.00	12.13	16.25	16.75
ABE	19.75	44.00	1.75	24.00	18.75	7.75	8.25
OFO	22.00	46.25	4.00	26.00	20.50	10.00	10.50
ODO	24.50	42.50	9.75	32.75	26.75	15.00	17.50
NKY	25.25	45.25	6.50	28.50	23.25	13.50	13.00
KRO	20.50	40.50	10.50	33.25	21.50	17.50	17.00
DUA	3.50	27.75	21.50	52.50	38.50	26.00	26.50
BOA	6.00	26.00	24.00	53.00	41.00	28.50	29.00
BOK	6.75	17.50	24.75	44.50	34.25	29.25	29.75
KUB	6.50	26,50	24.50	56.75	41.50	29.00	29.50
ATI	0	26.00	18.00	28.00	35.00	22.50	23.00
ODU	25.50	0	58.00	33.00	41.00	25.50	26.00
KON	28.50	2.50	6.00	35.50	43.50	28.00	28.50
NEW	14.50	11.50	69.50	44.50	52.50	37.00	37.50
NNO	28.50	3.50	62.00	36.50	44.50	29.00	29.50
BOM	20.00	9.50	57.50	42.50	50.50	35.00	35.50
ADU	31.50	5.50	63.50	38.50	46.50	31.00	31.50
JUE	18.00	57.75	0	25.00	17.00	7.00	6.50
JUW	28.00	33.00	25.00	0	8.00	6.50	6.00
JUF	35.00	41.00	17.00	8.00	0	5.00	4.50
IND	22.50	25.50	7.00	6.50	5.00	0	0.50

Table 4. 3 The Cost Matrix

Destination

Source

	D1	D2	D3	D4	D5	D6	D7	Supply
S1	83.08	95.19	53.02	40.08	1.67	11.69	10.02	387
S2	81.41	93.52	51.35	42.17	2.51	10.86	10.85	360
S3	86.01	92.69	55.95	37.58	2.92	12.53	11.69	378
S4	83.08	62.83	53.02	20.88	48.01	30.06	30.9	342
S5	78.07	67.13	48.01	14.2	43	22.55	24.21	279
S6	24.22	57.62	20.04	68.05	45.09	23.38	30.06	330
S7	53.44	60.12	41.33	6.68	20.04	15.87	16.7	249
S8	50.1	58.29	38.83	4.18	16.7	13.36	14.2	304
S9	66.8	72.65	25.47	20.04	20.25	27.14	27.97	317
S10	32.98	73.48	2.92	40.08	31.31	12.94	13.78	346
S11	36.74	77.24	6.68	43.42	34.24	16.7	17.54	340
S12	40.92	70.96	16.28	54.69	44.67	25.05	29.23	311
S13	42.17	75.57	10.86	47.6	38.83	22.55	21.71	353
S14	34.24	67.64	17.54	55.53	35.91	29.23	28.39	322
S15	5.85	46.27	35.91	87.68	64.3	43.42	44.26	323
S16	10.02	43.43	40.08	88.51	68.47	47.6	48.43	304
S17	11.27	29.23	41.33	74.32	57.2	48.85	49.68	319
S18	10.86	44.23	40.92	94.93	69.31	48.43	49.27	328

S19	0	43.42	30.06	46.76	58.43	37.58	38.41	322
S20	43.42	0	96.56	55.11	68.47	42.53	43.42	341
S21	47.6	4.18	10.04	59.29	72.65	46.76	47.6	305
S22	24.22	19.21	116.07	74.32	87.68	61.79	62.63	328
S23	47.6	5.85	102.91	60.96	74.32	48.43	49.27	304
S24	33.4	15.87	96.03	70.98	84.34	58.45	59.29	334
S25	52.61	9.19	106.05	64.3	77.66	51.77	52.61	308
S26	30.06	96.56	0	41.75	28.39	11.69	10.86	310
S27	46.76	55.11	41.75	0	13.36	10.86	10.02	305
S28	58.43	68.47	28.39	13.36	0	8.35	7.52	408
S29	37.58	42.53	11.69	10.86	8.35	0	0.84	242
Demand	762	942	844	971	754	126	5000	

TABLE 4. 4 SUMMARY OF RESULTS OF DATA ANALYSED

From	To	Shipment	Cost per unit	Shipment cost
Source 1	**Destination 5**	**376**	**1.67**	**627.92**
Source 1	**Destination 7**	**11**	**10.02**	**110.22**

Source 2	**Destination 7**	**360**	**10.85**	**3906**
Source 3	**Destination 5**	**378**	**2.92**	**1103.76**
Source 4	**Destination 4**	**342**	**20.88**	**7140.959**
Source 5	**Destination 7**	**279**	**24.21**	**6754.59**
Source 6	**Destination 6**	**126**	**23.38**	**2945.88**
Source 6	**Destination 7**	**204**	**30.06**	**6132.24**
Source 7	**Destination 4**	**249**	**6.68**	**1663.32**
Source 8	**Destination 4**	**304**	**4.18**	**1270.72**
Source 9	**Destination 7**	**317**	**27.97**	**8866.49**
Source 10	**Destination 3**	**228**	**2.92**	**665.76**
Source 10	**Destination 7**	**118**	**13.78**	**1626.04**
Source 11	**Destination 7**	**340**	**17.54**	**5963.6**
Source 12	**Destination 3**	**311**	**16.28**	**5063.08**
Source 13	**Destination 7**	**353**	**21.71**	**7663.63**
Source 14	**Destination 7**	**322**	**28.39**	**9141.58**
Source 15	**Destination 1**	**323**	**5.85**	**1889.55**
Source 16	**Destination 1**	**304**	**10.02**	**3046.08**
Source 17	**Destination 7**	**319**	**49.68**	**15847.92**
Source 18	**Destination 1**	**104**	**10.86**	**1129.44**
Source 18	**Destination 7**	**224**	**49.27**	**11036.48**
Source 19	**Destination 7**	**322**	**38.41**	**12368.02**
Source 20	**Destination 2**	**341**	**0**	**0**
Source 21	**Destination 3**	**305**	**10.04**	**3062.2**
Source 22	**Destination 1**	**31**	**24.22**	**750.82**
Source 22	**Destination 2**	**297**	**19.21**	**5705.37**
Source 23	**Destination 2**	**304**	**5.85**	**1778.4**
Source 24	**Destination 7**	**334**	**59.29**	**19802.86**
Source 25	**Destination 7**	**308**	**52.61**	**16203.88**

Source 26	**Destination 7**	**310**	**10.86**	**3366.6**
Source 27	**Destination 4**	**76**	**0**	**0**
Source 27	**Destination 7**	**229**	**10.02**	**2294.58**
Source 28	**Destination 7**	**408**	**7.52**	**3068.16**
Source 29	**Destination 7**	**242**	**0.84**	**203.28**

Table 4. 5

The optimal transshipment cost for the area under study is GH₵172, 199.40