OPTIMAL TRANSPORT PRICING OF INLAND FREIGHT FOR CEMENT HAULAGE AT GHACEM LIMITED

BY

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DECLARATION

I hereby declare that this submission is my own work towards the MSc and that, to the best of my knowledge; it contains no material previously published by another person or material, which have been accepted for the award of any other degree of the University, except where the acknowledgement has been made in the text.

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Supervisor(s) Name	Signature	Date

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Head of Dept. Name	Signature	Date

DEDICATION

Dedicated

To

My beloved family

Sarah Martinson

Yaa Martinson

Akua Martinson

ABSTRACT

Cement is a key element of modern construction and its production at Ghacem limited takes place only at Tema and Tarkoradi whiles consumption occurs across the breadth and length of Ghana. Transportation therefore plays a major role in the distribution of the product and contributes to a portion of the landed price of cement to the consumer at distant locations. This study attempts to develop a model for optimal transport pricing of inland freight for cement haulage at Ghacem limited for cement distribution in Ghana. In order to achieve the research objectives, literature on product transport pricing between firms and the consumer and the mathematical theory of linear programming for solving transportation problems were reviewed. Results of the transportation model which was undertaken with the aid of Microsoft Excel Solver 2003 application, used data of cement supply and consumption activity recorded by Ghacem in year 2010. The model revealed and optimal transport pricing solution and also indicated a pattern of routes from different sources (supply) to different destinations (demand) if transportation costs were to be minimized. Owing to its current pricing scheme known as the "mill price model"; where firms choose their locations, price their products and consumers incur the transportation cost to their demand destinations, Ghacem does not completely control the physical distribution of the product and therefore has no comprehensive transport cost model for comparison with the derived optimal transport price in this work. However, one purpose of the theory of optimal pricing using the transportation model is to predict what the optimal price should consist of in terms of cost, making the theory fit for empirical development and practical application as had been carried out in this case with the goal of helping to reduce the net cost of cement to consumers at distant locations.

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TABLE OF CONTENTS Page

TABLE OF CONTENTS CONTINUATION

TABLE OF CONTENTS CONTINUATION

TABLE OF CONTENTS CONTINUATION

LIST OF TABLES Page

LIST OF FIGURES Page

CHAPTER ONE

INTRODUCTION

1.0 Introduction

Cement is a key element for modern construction and its production at Ghacem limited takes place only at Tema and Takoradi whiles consumption occurs across the breadth and length of Ghana. Transportation therefore plays a major role in the distribution of the product and contributes to a portion of the landed price of cement to the consumer at distant locations. The arrangements by which the buyer pays transfer costs can take several forms. For example, the seller may take responsibility for delivery, and may either move the goods itself or contract with a transfer agency; but in either case it charges the buyer a delivered price that includes all transfer costs.

Alternatively, buyers may contract with a transfer agency or move the goods themselves. Transportation has tremendous economic impacts and affects our economic activity and what we consume. It is therefore important to optimize our transportation systems to minimize total costs and maximize total benefits. Concerns therefore on cement haulage and the impact of the transport cost on cement price affordability makes optimal modelling of its haulage and transport pricing important worth considering.

1.1 Background of Thesis

Industries in which transportation cost account for a substantial share of the total cost of selling a product such as cement, steel, fertilizer, petroleum products and others frequently uses delivered pricing schemes (Stigler, 1949). Instead of charging a uniform price to any consumer who travels to the "mill" to pick up the product, firms charges prices inclusive of freight that may vary as a function of the buyer's location. For the purpose of modelling the issue one might imagine that there is a total cost for moving a product or commodity from its store to the consumer's location. It's assumed that the burden of shipping a commodity from a firm or store to a consumer is shared by both sellers and buyers. So the consumer in the model pay exogenously set of proportion of the transport cost while firms pay the remainder (Sudipta and Hrachya, 2003).

The spatial competition literature in the Hotelling (1929) tradition has two main strands. One concerns itself with models of mill pricing in which firms choose location and prices, while the spatially dispersed consumers pay the cost of travelling to the firm to buy the product. The other strand of the literature assumes that firms absorb the transport cost of shipping the item to the consumers and is called uniform delivery pricing. Firms choose locations and prices and transport the product to geographically spread out consumers each of whom pays the same price.

Assuming an exogenously transport cost sharing is reasonable since the consumers have their share of the transport cost, while firms have to incur part of the transport cost which are specific to them. When the consumers' share of the transport cost goes to zero, we have the uniform delivery price model and when they bear the entire cost, we obtain the mill pricing model. The mill price models trace their heritage from the original Hotelling (1929) model. Typically in these models, firms choose locations, price their products and consumers incur the transportation cost and this is the pricing model at Ghacem for cement distribution in Ghana.

Pricing is a method of resource allocation and there is no such thing as the 'right' price, rather there are optimal pricing strategies to permit specified aims to be achieved. For example, the optimal price aimed at achieving profit maximization may differ from that needed to maximize equity and social welfare (Bennathan and Walters, 1979).

Buyers and sellers in the real world are dispersed over geographical space. It has been argued that the dispersed nature of market activities can be a source of market power for firms. Each firm has only a few rivals in its immediate neighbourhood. Similarly, consumers who are at a considerable distance from a firm will not buy from that firm since they have to pay very high transport costs. The relative location of the firms with respect to the consumers is a crucial determinant of the degree of competition. Consequently, once one recognizes the importance of space, it is obvious that competition in the real world occurs only among a few and is best analyzed in a strategic game setting (Hrachya 2000).

Equity and social issues are important and government and society are legitimately concerned about them. It is therefore, necessary not only to identify a transport pricing policy that meets profit targets with minimal losses in economic efficiency, but also to evaluate the effects of such on social equity.

When a firm out of strategic reasons or by regulation in public interest transports its products to the consumer at rates that are persistently below the relevant marginal cost, a mechanism needs to be evolved to fund the gap. If the firm is unable to finance the gap with subsidies then it may be forced to resort to cross-subsidization. These results in charging some users above the marginal cost to offset losses made in transporting the product to where prices are fixed at levels that do not cover the relevant marginal cost. Since uniform spatial pricing involves full freight absorption, it is particularly an acute form of uniform delivery pricing, causing nearby consumers to cross-subsidize distant consumers.

Within the industry in Ghana, there are few key players but the competition is intense like any other industry. A company must understand how to differentiate its products, innovate, formulate strategies not only in the development of products and managing its businesses but as well as to formulate strategies on how to gain wide and strong market share, and have a strong position in the industry. The ability to place the company in a solid and strategic spot determines the capability of the company to reach and maintain leadership in the industry. There is often a tendency to overlook the important fact that the problem of transport pricing is an integral part of the overall problem of resource use in the geographical space of the economy.

Consideration of transportation costs causes the pattern of distribution of the commodity to become an essential factor in determining the total transportation costs. Problems of allocation arise whenever there are a number of activities to perform, but limitations on either the amount of resources or the way they can be spent prevent us from performing each separate activity in the most effective way conceivable. In such situations the allotment of available resources to the activities is made in a way that will optimize the total effectiveness (Sasieni et. al, 1959).

Least-cost allocations (shipping routes) may not necessarily consist of shipments travelling from one region to neighbouring regions. This fact is due to the nature of production and consumption in each region and to the assumption that a surplus region can ship only to a deficit district. It is possible that one surplus producing region could be surrounded by other surplus producing regions. In this case the least-cost solution may result in the former region shipping to more distant regions.

Conversely, one deficit region surrounded by other deficit regions might be forced to receive shipments from distant surplus regions. Another possibility is that the deficit of a particular region may be greater than the surplus of any neighbouring region or regions. In such a situation it would be necessary for the deficit region to receive shipments from more distant surplus regions. The same type of logic could be applied to a region, whose surplus is greater than the combined regions of neighbouring regions (Gannaway, 1981).

Accurate regional supply and demand functions for any commodity are very difficult to estimate; so, predetermined estimates of the quantity available for shipment and required in each region must be used. As a result, regional surpluses and deficits are not a function of price. The surplus or deficit of each region can be determined through the use of these predetermined estimates of quantities shipped and consumed.

With the above stated information, linear programming can be used to obtain the optimum distribution pattern which minimizes total transportation costs. This pattern is consistent with the economic goals of producers and consumers. Transportation costs add to the total costs faced by producers and the final price paid by consumers. Therefore, minimization of transfer costs is in the economic interest of both parties. Transportation of cement to different locations in Ghana and its cost optimization is therefore important to the economic interest of both Ghacem as the producer and the consumer who pays for the final price of the product. What this work seeks to do is to study and develop a shipment scheme that will optimize transport pricing of cement haulage with the anticipation of reduced net cost for the distribution of Ghacem cement in Ghana.

1.2 Company Profile

Ghacem limited is a manufacturer of Portland cement with the brand names of Ghacem Super Rapid and Ghacem Extra of class 32.5R and 42.5N respectively. It was founded by the Government of Ghana in collaboration with Norcem of Norway in 1967, then Ghana Cement Works with an initial capacity of 300 tonnes per annum. The company's core investor and technical partner was Scancem ANS of Norway. Heidelberg cements A.G of Germany acquired controlling shares in the holdings of Ghacem through Scancem ANS of Norway in 1999 and Ghacem had since become a member of the HeidelbergCement Group of companies worldwide.

The company has two production plants for the production of Portland cement and sited in Tema and Takoradi respectively. The increasing demand for cement in Ghana necessitated expansions on the Tema and Takoradi plants over the years to its present capacity of 2.4

million tonnes per annum. With a conscious effort to include local content in the raw material base for the manufacturing of its products, Ghacem had since 2004 invested to partially substitute imported raw materials with local content. Commissioned limestone quarries in the Eastern and Western regions are currently providing about twenty five percent local raw materials content for the manufacturing of Ghacem brands of cement.

The finished products of the company (Portland cement and Portland Limestone cement) are delivered to the market in bags of 50 kg weight (about 88 percent of the total sales) with the rest delivered in bulk (powdered form) via purpose-made vehicles to customers or end users. Customers of the company's product are largely corporate construction companies, professional and small scale cement product manufacturers, real estate developers, industrial and engineering companies, government and individuals.

Ghacem's cement manufacturing plants are strategically positioned at the two marine port entries in Ghana; namely the Tema and Takoradi ports. From these locations, the northern segment of the country's cement need is conveniently serviced by the Takoradi plant whiles the southern part is serviced by the Tema plant. Depending on adverse variation in any of the plant output, there is an immediate support from the other to ensure regular and sustained cement supply to the market at all times.

At present, Ghacem employs about 300 team members across the country comprising of both permanent and sub-contract staff. The company's local headquarters is at Tema and markets its product across the length and breadth of Ghana via sales centres and depots in all the regional capitals for customers and accredited distributors' of the company to make payments and subsequently lift their consignment from the factory or depots.

1.2.1 Product

Ghacem has been in the production of Portland cement in Ghana since 1967. Portland cement is a key element of modern construction and it would have been difficult to imagine the world without it. We rely on it for the building of our homes, through to schools, hospitals, offices, roads, harbours, markets, stadia, airports, reservoirs for our water and other vital utilities.

1.2.2 Cement Basics

As a chemical material, cement binds or hardens and becomes strongly adhesive after application. Because is so adaptable it is used in a wide variety of ways. What makes cement so useful in most applications is that it can be easily made into almost any shape. It has good compressive strength, which makes it able to carry heavy loads but very poor at handling tensile (pulling) or bending forces. Cement is used in three main ways. It is used either as paste, mortar or concrete in application. Usually taken to mean Portland cement, but could mean any other type of cement depending on the context. In the presence of water the chemical compounds within Portland cement hydrate causing hardening and strength gain. It can bind sand and gravel into a hard solid mass called concrete

Figure 1.1: Clinker

Figure 1.2: Cement powder

<u>Difference between **Cement** (right) and **clinke**r (left).</u>

Portland cement is the most widely used type of cement and is so named because of the resemblance of it properties with a well-known natural stone quarried at Portland in the United Kingdom. Joseph Aspin, a Yorkshire brick-layer is regarded as the discoverer of Portland cement. Although there are several variations of commercially manufactured Portland cement, they each share many of the same basic raw materials and chemical components.

Portland cement is made by grinding clinker and a little added gypsum and the chief chemical components of clinker are calcium, silica, alumina, and iron. Calcium is derived from limestone, marl or chalk, while silica, alumina and iron come from the sands, clays and iron sources. Ghacem limited is one of the key players in the Portland cement manufacturing industry in Ghana today. Over the years since 1967, Ghacem limited has been and continue to maintain leadership as the number one cement manufacturing and distribution company in Ghana.

1.2.3 Business Objectives

Ghacem limited aims to be the “first to volume and first to market”. This means that their primary objective is to be both innovative in quality mass production and marketing of their product. With its direct and indirect marketing models, it aims to sell to both direct end users and also through its supply chain to the customer. From this approach it enables it to have a direct view of the customer and also generate shared wealth with distributors or resellers of its product.

1.2.4 Industry Environment

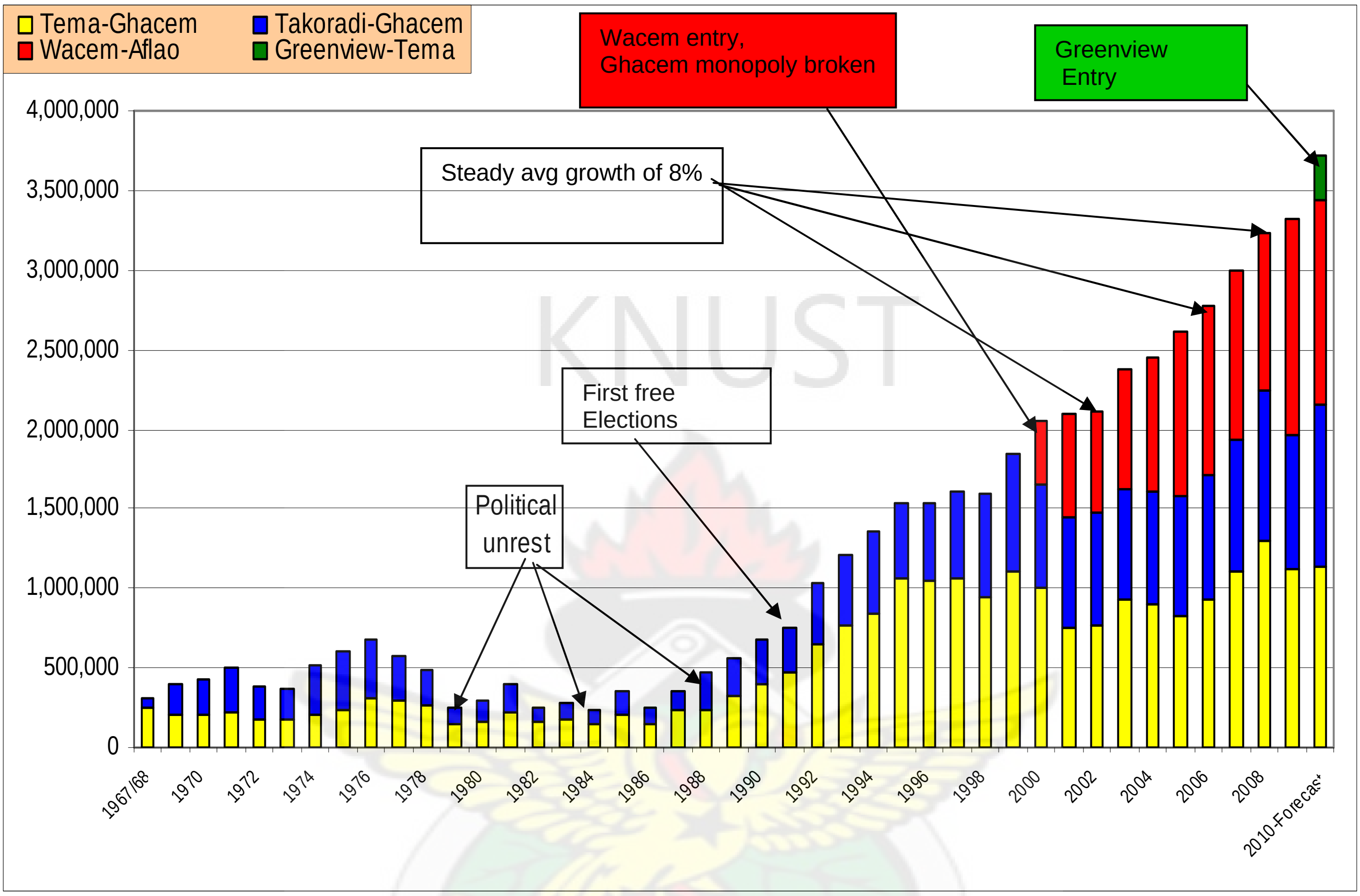
The market of cement is distinguished to be one of the fastest growing industries today in Ghana due the country’s infrastructural deficiency as a developing economy. The business environment is fast-paced as the product life cycle of cement is short. The logistics and distribution models must therefore be efficient with little room for error since the product life cycle is short and massive in weight for handling. Generally, the market of the cement industry is dependent upon national and international economic climate. The basic factors that affect the industry includes economic growth, political situations, laws and local government regulations, trade policies and the competition between manufacturers locally and internationally.

Besides its profit focus, Ghacem understands the importance of sustainable development, and continually seek ways to reduce the environmental impact of its operations by balancing materials demand with a commitment to environmental sustainability. Accordingly, it conducts business with respect and care for the environment and committed to preserving and improving the ecologies in which it operate and devote considerable resources to environmental quality efforts. Ghacem is therefore ISO 14001 compliance and the only cement industry in Ghana with certified safety and environmental guidelines on its operations.

1.2.5 Industry Players

The dominating companies in the cement industry in Ghana today are Wacem, Greenview and Ghacem limited. Each of them has their own way of gaining position in the market. As the sole cement manufacturer and distributor in Ghana at its inception in 1967, Ghacem has lost monopoly of the cement market to competition with new entries. Wacem limited with a brand called Diamond cement was the second to enter the market as a manufacturer and distributor of cement in Ghana in 2000.

Latest to enter the market is Greenview in 2010 and whose business is the processing of imported finished product for distribution. Among these players in the cement business, Ghacem now holds a market share of 58 percent from a previous position of 100 percent a decade ago (Ghacem Marketing Budget and Competition Report, 2010).



	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
GHACEM	81.07	69.09	69.9	68.58	65.84	60.8	61.41	64.36	70.31	59.12	58.03
WACEM	18.93	30.91	30.1	31.42	34.16	39.2	38.59	35.64	29.69	40.88	35.36
GREENVIEW	0	0	0	0	0	0	0	0	0	0	6.61

Figure 1.4: Ghacem Marketing Budget and Competition Report, 2010

1.2.6 Distribution and Sales Model

Ghacem's current marketing and distribution activities are organized in nine out of the ten regions in Ghana: Greater Accra, Eastern, Central, Western, Ashanti, Brong Ahafo, Northern, Upper East and Upper West. Each region has either a sales centre or combination of sales centres and a depot for customers and accredited distributors' of the company to make payments and subsequently lift their consignment from the factory or depots.

It has been indicated that distribution refers to the process of making products available in the right quantities and locations when customers want them. It encompasses many different concepts and ideas, such as physical distribution, inventory or stock levels, location, transport, and channels (NetMBA, 2007).

In terms of location decisions, Ghacem decided to strategically place its manufacturing plants near the marine ports of entry to Ghana where its import dominant raw material base can easily be facilitated. This saves the resources of the company in terms of arduous re-handling of raw materials needed to sustain the production of its products. Although Ghacem is able to save in one sense, it also somehow involves higher transport costs in terms of delivery of the finished goods to the consumers. The company manages the placement of products by focusing on physical distribution. Ghacem's distribution model involves a combination of direct and chain systems of making the product available to the customer.

Distribution model

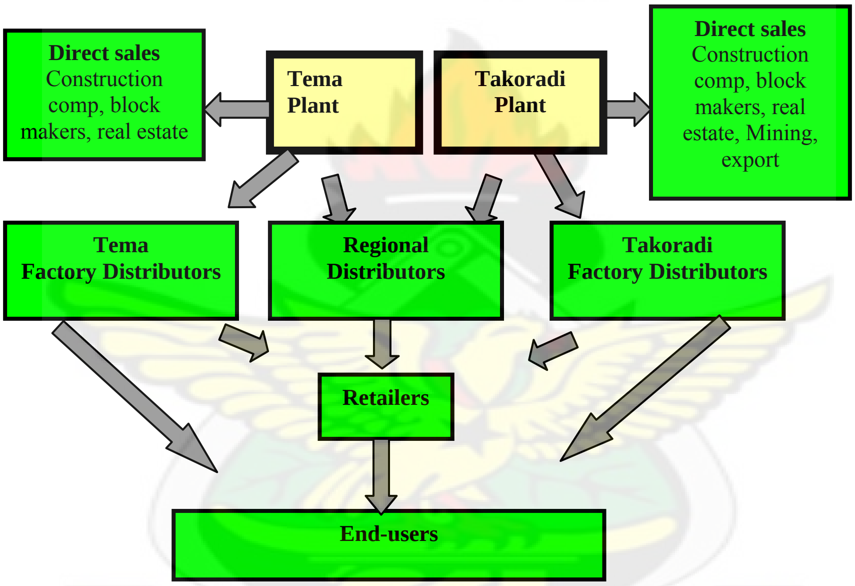


Figure 1.5: Schematic of Ghacem Distribution Model

1.2.7 Direct Sales Distribution

The direct distribution segment involves companies or customers who buy their products direct from Ghacem without through a distributor or reseller. This is largely influence by the product type and packaging. The product brand of Ghacem Extra which is meant for advance construction projects requiring higher strength specifications is marketed to customers or end users direct without through an intermediary whether delivered in bags or bulk (powdered form). This is largely patronized by construction companies and mining companies with technical requirements for higher strength specifications for their build. Another group of customers who fall into the direct sales distribution market are those who buy the brand of Ghacem Super Rapid in bulk for direct use like; cement products like pre-fabricated components, pre-cast and pre-stressed concrete beams, sandcrete and concrete blocks, roof tiles and Government projects.

Customers who buy the product in bulk, notwithstanding the brand because of the special case of handling (through purpose-made delivery vehicles) also enjoys direct sale from Ghacem. In all cases of the direct sales, which constitute twelve percent of Ghacem's total cement market volume (Ghacem Marketing Budget and Competition Report, 2010), customers pay for the product at ex-factory price but incur the cost of delivery.

1.2.8 Chain Distribution

In the chain distribution model which accounts for about 88 percent of Ghacem cement supply to the market, distribution is effected through a network of approximately 200 accredited distributors scattered across all the regions in Ghana (Ghacem Distributors Performance Report, 2010). The distributors are a chain of wholesalers who buy the cement in large quantities and in turn sell the product either directly to customers, or to retailers who in turn sell it to customers. The product might change hands several times before it eventually reaches the customer. This is what the "distribution channel" means.

The existing system had been developed around two implicit assumptions. The first is that the distributor (wholesaler) is the "customer" of the Ghacem distribution process, not the end user. The logic is that Ghacem distributes cement to the dealer and the dealer distributes through the retailer who also passes on the distribution to the end user. The second assumption is that, significant product (cement) inventory carried by the distributor creates an incentive (financing cost avoidance to Ghacem) to increase the rate of sales. Thus the distribution system operated as a "push" system. Neither of these assumptions is unique to the Ghacem distribution system, in fact they reflect the dominant logic of product distribution of many physical industrial goods. In the distribution network of Ghacem, the transportation and handling cost adds to the net cost of the cement to the consumer. Meaning that, the price of cement varies as a function of the consumer or buyer's location distance from the factory.

1.2.9 Products Pricing

Currently, Ghacem has two main products on the market with brand names Ghacem Super Rapid and Ghacem Extra of class 32.5R and 42.5N respectively but offered in four forms with accompanying ex-factory prices as shown in the table below.

Product	Cost per bag of 50 Kilogram weight in Cedis	Cost per tonne of powdered bulk weight in Cedis
Ghacem Super Rapid Class 32.5N	10.35	201.26
Ghacem Extra Class 42.5 N	11.42	220.80

Table 1.1: Self collect Ex-factory prices. Ghacem Marketing Department – 8th July 2009

Prices of cement are inclusive of Value Added Tax (VAT) of 12.5% and National Health Insurance Levy of 2.5% respectively. These are purely ex-factory without transportation cost.

1.3 Problem Statement

Cement is a major infrastructural development material whose demand cut across all Ghanaian communities both far and near from the supply sources. Ghacem limited, the leading manufacturer and distributor of cement in Ghana currently distributes its product at regional sales centres in Ghana at prices that vary as a function of the location distance from the factory. Transportation costs add to the total costs faced by producer and the final price paid by the consumer. Therefore, minimization of transfer costs is in the economic interest of both parties.

The challenge for Ghacem is the development of an effective transport pricing mechanism in a manner that minimizes the cost of transporting cement from specified origins to specified destinations. Therefore, the focus of this work is the application of a mathematical model to establish an optimal transport pricing patterns for cement shipment at Ghacem and see how likely it will affect cement prices at different locations in the country.

1.4 Objectives

The objective of this study is to examine the existing transport pricing scheme at Ghacem limited and seek to:

1. Mathematically model the shipment of Ghacem cement from the factory to its regional sales centres for distribution in Ghana as a transportation problem.
2. Determine the haulage or shipment of cement between production and distribution centres that will optimize transport pricing using the linear programming transportation model.

1.5 Methodology

Data collection was mainly from secondary sources and consulted information's included journals, magazines articles, news papers and also previous research reports. Company reports, document and online documents were also explored. Existing findings and knowledge on journals and books were also treated as secondary data.

Transport prices from both official Ghacem transport and private transport operators were obtained for the cost of trucking cost between supply and destination point for cement shipment. Data on production and consumption patterns of Ghacem regional distribution centres collected for the analysis was limited to the year 2010 with no consideration given to carryover. The basic computer model adopted for the Mathematical modelling of the transportation problem was Microsoft Excel Solver, 2003. Excel is a powerful spread sheet package used for solving mathematical and business problems.

The mathematical program used is a linear programming model referred to as the "transportation model." This model deals with the selection of shipping routes in a manner that minimizes the cost of transporting a uniform commodity from a specified origin to a specified destination. Standard models are not designed to necessarily "fit" actual flow patterns, but are used to determine what the flows should be if transportation costs are to be minimized. Using the target production capacities from the manufacturing plants as supply source against regional market centres as destination points, the transportation model was used to obtain an optimized least-cost transport flow patterns. For the purpose of this work, data used for the study dealt only with the year 2010 with no consideration given to carryover.

1.6 Justification

Businesses are continuously attempting to innovate and advance their organizational effectiveness through introducing changes that will motivate them to improve their level of performance. In businesses, transportation and distribution of products is essential. It should be one of the important processes in business (Chase, R 1998). For effective transportation of products, cost of delivery should be considered with an ultimate aim of minimisation of the total cost of the product.

The importance of this work is based on the argument that locations farther from the production centres of Ghacem production plants in Ghana (Tema and Takoradi) and also with deprived economic opportunities happens to pay more for the price of cement because of haulage cost. The mathematical modelling of the haulage pattern seeks to determine what the flows should be if transportation costs are to be minimized with the goal of helping to reduce the net cost of cement to consumers at distant locations.

So achieved, both the producer (Ghacem) and consumers would benefit if cement at regional sale centres sell at competitive prices because of reduced transport cost. The net effect would be the improvement of housing and construction delivery in Ghana and adding to the growth of the economy.

1.7 Organization of Thesis

Chapter one gives the background theory on transport pricing models and transportation models on linear programming. Profile on Ghacem limited as the reference company for the case study is also included. Chapter two provides an overview of existing literature on economics of transport pricing models on product shipment in conjunction with the transportation models on linear programming. Chapter three describes the framework on the mathematical modelling of the transportation problem. The chapter also contains description of the computer software application used for generating the results. Description of the data used in the analysis and results are presented in Chapter four. Chapter five includes the thesis summary, conclusions, limitations and an outline of recommendations.

CHAPTER TWO

LITERATURE REVIEW

2.0 Introduction

The literature review focuses on the links between the economics of product transport pricing between firms and consumers and the mathematical development of linear programming for solving transportation problems. Issues involved can be put into context by considering literature from the following sources. First, economics of product transport pricing between firms and consumer approaches are discussed and finally, the mathematical theory of linear programming for solving transportation problems is reviewed.

2.1 Transport Price Sharing

The original Hotelling (1939) literature on spatial competition has two main strands. One concerns itself with models of mill pricing in which firms choose location and prices, while the spatially dispersed consumers pay the cost of travelling to the firm to buy the product. The other strand of the literature assumes that firms absorb the transport cost of shipping the item to the consumers and is called uniform delivery pricing since all consumers pay the same price. In this work we look at a transport pricing scheme at Ghacem limited as model of a linear city that incorporates features of the mill pricing.

With a third concept by Hoover (1937), it is assumed that firms charge the same price to all consumers but have a cost of delivering to all those who purchase from them as in the models of uniform delivery pricing. Buyers on the other hand pay the price and also incur a transport cost which, for instance, reflects the delivery time associated with the good. This delivery time increases with the consumer's distance from the firm and is a source of disutility. It captures the opportunity cost of being able to consume sooner than later. The consumers' share of transport cost can be interpreted broadly to include time, effort and other transaction costs, asides from the costs of travel. This feature is common to models of mill pricing. Thus the model is a hybrid of the standard mill price and uniform delivery price models.

Anderson, de Palma and Thisse (1989) also shows that buyers and sellers in the real world are dispersed over geographical space and can be argued that the dispersed nature of market activities can be a source of market power for firms. Each firm has only a few rivals in its immediate neighbourhoods. Similarly, consumers who are at a considerable distance from a firm will not buy from that firm since they have to pay very high transport costs. The relative location of the firms with respect to the consumers is a crucial determinant of the degree of competition. Consequently, once one recognizes the importance of space, it is obvious that competition in the real world occurs only among a few and is best analyzed in a strategic game setting. The economic relevance of location games does not stem exclusively from their initial geographical set-up. The idea can be extended to competition among firms selling differentiated products where each firm's product is viewed as a point in the characteristic space.

Under the uniform delivery pricing models, Beckmann and Thisse (1986) have in their literature that, where a firm quotes a single delivery price to all its customers, the non-existence problem is even more severe. It arises because the rationing of some consumers by one firm allows its rival to service the other segment of the market at a high price. This gives the first firm an incentive to undercut, thereby destroying the equilibrium.

d'Aspremont et.al, (2000) also explained that the most common pricing policies in sectors like cement are the mill pricing and price discrimination (uniform delivery). These two pricing policies are strategically quite different and therefore it is highly likely that they lead to different outcomes in terms of consumer or social welfare.

Thisse and Vives (1988) in their stream of research compares the two pricing policies within a pricing game context and tries to find out the equilibrium pricing policy and in most cases its implications for the consumer, producer and social welfare. In their benchmark paper, they compared exactly the same two pricing policies in a pricing game context and show that uniform delivery price is the unique Nash equilibrium of the game. This outcome appears to be a Prisoner's Dilemma result for the firms and prices that consumers pay under mill pricing is higher than that they pay under uniform delivery price.

Similarly, Cooper et. al, (2004) compared uniform delivery pricing and mill pricing from antitrust perspective and advocates uniform delivery pricing against mill pricing in a spatial context. But, they all assume that firms are free to choose between the two pricing policies and they choose a pricing policy as a result of a pricing game.

Norman (1981) compared mill pricing and uniform delivery pricing and concludes that welfare differences between the two pricing policies are not significant and which one is better depends on the specific assumptions about the type of competition in the market. In particular, he considers Loeschian competition, in which firms behave like a monopolist in their respective fixed regions, and Greenhut-Ohta competition, in which each firm assume that when it changes its price in one direction, the other firm will react in an opposite way. Norman (1981) again concluded that mill pricing is better in the former case and uniform delivery price is better in the latter, although the difference is not significant.

Also, Hobbs (1986), in his study compares the same policies under Bertrand and Cournot competition and concludes that: Price discrimination acts as a check upon local market power; instead of competing for a few customers at market borders, as under mill pricing. Uniform delivery price firms compete wherever the prevailing price is above their marginal cost of production and transport. The result can sometimes be lower mean prices and greater welfare than under mill pricing.

However, in this thesis, the aim is not to compare the two pricing policies; namely the mill price and uniform transport pricing for cement haulage or shipment in context, in terms of their effects on consumers welfare and firms profits but on how to optimally model the least cost transport price for the existing pricing scheme at Ghacem limited.

2.2 The Transportation Model

In mathematics and economics, transportation theory is a name given to the study of optimal transportation and allocation of resources. The problem was formalized by the French mathematician Monge in 1781. Major advances were made in the field during World War II by the Soviet/Russian mathematician and economist Kantorovich (1942). Consequently, the problem as it is stated is sometimes known as the Monge–Kantorovich transportation problem.

Often in supply chain optimization multi-items have to be considered together, due to the dependency of the cost structure or the operational constraints on the total quantities transported and/or replenished. In other cases, the exact composition of the individual items in a single vehicle/batch is important. Other complicating characteristics of multi-item transportation/replenishment problems include capacity limitations of the vehicles/batches, time dependency of demand and cost parameters and the existence of fixed costs per vehicle/batch. However, Florian et al., (1980) added that dynamic lot-sizing problems with capacity restrictions are known to be hard problems when only one vehicle (batch) is allowed in each period and the capacity limitation is time-dependent. The transportation model is generally considered in conjunction with linear programming. However, according to Dorfman et al., (1958), the "transportation problem" was originated and solved by Hitchcock before the general concept of linear programming was developed.

Dantzig developed linear programming in 1947 as a technique for planning the diversified activities of the United States of America Air Force. Hitchcock (1960) gave a mathematical solution to the problem of homogeneous product distribution, with minimization of transportation cost as the desired goal. The problem was solved through the use of geometrical interpretation as an analytical aid in finding the "best vertex".

Koopmans (1951) gave a mathematical explanation on the use of the simplex method and linear programming to provide solutions to the problem of minimization of transportation cost. He also stated that discrepancies between actual shipping and "efficient" rates are often present in transportation systems subject to government operation or regulation. These discrepancies are the simple and crude notions of 'fairness' which have historically dominated such activity under the watching eyes of highly interested local and functional groups of population and industry.

Heady and Candler (1960) explained, in a general manner, the use of linear programming to allocate the surplus product of producing areas to other deficit areas in a feasible solution. A feasible solution is one that will not violate the following restrictions:

(a) A surplus region cannot ship more than its total production; and

(b) A consuming region cannot import more than its total consumption.

Important assumptions for the transportation model, as given by Heady and Candler (1960), are:

(i) Resources and products are homogeneous;

(ii) Quantities of resources or products available at the origins and the quantity requirements of the destinations are known and total quantity required is equal to total quantity available;

(ii) Cost of converting resources to products or of moving the commodity from origins to destinations is known and independent of the number of units converted or moved;

(iv) There is an objective to be maximized or minimized;

(v) Transportation and conversion can be carried on only at non-negative levels.

The authors then showed how modifications of the transportation model can be used to provide solutions when there are inequalities of quantity available and quantity required, processing problems and procurement problems.

Dorfman et al., (1957) again gave a more detailed analysis of the linear programming process as applied to a transportation problem. The authors explain that if there were, for example, M points of origin and N destinations, M > 1 and N > 1, there would be (MN) activities to be considered.

Levels of these activities would have to satisfy M restrictions relating to origins and N restrictions relating to destinations, making a total of (M+N). But if any (M+N-1) restrictions are satisfied, the volume of shipments left over must be just enough to satisfy the last restriction if the solution is valid. As a result, only (M+N-1) restrictions will be effective, and a minimum-cost set of routes will exist in which only (M+N-1) of the activities are used at positive levels. A basic solution was then developed in which the number of routes used at positive levels was equal to the number of restraining equations. The authors then described the iterative process through which the basic solution was improved until an optimal solution was obtained.

Takayama and Judge (1971) in the Netherlands developed and interpreted the classical transportation model and discussed an example of minimizing total transportation costs for interregional shipments of homogeneous commodities. The assumptions and restrictions of the model were discussed. Extensions of the model were also presented which could handle situations where total regional supplies are unequal to total regional demands, production costs and transportation costs are to be minimized, net revenue is to be maximized, and multiple commodities which are substitutes for each other are to be shipped.

Dietrich (1968) conducted a study to determine the least-cost locations and optimum levels of cattle feeding and fed-cattle slaughter among 27 regions in the United States of America to measure the effects of specified changes in regional feedlot size on the optimum locations and levels of feeding and slaughter, and showed the least cost shipment routes for feeder cattle, feed grain, fed slaughter cattle, and dressed fed beef.

Judge and Wallace (1959) conducted a three-part study in which they used a transportation model to develop a spatial price equilibrium model for the beef sector of the economy and the pork marketing system in the United States of America. The first part of the study was concerned with determining a set of spatial equilibrium prices of beef and the quantities consumed in each region, the quantity of beef exported and imported for each region under equilibrium conditions, the aggregate net trade and corresponding total transport cost, and the volume and direction of trade between each possible pair of regions that minimize the transport costs for beef distribution. The model was applied to 1955 data and assumed that slaughter took place at the location of production. An optimum solution using 21 regions was derived, and then the model was used to evaluate the effects of changes in transport costs on optimal shipments.

Sprott (1973) used a transportation model to identify and analyze 1971 patterns of hog production, slaughter, and consumption for the United States of America by major regions. The author used only truck shipping rates in computing transportation charges for hogs and pork. The simplex algorithm was the forerunner of many computer programs that are used to solve complex optimization problems (Baynton, 2006). These applications are used extensively in a variety of situations. One of the most important applications of the simplex method is the transportation method (Zitarelli & Coughlin, 1989). Zitarelli and Coughlin again presented the Shell oil study but concentrated on the Chicago area sub region to reduce the number of variables. The study used their problem to illustrate how transportation problems can be solved using a simplex tableau.

The transportation method can also be used to reduce the impact of using fossil fuels to transport materials (Case, 2007). Zierer et al., (1976) studied the practical applications of linear programming to Royal Dutch Shell's distribution system. In 1976 Shell marketed over a dozen grades of liquid petroleum products. Their East of the Rockies (EOR) region included three refineries and over 100 terminal demand points. Shell's other distribution system, West of the Rockies Region (WOR) comprised the rest of the U.S. The Zierer, Mitchell and White study was restricted to the EOR Region. The task of making Shell's products available to customers was considerably complex but the computations were essential since from 10 to 20 percent of Shell's revenues were allocated to transportation costs.

In 1976 the Chicago area sub region had two primary Shell oil refineries where oil was refined into various grades of petroleum products. These refineries were located in East Chicago, Indiana and Hammond, Indiana. The two major storage and shipment terminals were located in Des Plains, Illinois, and Niles, Michigan. In actual practice the problem was much more complex than the one presented by Zitarelli and Coughlin. It involved over 1,200 variables and 800 constraints because there were more complex decisions to be made such as which mode of transportation to use (including pipelines, barges, trucks and tankers). In 1976 the typical problem faced each day could be solved on a computer in about one-half hour at a cost of about $100. Such reports generated about ten optional reports because there were various goals and managers with different responsibilities using the same data from Zitarelli & Coughlin.

All of the studies and research reviewed in this chapter on transportation utilized a linear programming transportation model, either two-dimensional or multidimensional, to obtain least-cost shipping patterns. There have been several studies with the objectives of transport cost minimisation using the transportation model in linear programming. This work also indentifies the importance of transportation on product pricing and seeks to apply the mathematical model of linear programming to solve a typical transportation problem of a cement industry (Ghacem Limited) in Ghana with the objective of minimising the transport cost of cement haulage.

CHAPTER THREE

METHODOLOGY

3.0 Introduction

Cement is produced and consumed in differing amounts in each of the geographical regions of Ghana employed in this study. It is assumed that the producer (Ghacem) has the economic goal of profit-maximization and that every consumer has the goal of obtaining a desired amount of the product at the least possible cost. However, some regions produce more cement than consumers in the regions and are willing to buy at the prevailing prices, while other regions produce no cement to satisfy consumers' requirements at the prevailing prices. Both producers and consumers would benefit if the surplus producing regions transport enough cement to the deficit consuming regions to fulfil the requirements which exist at the prevailing prices in the deficit regions.

Transportation costs add to the total costs faced by producers and the final price paid by consumers. Therefore, minimization of transfer costs is in the economic interest of both the producer and consumer.

3.1 The Transportation Problem

Transportation problems are primarily concerned with the optimal (best possible) way in which a product produced at different factories or plants (called supply origins) can be transported to a number of warehouses (called demand destinations). The transportation problem basically seeks to find the best way to fulfill the demand of say n demand points using the capacities of say m supply points. The objective in a transportation problem is to fully satisfy the destination requirements within the operating production capacity constraints at the minimum possible cost.

Whenever there is a physical movement of goods from the point of manufacture to the final consumers through a variety of channels of distribution (wholesalers, retailers, distributors etc.), there is a need to minimize the cost of transportation so as to increase the profit on sales. Transportation problems arise in all such cases as providing assistance to top managers in ascertaining how many units of a particular product should be transported from each supply origin to each demand destinations so that the total prevailing demand for the company's product is satisfied, while at the same time the total transportation costs are minimized.

Bressler and King (1978) noted that widely separated regions may not engage in trading because the costs of transfer exceed the price differences that exist in absence of trade, therefore, great distances and expensive transportation restrict trade whiles technological developments that reduces transfer cost can increase trade. Identification of surplus and deficit regions, quantities shipped, and which region should ship available surplus to which deficit region often becomes a complicated task. Consideration of transportation cost causes the pattern of distribution of the commodity to become an essential factor in determining the total transportation cost.

Sasieni et al., (1959) noted that problems of allocation arise whenever there are a number of activities to perform, but limitations on either the amount of resources or the way they can be spent prevent us from performing each separate activity in the most effective way conceivable. In such situations we wish to allot the available resources to the activities in a way that will optimise the total effectiveness.

3.2 The Transportation Algorithm

From Amponsah's (2009) lecture notes, the transportation problem deals with a special class of linear programming problems in which the objective is to transport a homogeneous product manufactured at several plants (origins) to a number of different destinations at a minimum total cost. The total supply available at the origin and the total quantity demanded by the destinations are given in the statement of the problem. The cost of shipping a unit of goods from a known origin to a known destination is also given. The objective is to determine the optimal allocation that results in minimum total shipping cost.

The model deals with how to get the minimum-cost plan to transport a commodity from a number of sources (m) to number of destination (n). The solution algorithm to a transportation problem can be summarized into the following steps:

Step 1: Formulate the problem and set up in a pattern that uses all the products available and satisfies all requirements. This is called developing an initial basic solution. The formulation of transportation problem is similar to a Linear Programming problem formulation. Here the objective function is the total transportation cost and the constraints are the supply and demand available at each source and destination, respectively.

The general mathematical model may be given as follows:

Minimize $Z = \sum c_{ij}x_{ij}$

Subject to:

$x_{ij} \leq S_i$ for i = 1,2, ..., m (supply)

$x_{ij} \geq D_j$ for j = 1,2, ..., n (demand)

$x_{ij} \geq 0$

For a feasible solution to exist, it is necessary that total capacity equals total requirements.

Total supply = total demand or $\sum S_i = \sum D_j$.

If total supply = total demand then it is a balanced transportation problem.

$S_i = D_j$

S_i (supply) and D_j (demand) are all positive integers.

Each variable xij appears in exactly two constraints, one is associated with the origin and the other is associated with the destination. Putting in the matrix from, the elements of the matrix are either 0 or 1.

Table 3.1: The transportation tableau

						Supply
O_1	c_{11}	c_{12}	…..		c_{1n}	a_1
O_2	c_{21}	c_{22}	…..	….	c_{2n}	a_2
…	……	…..	…..	…..	…..	
O_m	c_{m1}	c_{m2}	….	…	c_{mn}	a_m
Requirement	D_1	D_2	……		D_n	

Step 2: Obtain an initial basic feasible solution.

This initial basic solution can be obtained by using any of the following methods:

(i) North West Corner Rule

(ii) Least-Cost Method

(iii) Vogel Approximation Method

The solution obtained by any of the above methods must fulfill the following conditions:

(i) The solution must be feasible, meaning, it must satisfy all the supply and demand constraints. This is called rim condition.

(ii) The number of positive allocations must be equal to (m+n–1), where, m is number of rows and n is number of columns.

The solution that satisfies both the above mentioned conditions is called a non-degenerate basic feasible solution.

Step 3. Test the initial solution for optimality.

Using any of the following methods can test the optimality of obtained initial basic solution:

(i) Stepping Stone Method

(ii) Modified Distribution Method (MODI)

If the solution is optimal then stop, otherwise, determine a new improved solution

3.2.1 Initial Basic Feasible Solution (IBFS)

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. A feasible solution to a transportation problem is basic if and only if the corresponding cells in the transportation table do not contain a loop. The three common methods used to obtain the initial basic solution differ in the "quality" of the starting basic solution they produce and better starting solution.

3.2.2 Northwest Corner Method

To find an Initial Basic Feasible Solution using the Northwest Corner Method, we proceed as follows:

Step 1: The first assignment is made in the cell occupying the upper left-hand (North West) corner of the transportation table.

The maximum feasible amount is allocated there, thus $x_{11} = \min(a_1, b_1)$.

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

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

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

Continue this until all the requirements and supplies are satisfied.

3.2.3 Least-Cost Method

The minimum-cost method finds a better starting solution by concentrating on the cheapest routes. The method starts by assigning as much as possible to the cell with the smallest unit cost. Next, the satisfied row or column is crossed out and the amounts of supply and demand are adjusted accordingly. If both a row and a column are satisfied simultaneously, only one is crossed out, the same as in the northwest–corner method .Next, look for the uncrossed-out cell with the smallest unit cost and repeat the process until exactly one row or column is left uncrossed out.

3.2.4 Vogel's Approximation Method (VAM)

To find an initial basic feasible solution using the Vogil's Approximation Method, we proceed as follows:

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

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

Step 3: Re compute the column and row differences for the reduced transportation table and go to step 2. Repeat the procedure until all the rim requirements are satisfied. VAM determines an initial basic feasible solution, which is very close to the optimum solution.

3.2.5 Comparison of Methods

The Northwest Corner Method has the advantage of a quick solution because computations take shorter time but yields a bad solution because it is very far from optimal solution. The Least-Cost Method is used to obtain the shorter road and yields better starting basic solution because it gives initial solution very near to optimal solution but the solution is slow because computations take longer time.

Advantage of Vogel's Approximation Method is that it yields a basic feasible solution close to optimality and thus performs better than the Northwest Corner Method or the Least Cost Method. Unlike the Northwest Corner Method, the Vogel's Approximation Method may lead to allocation with fewer than (m + n -1) non-empty cells even in the non-degenerate case. The method is however slow and computations takes time.

3.2.6 Degeneracy

If the basic feasible solution of a transportation problem with m origins and n destinations has fewer than (m+n–1) positive x_{ij} (occupied cells), the problem is said to be a degenerate transportation problem.

Degeneracy can occur at two stages:

(i) At the initial solution

(ii) During the testing of the optimal solution

To resolve degeneracy, we make use of an artificial quantity (d). The quantity d is assigned to that unoccupied cell, which has the minimum transportation cost. For calculation purposes the value of d is assume to be zero.

3.2.7 Improvement to Optimality

The solution obtained from the three method discussed earlier are feasible but not necessarily optimal. Improvement to their optimality is achieved by employing the following methods:

(i) Stepping Stone Method;

(ii) Modified Distribution Method (MODI).

3.2.8 Steppingstone Method

The Steppingstone Method, being a variant of the simplex method, requires an initial basic feasible solution which it then improves to optimality. Such an initial basic feasible solution may be obtained by any of the method discussed earlier on and the method may be outlined as follows:

Step 1: Determine an initial basic feasible solution using any one of the following:

(i) North West Corner Rule:

(ii) Matrix Minimum Method: and

(iii) Vogel Approximation Method

Step 2: Ensure the number of occupied cells is exactly equal to (m+n-1), where m is the number of rows and n is the number of columns.

Step 3: Select an unoccupied cell. Beginning at this cell, trace a closed path, starting from the selected unoccupied cell until finally returning to that same unoccupied cell.

Step 4: Assign plus (+) and minus (-) signs alternatively on each corner cell of the closed path just traced, beginning with the plus sign at unoccupied cell to be evaluated.

Step 5: Add the unit transportation costs associated with each of the cell traced in the closed path. This will give net change in terms of cost.

Step 6: Repeat steps 3 to 5 until all unoccupied cells are evaluated.

Step 7: Check the sign of each of the net change in the unit transportation costs. If all the net changes computed are greater than or equal to zero, an optimal solution has been reached. If not, it is possible to improve the current solution and decrease the total transportation cost, so move to the next step.

Step 8: Select the unoccupied cell having the most negative net cost change and determine the maximum number of units that can be assigned to this cell. The smallest value with a negative position on the closed path indicates the number of units that can be shipped to the entering cell. Add this number to the unoccupied cell and to all other cells on the path marked with a plus sign. Subtract this number from cells on the closed path marked with a minus sign.

3.2.8 Modified Distribution Method (MODI) or (u - v) method

The modified distribution method, also known as MODI method or (u - v) method provides a minimum cost solution to the transportation problem. In the stepping stone method, we have to draw as many closed paths as equal to the unoccupied cells for their evaluation. To the contrary, in MODI method, only closed path for the unoccupied cell with highest opportunity cost is drawn. The MODI method is an improvement over the stepping stone method

The method, in outline, is as follows:

Step 1: Determine an initial basic feasible solution using any one of the three methods given below:

(i) North West Corner Rule;

(ii) Matrix Minimum Method; and

(iii) Vogel Approximation Method.

Step 2: Determine the values of dual variables, u_i and v_j, using $u_i + v_j = c_{ij}$

Step 3: Compute the opportunity cost using $c_{ij} – (ui + v_j)$.

Step 4: Check the sign of each opportunity cost. If the opportunity costs of all the unoccupied cells are either positive or zero, the given solution is the optimal solution. On the other hand, if one or more unoccupied cell has negative opportunity cost, the given solution is not an optimal solution and further savings in transportation cost are possible.

Step 5: Select the unoccupied cell with the smallest negative opportunity cost as the cell to be included in the next solution.

Step 6: Draw a closed path or loop for the unoccupied cell selected in the previous step. Please note that the right angle turn in this path is permitted only at occupied cells and at the original unoccupied cell.

Step 7: Assign alternate plus and minus signs at the unoccupied cells on the corner points of the closed path with a plus sign at the cell being evaluated.

Step 8: Determine the maximum number of units that should be shipped to this unoccupied cell. The smallest value with a negative position on the closed path indicates the number of units that can be shipped to the entering cell. Now, add this quantity to all the cells on the corner points of the closed path marked with plus signs, and subtract it from those cells marked with minus signs. In this way, an unoccupied cell becomes an occupied cell.

Step 9: Repeat the whole procedure until an optimal solution is obtained**.**

3.3 Solving a Transportation Problem as a Linear Programming Problem

A Transportation Problems can be modelled as a Linear Programming problem. To set up the Transportation Problem as a Linear Programming problem (LP), the following elements need to be considered:

3.3.1 Variables

The variables in the LP model of the Transportation Problem will hold the values for the number of units shipped from one source to a destination. A variable with double subscripts is used for this problem.

X_{ij} = Number of units shipped from Source i to Destination j

3.3.2 Objective Function

The objective function contains costs associated with each of the variables. It is a minimization problem. Let C_{ij} denote the cost of shipping one unit from Source i to Destination j. The general mathematical model may be given as follows:

Minimize total cost (Z) = $\sum_{ij} c_{ij} x_{ij}$, for i = 1, 2….,m and j = 1, 2....,n

3.3.3 Constraints

The constraints are the conditions that force supply and demand needs to be satisfied. In a transportation problem, there is one constraint for each node.

Let Si denote source capacity and Dj denote destination needs

$\sum_{i=1}^{m} X_{ij} \le S_i$, for i = 1, 2…,m. Thus quantity supplied cannot exceed source capacity.

$\sum_{j=1}^{n} X_{ij} \ge D_j$, for j =1, 2, …, n. Thus quantity received must be sufficient to meet demand.

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

One of the most important and successful applications of quantitative analysis to solving business problems has been in the physical distribution of products, commonly referred as transportation problems. Basically the purpose is to minimise the cost of shipping goods from one location to another so that the needs of each arrival area are met and every shipping location operates within its capacity. Sasieni et al., (1959) again outlined the major assumptions and restrictions which must be made in order to use a linear programming transportation model to determine cost-minimizing shipments as follows:

(i) the commodity traded is a homogeneous product produced under purely competitive conditions so that consumers are indifferent to the original source of the commodity;

(ii) each producer has the goal of profit maximization;

(iii) all regions engaging in cement distribution are connected by known transportation rates which are independent of the direction and volume of trade;

(iv) regional quantities of the commodity available for shipment and required are known or predetermined;

(v) regional surpluses or deficits exist at only one point in the regional sale centres;

(vi) the total amount of product shipped from an origin cannot exceed the total surplus of that region;

(vii) the total amount received by a destination must not be greater than the total deficit of that region;

(viii) surplus regions may ship only to deficit regions, and deficit regions may receive only from surplus regions.

(ix) all shipments are one-way from surplus to deficit regions.

The objective of the transportation problem in this work was to minimize the total cost of transportation of cement. Therefore, linear programming and all the previously discussed assumptions and restrictions did apply in this situation

3.4 Computer Model

Transportation problems are also linear programming problems and can be solved by simplex method but it is tedious to solve them manually when they contain hundreds of variables and constrains. However, with the help of computer soft ware programmes, complex problems are easily solved within seconds. The basic computer application adopted for the Mathematical modelling of the transportation problem was Microsoft Excel Solver, 2003. Excel is a spreadsheet package that lends itself to the solving of linear programming transportation problems. Winston (2003) describes Excel as a powerful spread sheet package used for solving mathematical and business problems and have tremendous potential to help people work more efficiently by providing ways to manipulate and therefore internalize data in ways that would be impossible or difficult to do otherwise. With its application, data inputs and the construction of relationships among data elements are readable and easy to understand.

In his teaching notes on some practical issues with Excel Solver, Evans (2008) states that spreadsheets have become the principal software application for teaching decision models in most business schools and in particular, used extensively for solving and analysing optimization models. In its use for solving transportation problems, the foundation of the processes is built on an optimization model and the spreadsheet design must assign cells for target cells, changing cells and constraint functions to ensure there is a relationship data in the spreadsheet for the following:

(i) the quantity to be maximized or minimized

(ii) the decision variables

(iii) the quantity to constrain

CHAPTER FOUR

DATA COLLECTION AND ANALYSIS

4.0 Introduction

This chapter uses basic data of cement stocks from the production plants and shipment activities to the sales distribution points of Ghacem chain distribution system to present analysis of the linear programming model of the transportation cost minimisation problem hypothesis develop in Chapter three. The results of the transportation model run for optimal transport pricing solution using Microsoft Excel Solver 2003 are also presented.

4.1 Supply Sources and Destination Points

Since the work was limited to Ghacem cement haulage, all of the data required for the study were obtained directly from Ghacem sources. This session, thus, deals with the details of originating sources and destinations points of cement haulage and collection of the necessary data.

Ghana as the host nation, from which Ghacem operates, is divided into two (2) supply sources and ten (10) destinations points for cement distribution for the purpose of this analysis. From the ten (10) destination sales points, the two plants supplies all the requirements of the sales centres. Figures (4.1) and (4.2) give a simple flow pattern of the supply sources and destination points for Ghacem cement distribution. Supply and destination demarcation was based on the data availability and concentration of cement production and consumption activity. Ghacem sales centres were designated to represent the destination points while the factories or the plants represents supply source.

The selection of the supply source and destination points was made on the basis of the amount of cement supply and consumption activity recorded in year 2010. For each of the supply and destination points, supply and consumption for 2010 were obtained from Ghacem sources.

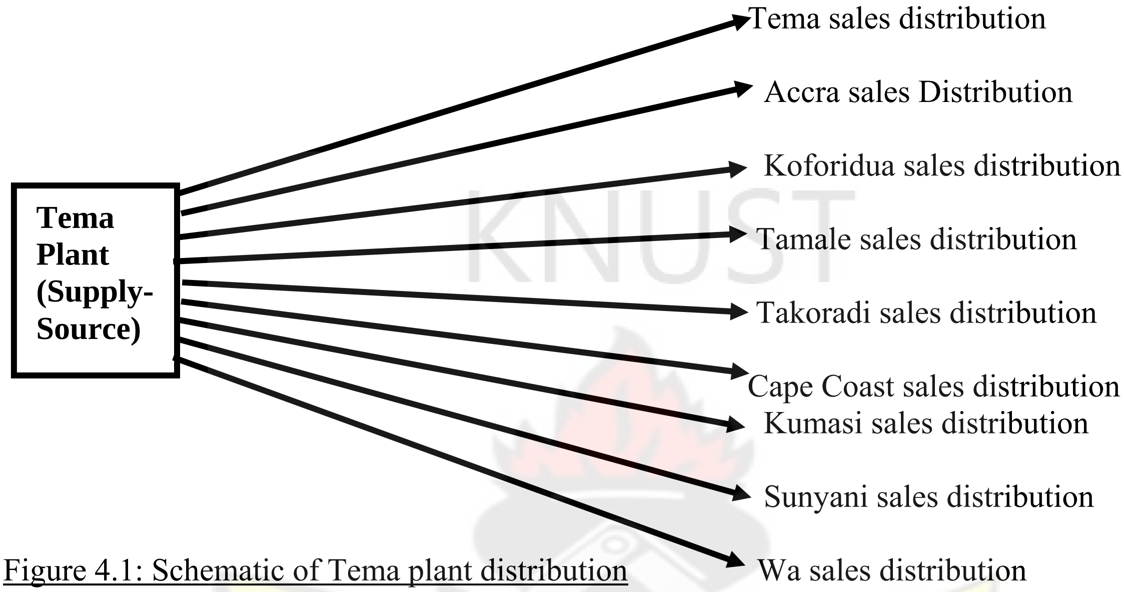


Figure 4.1: Schematic of Tema plant distribution

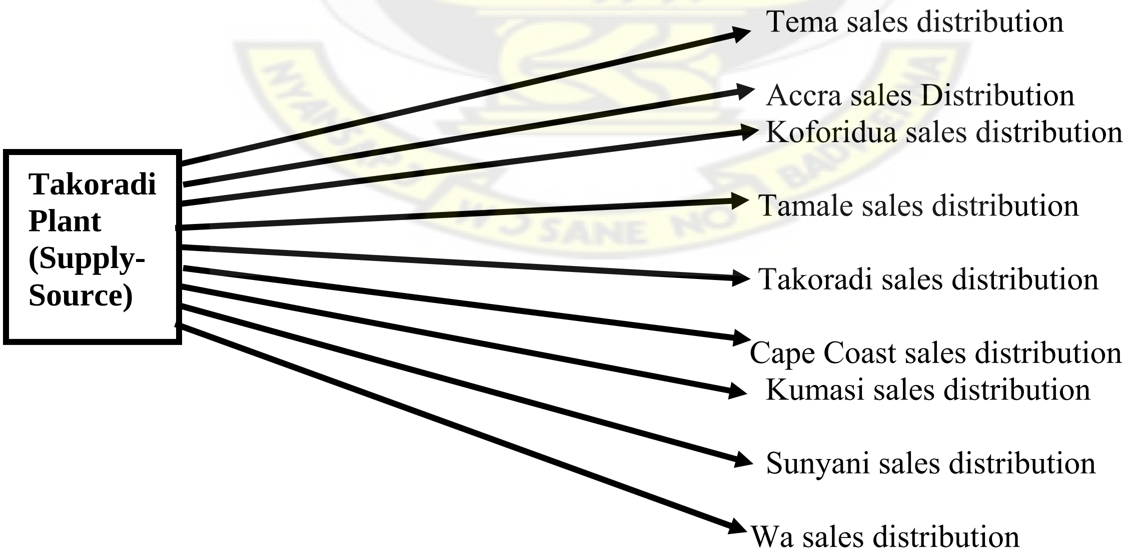


Figure 4.2: Schematic of Takoradi plant distribution

For purposes of the analysis, only cement that goes through the chain distribution network was considered {refer to appendices on regional distribution (RD) data}. This particular Ghacem stock and distribution in Ghana was assumed to be a "closed" system. That is, no exporting or importing of non Ghacem product was allowed between any of the regions in and any area outside the borders of Ghana. Under this assumption, only interregional shipments of Ghacem cement were considered, and production and consumption totals for year 2010 were all forced to equal each other.

Therefore, cement produced from the two plants was consumed in the 10 regions. This was to simplify statistical analysis and focused the attention of the study on shipments within the confines of Ghana. It also assumed that the requirements of each destination could be filled with Ghacem products, thereby avoiding consideration of other cement products. Implicit in the equality of production and consumption totals is the assumption that there is a time lag of less than a year between production and consumption. This may not be realistic, but it was necessary since this study dealt only with the year 2010 with no consideration given to carryover.

The determination of each point as a surplus shipping region or a deficit receiving region, and the amount of the regional surplus or deficit, was necessary to provide constraints for the Linear Programming model. For the movement from production to the distribution, the difference between regional production (RP.) and regional consumption (RC) was calculated. If RP exceeded RC, the region had surplus production which could be shipped to other regions. Conversely, if RC exceeded RP, the region had to fill its deficit of consumption from other producing regions. The calculated surpluses and deficits were used as the regional constraints in the computer model.

4.2 Transport Rates

Transportation costs were considered for shipments of cement by truck only. Shipping rates for the various supply and destination points for cement haulage were obtained from Ghacem sources and Ghana Private Road Transport Union (GPRTU) branches at Tema and Takoradi haulage offices respectively. Ghacem has ten sale centres for cement distribution that receives its supply source from either Tema or Takoradi plant. These are Cape Coast, Koforidua, Accra, Sunyani, Takoradi, Kumasi, Tamale, Wa and Tema.

Table 4.1: Transport rates per ton

From	To	Rate (GH¢) per tonne
Tema Plant (Factory)	RD11	30
	RD12	18
	RD13	11
	RD14	48
	RD15	40
	RD16	34
	RD17	50
	RD18	68
	RD19	7
Takoradi Plant (Factory)	RD21	16
	RD22	40
	RD23	34
	RD24	34
	RD25	8
	RD26	28
	RD27	50
	RD28	64
	RD29	40

Source: Tema Ghacem and Takoradi Ghacem Truck Union of GPRTU

4.3 Mathematical Formulation

Ghacem manufacturing company produces cement at factories or plants situated at various places (called origins) and supply them to sales depots (called destination). Here the availability as well as requirements of the various sales distribution points are finite and constitute the limited resources. This type of problem is known as distribution or transportation problem in which the key idea is to minimize the total cost of transportation. One of the most successful applications of quantitative analysis to solving business problems has been in the physical distribution of products, commonly referred as transportation problems. Basically the purpose is to minimize the cost of shipping goods from one location to another so that the needs of each arrival area are met and every shipping location operates within its capacity.

Let say three factories, producing cement be say, A_1, A_2 and A_3 from where the cements are to be supplied to five sales depots say B_1, B_2, B_3, B_4 and B_5. Let the number of quantity of cement produced at A_1, A_2 and A_3 be a_1, a_2 and a_3 respectively and the demands at the depots be b_2, b_1, b_3 b_4 and b_5 respectively.

We assume the condition, $(a_1+a_2+a_3) = (b_1+b_2+b_3+b_4+b_5)$

Implying all the quantities of cement produced are supplied to the different depots.

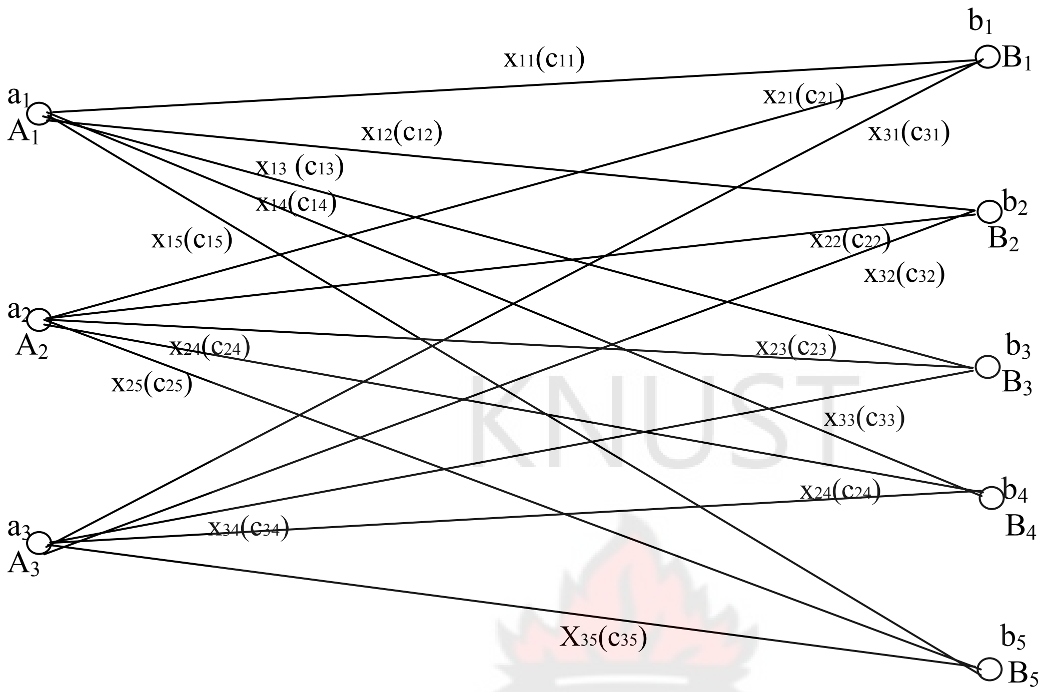
Let the cost of transportation of one tonne of cement from A_1 to B_1 be c_{11}. Similarly, the costs of transportations in other cases are also shown Figure 4.3 and Table 4.2.

Let out of a_1 cement available at A_1, x_{11} be taken to B_1 depot, x_{12} be taken to B_2 depot and to other depots as well, as shown in Figure 4.3 and Table 4.2.

Total quantity of cement to be transported forms A_1 to all destinations, i.e., B_1, B_2, B_3, B_4 and B_5 must be equal to a_1.

$$\therefore \quad x_{11}+x_{12}+x_{13}+x_{14}+x_{15}=a_1 \qquad (1)$$

Figure 4.3: Network representation of the transportation problem



Similarly, from A_2 and A_3 let the quantity of cement transported be equal to a_2 and a_3 respectively.

$\therefore\ x_{21}+x_{22}+x_{23}+x_{24}+x_{25} = a_2$ (2)

and $x_{31}+x_{32}+x_{33}+x_{34}+x_{25} = a3$ (3)

On the other hand it should be kept in mind that the total number of quantities of cement delivered to B_1 from all units or plants must be equal to b_1, that is:

$x_{11}+x_{21}+x_{31} = b_1$ (4)

Similarly, $x_{12}+x_{22}+x_{32} = b_2$ (5)

$x_{13}+x_{23}+x_{33} = b_3$ (6)

$x_{14}+x_{24}+x_{34} = b_4$ (7)

$x_{15}+x_{25}+x_{35} = b_5$ (8)

With the help of the above information the following table is constructed:

Table 4.2: Transportation Cost Table Format

Sales Depot / Factory	To B_1	To B_2	To B_3	To B_4	To B_5	Stock
From A_1	$x_{11}(c_{11})$	$x_{12}(c_{12})$	$x_{13}(c_{13})$	$x_{14}(c_{14})$	$x_{15}(c_{15})$	a_1
From A_2	$x_{21}(c_{21})$	$x_{22}(c_{22})$	$x_{23}(c_{23})$	$x_{24}(c_{24})$	$x_{25}(c_{25})$	a_2
From A_3	$x_{31}(c_{31})$	$x_{32}(c_{32})$	$x_{33}(c_{33})$	$x_{34}(c_{34})$	$x_{35}(c_{35})$	a_3
Demand or Requirement	b_1	b_2	b_3	b_4	b_5	

The cost of transportation from Ai (i=1, 2, 3) to Bj (j=1, 2, 3, 4, 5) will be equal to

$$Z = \sum c_{ij}\, x_{ij} \qquad (9)$$

Where the symbol $\sum$ put before $c_{ij}\, x_{ij}$ signifies that the quantities $c_{ij}\, x_{ij}$ must be summed over all i = 1, 2, 3 and all j = 1, 2, 3, 4, 5. Thus we come across a linear programming problem given by equations (1) to (8) and a linear function (9).

We have to find the non-negative solutions of the system such that it minimizes the function

Thus $$\sum_{ij} c_{ij}\, x_{ij} = Z = \text{Minimum} \qquad (10)$$

We can think about a transportation problem in a general way if there are m sources (say A_1, A_2... A_m) and n destinations (say B_1, B_2... B_n). We can use a_i to denote the quantity of goods concentrated at points A_i (i=1, 2 ..., m) and b_j denote the quantity of goods expected at points B_j (j =1, 2 ..., n). We assume the condition that, $(a_1+a_2+....+a_m) = (b_1+b_2+....+b_n)$ implying that the total stock of goods is equal to the summed demand for it.

4.4 Ghacem Transport Problem Formulations

The performance of the mathematical model formulated earlier in section 4.3 is tested to find the actual levels of transport pricing optimality. To accomplish this, the transport rate data, regional production capacities from the plants and the regional distribution figures (refer to appendices A) were used to draw Table 4.3.as shown below.

Table 4.3: Ghacem Production, Distribution, Consumption, Surplus and Deficit for Chain Distribution in Ghana

Regional Distribution (RD)	Production (tonnes)	Consumption (tonnes)	Surplus (tonnes)	Deficit (tonnes)
RD1	-	205,600	-	205,600
RD2		11,780		11,780
RD3		28,010		28,010
RD4		51,510		51,510
RD5		90,820		90,820
RD6		32,820		32,820
RD7	536,570	376,560	160,010	
RD8		22,440		22,440
RD9	753,050	461,720	291,330	
RD10		8,360		8,360
Totals	1,289,620	1,289,620	451,340	451,340

From the existing distribution arrangement at Ghacem, Bolgatanga derives its supplies from Tamale and therefore was not considered as a primary regional distribution (RD) point in the analyses. Its deficit supplies were combined to that of Tamale and so reducing the primary marketing points for distribution to nine (9) instead of ten (10).

Table 4.4: Transport Cost, Supply and Demand for Ghacem Chain Distribution of Cement

Sales / Plant	MK1	MK2	MK3	MK4	MK5	MK6	MK7	MK8	MK9	Supply Available (tonnes)
Plant 1	GH¢ 30	GH¢ 18	GH¢ 11	GH¢ 48	GH¢ 40	GH¢ 34	GH¢ 50	GH¢ 68	GH¢ 7	753,050
Plant 2	GH¢ 14	GH¢ 40	GH¢ 34	GH¢ 34	GH¢ 8	GH¢ 28	GH¢ 50	GH¢ 64	GH¢ 40	536,570
Demand (tonnes)	28,010	51,510	205,600	34,820	376,560	90,820	34,220	8,360	461,720	**1,289,620**

*MK denotes market

Combining the mathematical formulated equations of Section (4.3) respectively, Ghacem transport pricing for cement haulage was formulated using figures from Table (4.6) as follows:

Because Ghacem must determine how much cement is sent from each plant to each distribution market, we defined (for i = 1, 2 and j = 1, 2, 3, …, 9)

x_{ij} = number of (tonnes) cement produced at plant i and sent to market j.

In terms of variables, the total cost of supplying the cement demand to markets 1- 9 may be written as

$8x_{11}+10x_{12}+18x_{13}+50x_{14}+34x_{15}+30x_{16}+34x_{17}+40x_{18}+68x_{19}$ (11) (cost of shipping cement from plant1)

$+34x_{21}+32x_{22}+30x_{23}+64x_{24}+8x_{25}+16x_{26}+28x_{27}+34x_{28}+64x_{29}$ (12) (cost of shipping cement from plant2)

Ghacem transportation problem faced two types of constraints. First the total cement supplied by each plant could not exceed the plant's capacity. The total amount of cement sent from plant 1 to the nine markets could not exceed 753,050 tonnes. Each variable with first subscript 1 represented a shipment of cement from plant 1, so the expressed restriction by the Linear Programming (LP) constraint was;

$$x_{11} + x_{12} + x_{13} + x_{14} + x_{15} + x_{16} + x_{17} + x_{18} + x_{19} \leq 753,050$$

In a similar fashion, a constraint was found that reflected plant 2 capacity. Because cement was supplied by the plants, each was a supply point and the constraint ensured that the total quantity shipped from the plant did not exceed plant capacity, was a supply constraint. The Linear Programming formulation of the Ghacem transportation problem contained the following two supply constraints:

$$x_{11} + x_{12} + x_{13} + x_{14} + x_{15} + x_{16} + x_{17} + x_{18} + x_{19} \leq 753,050 \qquad (13)$$

$$x_{21} + x_{22} + x_{23} + x_{24} + x_{25} + x_{26} + x_{27} + x_{28} + x_{29} \leq 536,570 \qquad (14)$$

Constraints were also applied that ensured each market did receive sufficient cement to meets its demand. Each market demanded cement, so each was a demand point. From Table (4.6), market 1 did receive at least 28,010 tonnes. Each variable with second subscript 1 represented a shipment to market 1 so the following constrained was obtained.

$$x_{11} + x_{21} \geq 28,010$$

Similarly constraints for each of the markets 2, 3, 4, 5, 6, 7, 8 and 9 were obtained. A constraint that ensured that each location received it demand is a demand constraint. Ghacem transportation problem was therefore made to satisfy the following nine demand constraints.

$x_{11} + x_{21} \geq 28,010$ (Market 1 demand constraint) (15)

$x_{12} + x_{22} \geq 51,510$ (Market 2 demand constraint) (16)

$x_{13} + x_{23} \geq 205,600$ (Market 3 demand constraint) (17)

$x_{14} + x_{24} \geq 32,820$ (Market 4 demand constraint) (18)

$x_{15} + x_{25} \geq 376{,}560$ (Market 5 demand constraint) (19)

$x_{16} + x_{26} \geq 90{,}820$ (Market 6 demand constraint) (20)

$x_{17} + x_{27} \geq 34{,}220$ (Market 7 demand constraint) (21)

$x_{18} + x_{28} \geq 8{,}360$ (Market 8 demand constraint) (22)

$x_{19} + x_{29} \geq 461{,}720$ (Market 9 demand constraint) (23)

Because all the x_{ij} must be non-negative, the sign restrictions $x_{ij} \geq 0$ ($i = 1, 2$; $j=1, 2, 3,\ldots,9$) was added. Combining the objective function, supply constraint, demand constraint and sign restriction yielded the following LP formulation of Ghacem transportation problem.

Minimise $Z = 8x_{11}+10x_{12}+18x_{13}+50x_{14}+34x_{15}+30x_{16}+34x_{17}+40x_{18}+68x_{19}+34x_{21}+32x_{22}$
$+30x_{23}+64x_{24}\ \ +8x_{25}+16x_{26}+28x_{27}+34x_{28}+64x_{29}$

Subject to

$$\left.\begin{array}{l} x_{11} + x_{12} + x_{13} + x_{14} + x_{15} + x_{16} + x_{17} + x_{18} + x_{19} \leq 753{,}050 \\ x_{21} + x_{22} + x_{23} + x_{24} + x_{25} + x_{26} + x_{27} + x_{28} + x_{29} \leq 536{,}570 \end{array}\right\} \text{Supply constraints}$$

$$\left.\begin{array}{l} x_{11} + x_{21} \geq 28{,}010 \\ x_{12} + x_{22} \geq 51{,}510 \\ x_{13} + x_{23} \geq 205{,}600 \\ x_{14} + x_{24} \geq 32{,}820 \\ x_{15} + x_{25} \geq 376{,}560 \\ x_{16} + x_{26} \geq 90{,}820 \\ x_{17} + x_{27} \geq 34{,}220 \\ x_{18} + x_{28} \geq 8{,}360 \\ x_{19} + x_{29} \geq 461{,}720 \end{array}\right\} \text{Demand constraints}$$

4.4 Excel Solver Application

Using the mathematical formulated equations earlier in Section (4.3), a general description of the model used for the transportation problem in the analysis was given as below;

i = Regions which serve as shipping origins of cement ($i = 1, 2 \ldots, m$)

j = Regions which are destinations for cement distribution ($j = 1, 2 \ldots, n$)

b_j = Quantity of cement required at the j-th destination in tonnes

x_{ij} = Quantity of cement shipped from the i-th origin to the j-th destination in tonnes

S_i = Excess quantity of cement available for shipment from the i-th origin in tonnes

C_{ij} = Cost per tonne of shipping cement from the i-th origin to the j-ith destination

The objective of minimizing the total transportation cost of cement shipment under the earlier restrictions and assumptions were stated with the notations as:

$$\sum_{j=1}^{n} \sum_{i=1}^{m} C_{ij} x_{ij} = Z = \text{a minimum} \qquad (24)$$

The stated objective was accomplished after the following constraints were placed upon the model:

$$\sum_{j=1}^{n} X_{ij} \leq S_i \qquad (i = 1, 2 \ldots, n) \qquad (25)$$

The total shipments of cement from any surplus origin could not exceed the total amount of excess cement at that region.

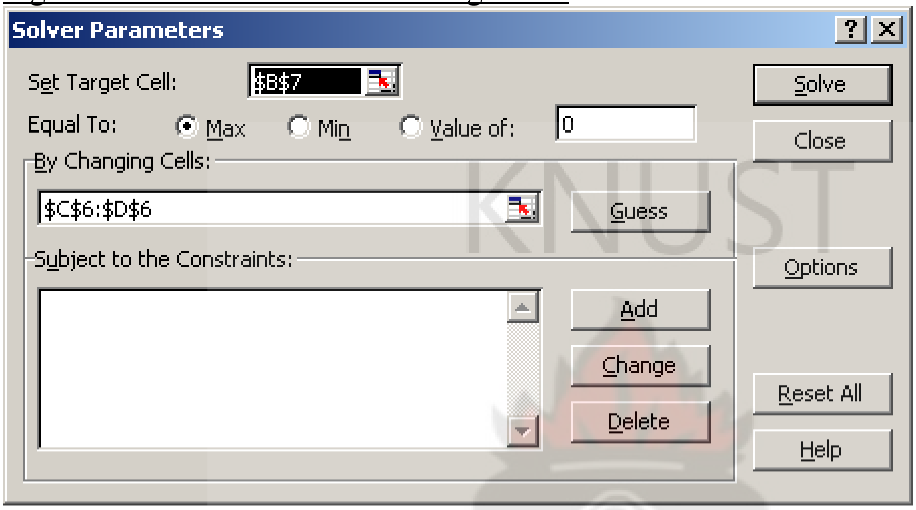
$$\sum_{i=1}^{m} X_{ij} \geq b_j \qquad (i = 1, 2 \ldots, n) \qquad (26)$$

The total shipments of cement to any deficit destination must be sufficient to the total requirement of cement at that region. Negative values did not have any meaning in the type of problem, therefore, it was necessary that all;

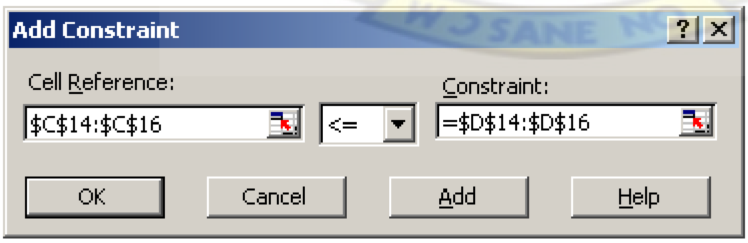
$S_i \geq 0$; $b_j \geq 0$; $X_{ij} \geq 0$ for cement.

Inputs into the Excel worksheet were guided by the objective function and the constraint on the cement requirements and excess available for shipment. The solver Add-Ins was selected and displayed the Solver Parameters dialog box as shown below.

Figure 4.4: Excel Solver 2003 Dialogue box



To incorporate the constraints, the constraint dialog box appeared and was completed. All constraints were also entered together and assigned the appropriate mathematical operator "≤ "or "≥" as shown below. For the purpose of this analysis, the requirement was minimization of Ghacem transportation cost, so min from dialog box window representing minimization was activated.



4.3 Computer Generated Results

Table 4.5: Excel 2003 Generated Results

Microsoft Excel 11.0 Answer Report						
Worksheet: [Transportation Problem.xls]Sheet1						
Report Created: 3/23/2011 3:49:24 PM						
Target Cell (Min)						
	Cell	**Name**	**Original Value**	**Final Value**		
	$U$6	Objective Fun Answer	0	15730320		
		Adjustable Cells				
	Cell	**Name**	**Original Value**	**Final Value**		
	$B$4	Variable value X11	0	0		
	$C$4	Variable value X12	0	51510		
	$D$4	Variable value X13	0	205600		
	$E$4	Variable value X14	0	0		
	$F$4	Variable value X15	0	0		
	$G$4	Variable value X16	0	0		
	$H$4	Variable value X17	0	34220		
	$I$4	Variable value X18	0	0		
	$J$4	Variable value X19	0	461720		
	$K$4	Variable value X21	0	28010		
	$L$4	Variable value X22	0	0		
	$M$4	Variable value X23	0	0		
	$N$4	Variable value X24	0	32820		
	$O$4	Variable value X25	0	376560		
	$P$4	Variable value X26	0	90820		
	$Q$4	Variable value X27	0	2.91038E-11		
	$R$4	Variable value X28	0	8360		
	$S$4	Variable value X29	0	0		
		Constraints				

Table 4.5 Continued

	Cell	Name	Cell Value	Formula	Status	Slack
	$U$7	Subject To Answer	753050	$U$7<=$W$7	Binding	0
	$U$8	Answer	536570	$U$8<=$W$8	Binding	0
	$U$9	Answer	28010	$U$9>=$W$9	Binding	0
	$U$10	Answer	51510	$U$10>=$W$10	Binding	0
	$U$11	Answer	205600	$U$11>=$W$11	Binding	0
	$U$12	Answer	32820	$U$12>=$W$12	Binding	0
	$U$13	Answer	376560	$U$13>=$W$13	Binding	0
	$U$14	Answer	90820	$U$14>=$W$14	Binding	0
	$U$15	Answer	34220	$U$15>=$W$15	Binding	0
	$U$16	Answer	8360	$U$16>=$W$16	Binding	0
	$U$17	Answer	461720	$U$17>=$W$17	Binding	0
	$B$4	Variable value X11	0	$B$4>=0	Binding	0
	$C$4	Variable value X12	51510	$C$4>=0	Not Binding	51510
	$D$4	Variable value X13	205600	$D$4>=0	Not Binding	205600
	$E$4	Variable value X14	0	$E$4>=0	Binding	0
	$F$4	Variable value X15	0	$F$4>=0	Binding	0
	$G$4	Variable value X16	0	$G$4>=0	Binding	0
	$H$4	Variable value X17	34220	$H$4>=0	Not Binding	34220
	$I$4	Variable value X18	0	$I$4>=0	Binding	0
	$J$4	Variable value X19	461720	$J$4>=0	Not Binding	461720
	$K$4	Variable value X21	28010	$K$4>=0	Not Binding	28010
	$L$4	Variable value X22	0	$L$4>=0	Binding	0
	$M$4	Variable value X23	0	$M$4>=0	Binding	0
	$N$4	Variable value X24	32820	$N$4>=0	Not Binding	32820
	$O$4	Variable value X25	376560	$O$4>=0	Not Binding	376560
	$P$4	Variable value X26	90820	$P$4>=0	Not Binding	90820
	$Q$4	Variable value X27	2.91038E-11	$Q$4>=0	Binding	0
	$R$4	Variable value X28	8360	$R$4>=0	Not Binding	8360
	$S$4	Variable value X29	0	$S$4>=0	Binding	0

4.4 Analysis of Results

The optimal solution of transporting cement among the regional distribution centres of Ghacem chain distribution network in Ghana for the model that utilized available inter regional transport rates effective in 2010 resulted in:

(i) A total cost of 15,730,320 Ghana cedis

(ii) A total shipment of 1,289,620 tonnes of cement.

The optimum distribution pattern which minimized the total transportation costs were as follows.

(i) Market 1, a (Cape Coast regional distribution) demand of 28,010 tonnes of cement was to be supplied by Plant 2 at cost of 448,160 Ghana cedis

(ii) Market 2, a (Koforidua Regional distribution) demand of 51,510 tonnes of cement was to be supplied by Plant 1 at a cost of 927,180 Ghana cedis.

(iii) Market 3, a (Accra regional distribution) demand of 205,600 tonnes of cement was to be supplied by Plant 1 at a cost of 2,261,600 Ghana cedis.

(iv) Market 4, a (Sunyani regional distribution) demand of 32,820 tonnes of cement was to be supplied by Plant 2 a cost of 1,115,880 Ghana cedis.

(v) Market 5 a (Takoradi regional distribution) demand of 376,560 tonnes of cement was to be supplied by Plant 2 at a cost of 3,012,480 Ghana cedis.

(vi) Market 6, a (Kumasi regional distribution) demand of 90,820 tonnes of cement was to be supplied by Plant 2 at a cost of 2,542,960 Ghana cedis.

(vii) Market 7, a (Tamale regional distribution) demand of 34,220 tonnes of cement was to be supplied by Plant 1 at a cost of 1,711,100 Ghana cedis.

Market 8, a (Wa regional distribution) demand of 8360 tonnes of cement was to be supplied to be by Plant 2 at a cost of 535,040 Ghana cedis.

Market 9, a (Tema regional distribution) demand of 461,720 tonnes of cement was to be supplied by Plant 1 at a cost of 3,232,040 Ghana cedis.

4.5 Comparison of Results

Currently Ghacem practices the mill price model; where firms choose their locations, price their products and consumers incur the transportation cost to their demand destinations. There is therefore no comprehensive transport cost model for comparison with the derived optimal transport price from this work. However, in addition to the derived optimized transport cost, the Ghacem haulage problem results also produced a pattern of selected routes from different sources (supply) to different destinations (demand) if transportation costs were to be minimized with the goal of helping to reduce the net cost of cement to consumers at distant locations.

CHAPTER FIVE

SUMMARY, CONCLUTIONS AND RECOMMENDATIONS

5.0 Introduction

This chapter provides an overview of the thesis, a summary of the procedures used and limitations of the study. Conclusions drawn from the results are discussed and recommendations for future work are proposed.

5.1 Summary

Cement is a key element of modern construction, from our homes, through to schools, hospitals, offices, roads, harbours, markets, stadia, airports, and others. We also rely on it for building reservoirs for our water and for other vital utilities. However, its production at Ghacem limited takes place only at Tema and Tarkoradi whiles consumption occurs across the breadth and length of Ghana, far and near from the production centres. Transportation therefore plays a major role in the distribution of the product and contributes to a portion of the landed price of cement to the consumer at distant locations.

In this work we have looked at two different pricing schemes; “mill pricing” and “uniform delivery pricing”. The mill pricing was explained as a model in which firms choose location and prices, while the spatially dispersed consumers pay the cost of travelling to the firm to buy the product. The uniform delivery pricing was also explained as model in which firms absorb the transport cost of shipping the item to the consumers. Firms choose locations and prices and transport the product to geographically spread out consumers each of whom pays the same price. Besides the literature on product transport pricing between firms and consumer, the mathematical theory of linear programming for solving transportation problems was also reviewed.

The major objective of this work had been to determine the haulage or shipment of cement between production and distribution centres that will optimize transport pricing using the trucking rate structure of year 2010. A linear programming transportation model was used to analyse the several movements of cement from production centres to regional chain distribution centres in order to achieve the objective.

Ghacem network of chain distribution of cement in Ghana were divide into two (2) originating sources and ten (10) regional destination points for cement distribution. Data on originating sources and destinations points of cement haulage were obtained from Ghacem as discussed earlier. Supply sources and destination demarcation was based on data availability and concentration of cement production and consumption activity from Ghacem Distributors Performance Report, 2010. Ghacem sales centres were designated to represent the destination points while the factories or the plants represented supply source. The selection of the supply source and destination points were made on the basis of the amount of cement supply and consumption activity recorded in year 2010.

For purposes of the analysis, only cement that went through the chain distribution network by truck was considered. This particular Ghacem stock and distribution in Ghana was assumed to be a "closed" system. That is, no exporting or importing of non Ghacem product was allowed between any of the regions in and any area outside the borders of Ghana and production and consumption totals for year 2010 was forced to equal each other.

The determination of each point as a surplus shipping region or a deficit receiving region, and the amount of the regional surplus or deficit, was necessary to provide constraints for the Linear Programming model. For the movement from production to the distribution, the difference between regional production (RP.) and regional consumption (RC) was calculated.

If RP exceeded RC, the region had surplus production which could be shipped to other regions. Conversely, if RC exceeded RP, the region had to fill its deficit of consumption from other producing regions. The calculated surpluses and deficits were used as the regional constraints in the transportation model.

The transportation model utilised the regional shortages and surpluses described above and were applied to each movement of cement being analysed. The available transportation rate in effect in 2010 was obtained from Ghacem and Ghana Private Road Transport Unions at Takoradi and Tema respectively. This analysis has been performed under the assumptions of pure competition. The assumptions include:

(i) a large number of transporters and distributors who are unable to affect the transport price of the commodity through individual actions;

(ii) absolute freedom of entry into and exit from haulage and distribution market;

(iii) excellent mobility of haulage and distribution inputs;

(iv) no outside or artificial restraints on the operation of the haulage and distribution market;

(v) all transporters and distributors have perfect knowledge of haulage market conditions;

(vi) a homogeneous product so that transporters and distributors are indifferent to the source of the commodity.

In reality, these characteristics of pure competition are not completely fulfilled. Entry into the haulage and distribution market is not absolutely free and constrains of no exporting and importing of non Ghacem products between any of the regions of Ghacem product distribution cannot hold. Though cement is a homogeneous product, mobility of its haulage and distribution inputs are far from being excellent and only trucking mode was considered.

Capital requirements in the cement haulage and distribution industry often restrict entry into the enterprise and mobility of resources. Transporters and distributors in the market rarely have complete knowledge of all market situations. However, pure competition conditions serve to simplify a complex analysis such as this one. These conditions also provide a standard sense to the entire analysis, since the linear programming model is standard. Consequently, the results provide an indication of what would happen if conditions of pure competition prevailed and the least-cost shipping routes were followed.

The results were biased by the assumptions of pure competition, but the extent of the bias was not quantifiable. The analysis of the haulage of cement under the rate structure described demonstrated that the total haulage cost for optimal shipments under the 2010 rate was fifteen million, seven hundred and thirty thousand, three hundred and twenty Ghana cedis (GH¢15,730,320) from a total haulage volume of one million, two hundred and eighty nine thousand, six hundred and twenty (1,289,620) tonnes. In addition, the mathematical modelling of the Ghacem haulage problem also produced a pattern of selected routes from different sources (supply) to different destinations (demand) if transportation costs were to be minimized with the goal of helping to reduce the net cost of cement to consumers at distant locations.

5.2 Conclusions

The objective of operationalising the mathematical theory of transportation in linear programming to make it applicable to a specific industry with economic concern of optimising transport pricing of inland freight for cement haulage at Ghacem limited in Ghana has successfully been carried out. Based on the analysis carried out which utilized available data of cement movements from supply sources to destination points among the regional distribution centres of Ghacem and inter regional transport rates effective in 2010, the determined optimal price of transporting one million, two hundred and eighty nine thousand, six hundred and twenty (1,289,620) tonnes of cement through the chain distribution network was fifteen million, seven hundred and thirty thousand, three hundred and twenty Ghana cedis (GH¢15,730,320).

Owing to its current pricing scheme known as the "mill price model"; where firms choose their locations, price their products and consumers incur the transportation cost to their demand destinations, Ghacem does not completely control the physical distribution of the product and therefore has no comprehensive transport cost model for comparison with the derived optimal transport price in this work.

However, one purpose of the theory of optimal pricing using the transportation model is to predict what the optimal price should consist of in terms of cost, making the theory fit for empirical development and practical application as had been carried out in this case. Should the model be adopted by say Ghacem to predict the financial result of an optimal transport price, then a system context is necessary in which the complete design of the transportation system concerned should be assumed to be adaptable.

In addition, it should be assumed that the least-cost design of every transport system is aimed at for top managers to ascertain how many units of a particular product should be transported from each supply origin to each demand destinations so that the total prevailing demand for the company's product is satisfied, while at the same time the total transportation costs are minimized. In the application of the linear programming based transportation model to any of the pricing schemes, whether the mill pricing or delivery pricing mode, there is no more an appropriate basic assumption for the purpose than that efficient factor combination are assigned.

5.3 Recommendations

Although the numerical analysis indicated a total optimal pricing result and also a flow pattern of routes from different sources (supply) to different destinations (demand) if transportation costs were to be minimized, the available data had limitation in the final destination of the cement distribution process. The highest volumes of cement distribution captured in the data for Tema and Takoradi respectively as consumption raises questions on their real consumption capacities compared to Accra and Kumasi which have the biggest markets. These questions may provide an explanation to the effect that the final destination of cement movement by a number of Ghacem distributors is unknown. Structured improvement of effective cement distribution to consumption destinations are therefore important and a prerequisite to obtaining a credible optimal transport pricing.

Though there is no existing data from Ghacem to compare with the results of this work because of the pricing scheme of consumers paying for the price of the product including transportation (where distant customers pay more because of transport cost), numerical analysis from the transportation model is designed to result in significant transport cost savings either to the producer or the customer. Future research can extend the analysis here in many directions of optimizing transport pricing. Considering the possibility of various cement shipment pricing schemes for Ghacem to make choices in the face of competition, the investigation of the following optimal transport pricing schemes could be an appropriate extension.

(i) The optimal transport pricing that Ghacem as a company can settle on as freight from a range of rate structures to deliver the same price for cement regardless of location to all regional distribution centres using the uniform delivery pricing scheme as a competition tool.

(ii) The optimal transport pricing that Ghacem can settle on in a zone pricing scheme under a range of rate structures where customers within a zone pay the same but higher in distant zones as a competition tool.

(iii) The optimal transport pricing that Ghacem as company can settle on under a range of rate structures in a freight absorption scheme where part or all freight charges are absorbed as a competition tool.

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Appendix A

Table of Regional Cement Distributions (RD)

RD1

Code	Index	Tonnes
D020	01	782
D023	02	8,418
D026	03	2,580
Total		**11,780**

RD2

Code	Index	Tonnes
A188	01	10,089
B070	02	730
B085	03	2,987
B142	04	2,557
D088	05	2,743
D102	06	5,679
Total		**28,010**

RD3

Code	Index	Tonnes
D005	01	2,083
D008	02	2,193
D010	03	3,943
D015	04	1,005
D017	05	4,251
A069	06	3,305
A209	07	14,323
A259	08	3,359
D110	09	17,048
Total		**51510**

Appendix A–Continued

RD4

A		
Code	Index	Tonnes
A042	01	6,624
A065	02	7,999
A117	03	20,275
A141	04	4,182
A171	05	11,056
A264	06	149
A121	07	6,491
A084	08	5,833
A260	09	16,883
D109	10	1,702
A185	11	8,086
	Subtotal	89,280
B		
Code	Index	Tonnes
D018	01	2,364
D049	02	3,107
D050	03	7,281
D051	04	4,769
A007	05	5,783
A016	06	12,886
A024	07	7,137
A116	08	11,500
A189	09	12660
A043	10	1,065
	Subtotal	68,552
C		
Code	Index	Tonnes
D053	01	1,173
D057	02	1,384
D058	03	2,487
D060	04	6,252
A081	05	12,294
A102	06	8,278
A193	07	3,737
A253	08	10,190
A268	09	1,973
	Subtotal	47,768
Total		**205,600**

Appendix A–Continued

RD5

Code	Index	Tonnes
D061	01	1,510
D063	02	3,562
D065	03	1,146
D070	04	8,324
B123	05	6,851
A257	06	676
B111	07	1,879
A204	08	753
D106	09	8,120
	Total	**32,820**

RD6

Code	Index	Tonnes
B086	01	6,457
B087	02	9,567
B089	03	9474
B090	04	42,009
B091	05	3,933
B093	06	5,491
B094	07	34,147
B095	08	5,931
B096	09	9827
B097	10	4,852
B098	11	19,210
B099	12	5,243
B100	13	10,061
B101	14	1,704
B102	15	13,639
B103	16	27,872
B104	17	19,767
B105	18	8,691
B106	19	15,813
B107	20	19,321
B108	21	16,658
B109	22	4,733
B113	25	15,052
B114	26	13,782
B115	27	5,516
B135	28	10,612
B136	29	11,899
B138	30	12,507
B139	31	5,642
B140	32	7,150
Total		**376,560**

Appendix A–Continued

RD7

Code	Index	Tonnes
D035	01	707
D041	02	967
D042	03	3,322
D044	04	2,446
D046	05	134
D047	06	543
D103	07	2,252
B046	08	1,547
B072	09	12,022
B084	10	5,335
B092	11	9,339
B124	12	5,114
B137	13	4,376
B149	14	17,327
B187	15	16,920
B189	16	8,469
Total		**90,820**

RD8

Code	Index	Tonnes
D076	01	1,592
D077	02	2,777
D078	03	920
D081	04	5,516
D082	05	1,027
D088	06	718
D091	07	1,378
D093	08	2,837
D105	09	5,675
Total		**22,440**

RD9

Code	Index	Tonnes
D097	01	7,801
D100	02	559
Total		**8360**

Appendix A–Continued

RD10

Code	Index	Tonnes
A021	01	10,476
A023	02	9,027
A047	03	11,157
A062	04	14,144
A089	05	17,507
A128	06	11,562
A143	07	5,538
A172	08	6,075
A207	09	31,058
A261	10	24,841
A263	11	20,626
A195	12	22,308
A015	13	13,604
A017	14	13,115
A108	15	11,171
A067	16	10,129
A100	17	9,402
A071	18	9,389
A103	19	8,237
A163	20	12,822
A162	21	17,346
A161	22	20,340
A025	23	9,939
A027	24	31,058
A029	25	20,841
A030	26	20,626
A032	27	22,308
A034	28	13,604
A079	29	13,110
A080	30	10,171
A082	31	10,189
Total		**461,720**

Table of Regional Cement Production (RP)

Pant/Factory	Index	2010 Cement Production Stock (Tonnes)
RP1	01	753,050
RP2	02	536,570

Source: Ghacem Distributors Performance Report, 2010

Appendix B

Microsoft Excel 11.0 Sensitivity Report							
Worksheet: [Transportation Problem.xls]Sheet1							
Report Created: 3/23/2011 3:53:03 PM							
Adjustable Cells							
			Final	Reduced	Objective	Allowable	Allowable
	Cell	Name	Value	Cost	Coefficient	Increase	Decrease
	$B$4	Variable value X11	0	12	30	1E+30	12
	$C$4	Variable value X12	51510	0	18	24	18
	$D$4	Variable value X13	205600	0	11	25	11
	$E$4	Variable value X14	0	12.00000001	48.00000001	1E+30	12.00000001
	$F$4	Variable value X15	0	30	40	1E+30	30
	$G$4	Variable value X16	5.82077E-11	0	30	1.99999997	1.999999998
	$H$4	Variable value X17	34220	0	50	1.999999999	50
	$I$4	Variable value X18	0	1.99999997	67.99999997	1E+30	1.99999997
	$J$4	Variable value X19	461720	0	7	35	7
	$K$4	Variable value X21	28010	0	16	12	18
	$L$4	Variable value X22	0	24	40	1E+30	24
	$M$4	Variable value X23	0	25	34	1E+30	25
	$N$4	Variable value X24	32820	0	34	12.00000001	36
	$O$4	Variable value X25	376560	0	8	30	9.999999998
	$P$4	Variable value X26	90820	0	28	1.999999998	1.99999997
	$Q$4	Variable value X27	0	1.999999999	50	1E+30	1.999999999
	$R$4	Variable value X28	8360	0	64	1.99999997	66
	$S$4	Variable value X29	0	35	40	1E+30	35
Constraints							
			Final	Shadow	Constraint	Allowable	Allowable
	Cell	Name	Value	Price	R.H. Side	Increase	Decrease
	$U$7	Subject To Answer	753050	0	753050	1E+30	0
	$U$8	Answer	536570	-1.999999998	536570	0	0
	$U$9	Answer	28010	18	28010	0	0
	$U$10	Answer	51510	18	51510	0	51510
	$U$11	Answer	205600	11	205600	0	205600
	$U$12	Answer	32820	36	32820	0	0
	$U$13	Answer	376560	9.999999998	376560	0	0
	$U$14	Answer	90820	30	90820	0	0
	$U$15	Answer	34220	50	34220	0	34220
	$U$16	Answer	8360	66	8360	0	0
	$U$17	Answer	461720	7	461720	0	461720