KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY,

KUMASI

INSTITUTE OF DISTANCE LEARNING

OPTIMUM PRODUCTION SCHEDULE: A CASE STUDY OF ERNEST CHEMISTS LIMITED

By

Bright Agyepong-Mensah - BBA (Banking & Finance)

A Thesis submitted to the Institute of Distance Learning,
Kwame Nkrumah University of Science and Technology
in partial fulfillment of the requirements
for the degree of
COMMONWEALTH EXECUTIVE MASTER OF BUSINESS ADMINISTRATION (CEMBA)

June, 2011

DECLARATION

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

Bright Agyepong-Mensah (PG3029609)

…… …… …….

Student Name & ID Signature Date

Certified by:

Dr. S. K. Amponsah

…… ..…… ……

Supervisor(s) Name Signature Date

Certified by:

Prof. I.K. Dontwi

…… …… …….

Dean, IDL Signature Date

ACKNOWLEDGEMENT

To God be the glory, great things He hath done.

I wish to express my heartfelt gratitude to Dr. S.K. Amponsah, head of Mathematics department, KNUST, Kumasi, for his valuable suggestions, directions and direct supervision of my project work to a successful end.

I am also indebted to my employer, Ernest Chemists Limited, for assisting me with some literature and production figures of the company.

Indeed, I am also grateful to my wife and friend, Doris, for her moral and diverse support to me during these difficult moments.

DEDICATION

This research project is dedicated to my wife and best friend, **Doris**, with love.

ABSTRACT

This study, which was conducted in Ernest Chemists Limited (ECL), presents a production scheduling solution for a manufacturing firm, all in an attempt to cut down manufacturing cost and increase efficiency. The creation of an optimum production schedule requires the modelling of the scheduling problem as a balanced transportation problem. An important result upon the implementation of the model is the allocation of the optimum level of production necessary to meet a given demand at a minimum cost.

The main objective of the study is to develop a quantitative model by which ECL and for that matter, manufacturing firms can meet their demand at a minimum cost. To achieve this objective the study adopted the quantitative approach in this research, by using a quantitative method to model the production problems of ECL as a balanced transportation problem, which can be solved using the simplex pivot method that makes it easy to find the Initial Basic Feasible Solution (IBFS). A balanced transportation problem is where total supply equals total demand. To find the basic feasible solution for the balanced transportation problem, the researcher used the Vogel's Approximation method (VAM), and then improved the IBFS to obtain optimality by using the Modified Distribution Method (MODI). After collecting the necessary data for the study, with an interview guide, the researcher came out with the optimum production schedule for ECL by using the Quantitative Manager for windows statistical software. The research revealed that, the company incurred a regular production cost of GHS 6,095,844.00 and an overtime cost of GHS 3,371,832.00**,** giving a total production cost of GHS 9,467,676.00 for producing 695,311cartons of the Big Joe pain reliever for the year, which were not all demanded within the period under review, without the optimum production model. With the model, the company required 596,695 cartons, at the cost of GHS 7,808,011.00, to meet its demand for the year instead. The researcher, therefore, recommends the usage of the proposed model to the management of Ernest Chemists Limited, to determine the optimum level of production to meet a given demand at a minimum cost.

TABLE OF CONTENTS

CONTENT **PAGE**

LIST OF TABLES

TABLE **PAGE**

CHAPTER ONE

INTRODUCTION

1.1 Background of the study

Production planning is one of the most important activities in manufacturing enterprises. Before the beginning of every financial year, many manufacturing companies prepare a production plan. The production plan gives the quantity of goods to be produced for each period during the financial year as well the demand for each period. The production plan can be executed weekly, monthly, quarterly or even yearly depending on the products of the company. Production scheduling is the allocation of available production resources over time to best satisfy some criteria such as quality, delivery time, demand and supply. An optimum production schedule is the production schedule, which efficiently allocates resources over time to best satisfy some set criteria i.e. the plan which allocates the optimum level of production resources necessary to meet a given demand at a minimum cost (Amponsah et al., 2011).

The production plan involves a set of particular kinds of products to be produced in a particular period of time and the structure of output. The optimal production plan is a dynamic phenomenon and it can only be realized by continuous effort to respond to the market by using available capital and human resources. The result of production planning is the production programme of the company, which includes the production variants for each product. The choice of the optimal production programme and optimal

technological variants is significantly reflected in the company's market position and in the quality of the company's operation.

In general terms, the production planning process involves generating a plan to satisfy customers in a manner that results in a reasonable profit (Lopez and Roubellat, 2008). A production problem includes production scheduling problem, machine capacity planning problem, storage and then freight scheduling problems. In the past two decades, technological advancements, international competitions and market dynamics have brought a major impact to the pharmaceutical industry. Intense competition encourages management to develop new production and supply methodologies in order to remain competitive (Abernathy, 1995). One key issue involves the allocation of scarce production resources over competing demands, which is a typical problem in dealing with many complex man-made systems (Cassandras, 1993).

This study shows how the researcher can optimize the production plan of the firm under investigation by using the Transportation model. The researcher presented the mathematical formulation of the problem and then solved it using the Quantitative Manager (QM) for windows software.

1.1.1 What is scheduling?

Time is the scarcest resource to humans. Scheduling is about making the most of a limited amount of time. Scheduling emerges in various domains, such as nurse scheduling, airplane landing scheduling, train scheduling, production scheduling. This thesis focuses on production scheduling. Production scheduling is an essential part of

the management of production systems: it lies at the very heart of the performance of manufacturing organizations. Effective scheduling can lead to due date performance that results in meeting the company's customer service goals, and reducing work-in-process inventories and production lead times (Vollmann et al., 1988). Hence, in the beginning of this century, the scheduler was seen as a problem anticipator and solver. From then on, scheduling has primarily been subject to research from a mathematical point of view, embodied by the operations research community. Some of the first books on scheduling theory were written by Conway et al. (1967) and Baker (1974). Since then, operations research has produced over 20,000 publications about the scheduling problem (Dessouky et al., 1995). In the operations research community, scheduling is usually defined as "allocating a set of resources to perform a set of tasks."In production systems, this typically concerns allocating a set of machines to perform a set of jobs within a certain time period. The result of scheduling is a schedule, which can be defined as: 'a plan with reference to the sequence of and time allocated for each item or operation necessary to its completion' (Vollmann et al., 1988; p. 536).

1.1.2 Some theoretical concepts to improve production planning and scheduling

Production scheduling has three primary goals or objectives. The first involves due dates and avoiding late completion of jobs. The second goal involves throughput times; the system, from the opening of a job order until it is completed. The third goal concerns the utilization of work centres (Hurtubise et al., 2004). According to Kriepl and Pinedo (2004), planning models differ from scheduling models in a number of ways. First, planning models often cover multiple stages and optimize over medium

term horizon, whereas scheduling models are usually designed for a single stage facility and optimize over a short term horizon. Secondly, planning models uses more aggregate information, whereas scheduling models use more detailed information. Thirdly, the objective to be minimized in a planning model is typically a total cost objective and the unit in which this is measured is a monetary unit; the objective to be minimized in a schedule model is typically a function of the completion times of the jobs and the unit in which this is measured is often output or time unit. Nevertheless even though there are fundamental differences between these two types of models, they often have to be incorporated into a single frame work, share information, and interact extensively with one another.

1.1.3 Different Approaches to Improving Production Scheduling

Because production scheduling activities are common, but complex, there exist many different views and perspectives of production scheduling. Each perspective has a particular scope and its own set of assumptions. Different perspectives lead naturally to different approaches to improving production scheduling. The three important perspectives are: problem-solving, decision making and the organizational perspective (Pinedo and Chao, 1999).

i. Problem-solving: Finding Optimal Schedules

When viewed from the problem-solving perspective, production scheduling is a fascinating puzzle to be solved by moving tasks around a Gantt chart, searching for the optimal solution. MacNiece (1951) gives a beautiful example of using a Gantt chart to

solve a scheduling problem. The problem is to determine if an order for an assembly can be completed in 20 weeks. The Gantt chart has a row for each machine group and bars representing already planned work to which is added the operations needed to complete the order. He argues that using a Gantt chart is a much quicker way to answer the question. More generally, the ability to formulate the problem rigorously and to analyze it to find properties of optimal solutions has attracted a great deal of research effort. In addition to exact techniques, there are a variety of heuristics and search algorithms used to find near-optimal solutions to these problems (Brucker and Peter, 2004). Although, there is a significant gap between scheduling theory and practice, some researchers have improved real-world production scheduling through better problem-solving (Dawande et al., 2004).

ii. Decision-making: Planning for Trouble

Decision-making is a slightly broader perspective on production scheduling. Decision-making is, in general, a process of gathering information, evaluating alternatives, selecting one, and implementing it. Schedulers must perform a variety of tasks and use both formal and informal information to make scheduling decisions. McKay and Wiers (2004) provide an excellent discussion of the decision-making perspective, starting with the tasks that schedulers perform each day. These include: situation assessment: what is where; crisis identification: what needs immediate attention; immediate re-sequencing and task reallocation: reactive decisions; complete scenario update: remapping the future; future problem identification: what problems can be foreseen; constraint relaxation and future problem resolution: discounting future problems, scheduling by

rote: dealing with the rest of the problem. Two important points should be highlighted. First, in this perspective, the production scheduling objective is "to see to it that future troubles are discounted" (Coburn, 1981).

The second point is that there is a place for problem-solving. The scheduling by rote task requires creating a schedule for the work that is not in process, assigning work to resources, and sequencing the operations subject to the constraints that the scheduler imposes to avoid future problems.

iii. The Organizational Perspective: Sharing Information

The organizational perspective, which is the most complete, views production scheduling as a system of decision-makers that transform information about the manufacturing system into a plan -the production schedule (Herrmann, 2004).

The following are among the key decisions in a production scheduling system:

i. releasing jobs for production,
ii. prioritizing jobs that require the same resources,
iii. assigning resources (people, equipment, or production lines) to jobs,
iv. reassigning resources from one job to another,
v. determining when jobs should be started, and
vi. interrupting jobs that should be halted.

The scheduler's tasks describe the activity within that node. The information that the scheduler needs arrives from other nodes, and the schedules that are created go to other nodes in the network.

1.2 Statement of the problem

As stated above, a vast amount of literature about scheduling problems has been produced in the last few decades. Yet, in spite of the vast body of research, and the fact that many practitioners in operations management are convinced of the fact that manual scheduling is to a great extent subject for improvement, the use of scheduling techniques in practice is scarce. For example, Pinedo (1992) states: "In spite of the fact that during this last decade many companies have made large investments in the development as well as in the implementation of scheduling systems, not that many systems appear to be used on a regular basis. Systems, after being implemented, often remain in use for only a limited amount of time; after a while they often are, for one reason or another, ignored altogether" (p. 2151).

This leads to the following initial research questions:

- Why are scheduling techniques often not used in manufacturing practice?
- How can this situation be improved?

In the research presented in this thesis, the use of quantitative method to develop an optimum production schedule to improve on the use of scheduling techniques in manufacturing practice is the focus. This emphasis is triggered by the fact that the idea that human schedulers can be replaced by techniques and information systems is past (e.g., Anthonisse et al., 1988; Ho & Sculli, 1997). Consequently, the reason to study human aspects of production scheduling lies in the fact that human schedulers ultimately determine the success of techniques by deciding whether to use or not to use them.

The above definition of scheduling is used as a guideline for the research to identify possible objects of interest to be studied in practice. However, although the given definition gives adequate support for conducting the research, it is felt that it at most represents the sheer sum of several scheduling theories, and that the underlying principles are somewhat unclear as a result. Apart from answering the research questions, this research might also result in new insights regarding the underlying principles of scheduling.

1.3 Objectives of the study

The major objective of this study was, thus, to establish an efficient production schedule that would allow Ernest Chemists Limited (ECL) to meet future demands at minimum total production cost. To achieve this, the study attempted to achieve the following specific objectives:

i. to identify the major production problem(s) at ECL,
ii. to identify the determinants of production cost of ECL,
iii. to use quantitative model to estimate the minimum production cost of Big Joe pain reliever,
iv. to identify the benefits of knowing the optimum production cost to the management of ECL.

1.4 Research questions

To achieve the above objectives, the study sort answers to the following questions:

i. what production problem(s) exists at ECL?

ii. what factors determine the major production cost of ECL?
iii. is there any way to determine an optimal number of the drug to be produced at an optimal cost?
iv. how important is the optimal production cost to policy makers and implementers at ECL?

1.5 Purpose of the study

A number of studies on production problem have been carried out during the past decades. This context emphasize on production scheduling problem. This will provide access to information about the potential impact of production problems on the cost of manufacturing firms. Discovering potential process problems well in advance of any process can help operators to quickly and effectively take corrective actions. This will help prevent or minimize the effects of production problems. It also gives information on maintenance management, production planning, operations scheduling, logistics and personnel to determine the true economic impact of production problems. Given this background, the need exists to establish a model for allocating the optimum level of production necessary to meet a given demand at a minimum cost. A major contribution of the study is the development of a model for optimizing production, which can be used by both academics and practitioners.

The first and foremost purpose of this study is for the researcher to meet one of the requirements for the degree of Commonwealth Executive Master of Business Administration.

Secondly, it is to serve as a secondary source of information for those interested in pursuing further studies in this area, apart from being an addition to existing knowledge. It will also serve as a benchmark to allow researchers to assess an organization's production problem.

From a practitioner's perspective, the results of the study will provide a production model which when implemented will help managers to produce to meet a given demand at minimum cost. Moreover, a better understanding of the production process problems will allow managers to alter their optimization models and to fully utilize this model to derive its purported benefits. This study will therefore help the management of ECL to determine the levels of production that will be necessary to meet their various forecasted demands at minimum cost.

1.6 Methodology

Many production problems can be modeled as balanced transportation problems, which can easily be solved using simplex pivot methods (Hermann, 2006). Simplex pivots for these problems do not involve multiplication but are reduced to additions and subtractions. For this reasons, it is desirable to formulate a production problem as a balanced transportation problem. This special structure of a balanced transportation problem makes it easy to find the initial basic feasible solution (IBFS). A balanced transportation problem is where total supply equals total demand. An unbalanced transportation problem is where total supply exceeds total demand or total demand exceeds total supply or dummy demands with a unit transportation cost of zero units. To

find the basic feasible solution for a balanced transportation problem, any of the following three methods can be used: the Northwest Corner Rule (NCR), the Least Cost Method (LCM) and the Vogel's Approximation method (VAM) (Dantzig and Wolfe (1951),). The researcher used a mathematical formula to model the production problem of the firm as a balanced transportation problem, then, the Vogel's Approximation Method to come out with the Initial Basic Feasible Solution (IBFS), and finally, obtained optimality, by improving on the basic feasible solution so obtained by using the Modified Distribution Method (MODI).

1.7 Scope of the study

The study primarily focuses on determining a production schedule that will meet all future demands at minimum total cost of a firm that produces only a single product.

To meet the time requirement of the study, the research was restricted to one company - Ernest Chemists Limited's manufacturing plant at Tema. The research covered the production of a single product only- Big Joe pain reliever.

1.8 Organization of the study

The thesis consists of five chapters. The first chapter introduces and reviews the background of the study. In the second chapter, headed, "literature review", relevant literature to this research in terms of concepts and findings, is put forward. Chapter three discusses the methodology and a brief overview of Ernest Chemists Limited. The fourth deals with data collection and analysis. Chapter five which is the last chapter presents the summary, conclusions and recommendations.

CHAPTER TWO

LITERATURE REVIEW

2.0 Introduction

This chapter outlines some pertinent literature on the pharmaceutical industry. The primary focus of this chapter is the recent literature on production problems, major determinants and other conditions affecting production cost in the pharmaceutical industry. Also, the chapter shall review some literature on the modeling of optimal production cost and its benefits.

(Comanor, 1986) reviewed the early literature on industry structure, pricing and effects of regulation, focusing almost exclusively on US regulations governing safety and efficacy in the 1960s and 1970s and related literature.

Scherer (1993) focused on issues related to pricing, profits and technical progress. Material covered in these earlier reviews is briefly reviewed here. The focus here was inevitably on US issues and evidence, given the dominance of US-based literature and firms in this industry. In this study, however, regulatory issues and evidence from other countries are included where possible, especially, Ghana and the West Africa sub-region. The focus on issues raised by regulation and policy is made without apology (Comanor, 1986). Regulation of safety, efficacy and quality fundamentally affect the industry's cost structure and the nature of competition, while regulation of price, reimbursement and promotion affect demand and profitability. By any measure,

regulation has been and remains a critical factor that shapes this industry and must be central to any realistic analysis of the industry.

2.1 Major production problems in the pharmaceutical industry

As the 21st century begins, the pharmaceutical and biotechnology industry has entered an era of explosive growth in innovation, investment and competition. At the same time, both established players and new entrants are facing significant challenges from the weak economy, downward pressure on prices, intense public scrutiny of ethical and business practices, and increasing regulation, Blake (2003). Some of the problem areas resulting from these challenges include the following:

(i)The costs of developing a New Chemical Entity (NCE) have been rising without a corresponding increase in Return on Investment (ROI). At the same time, the downturn in the equity markets has caused investors to focus more on business models and current earnings rather than innovation and the potential for future blockbuster products Brian (2002).

(ii) With a large number of new entrants at the low end of the industry and a trend towards mergers and acquisitions that has led to larger, more integrated firms with broad reach across the industry, there is an increasingly competitive business environment that has created further pressure on companies to quickly build successful product portfolios Steven (2002).

(iii) The need to satisfy the naturally different mindsets and cultural demands that exist between the scientific research and operational areas of a firm results in internal

organizational pressure that can hinder the successful adoption of new technologies and development of new products Stephanie (2002).

The specific reasons for these problem areas are as many and varied as there are firms in the industry, but there are some common themes that can be seen:

(i) Genomics, proteomics and other new information-based biotechnologies have helped make the drug discovery process more efficient, but implementing such technologies can require significant up front and ongoing investment. For example, a large pharmaceutical firm might be expected to spend $100M annually on genomics-related technologies Steven (2002). Despite the promise of these new technologies, true increases in productivity are often not realized. According to a senior IT director from a large pharmaceutical company recently, one reason for this is that much of the "low hanging fruit" has already been identified and picked, so tools such as High Throughput Screening (HTS) are not yielding the same results as they did earlier Kesler (2003).

(ii) New technologies coupled with intense merger and acquisition activity in the industry has led to structural changes in the competitive environment Steven (2002). The seeds planted by genomics and biotechnology have begun to yield a new crop of smaller companies that focus on a few instead of tens to hundreds of simultaneous NCE development projects. These companies tend to be more agile than the industry giants and can exploit their core expertise with a particular disease or therapeutic category. This has caused the industry giants to look at ways in which they can gain some of the advantages of the entrepreneurial environment that exists in these new biotech companies. For instance, GlaxoSmithKline has recently announced that it is re-organizing its R and D units to create six Centers of Excellence in Drug Discovery

that will allow for more flexibility, better allocation of funding, and improved productivity Blake (2003).

(iii) Finally, the effectiveness of new technologies can be hindered unless the company has put serious effort into developing and implementing change management processes throughout their organizations Stephanie (2002). An interview conducted by the author pointed out, that, there are essentially three types of people in a pharmaceutical company: the true research scientists, the sales force, and everyone else Kesler (2003). The first two groups are usually the most demanding in their technology needs, and in fact are often looking for ad hoc solutions that can be quickly built to meet an immediate need. In the case of research scientists in particular, they typically take an experimental approach to problem solving where they discover a problem, ask a question, conduct an experiment, and once there is an answer, move on to a new question that will perhaps require a new set of tools. This contrasts with the traditional approach to building an information system or business process, where the primary goal is to design something that can be re-used for many different types of problems Stephanie (2002).

2.2 Determinants of production cost in the pharmaceutical industry

The pharmaceutical industry incurs tremendous costs in bringing a new drug product to market. These costs generally fall into four areas (Viscusi, et al., 1995):

(i) Research and Development (R & D)

(ii) Pharmaceutical Regulation – (i.e., Food and Drug Board's activities)

(iii) Manufacturing

(iv) Advertising

(i) Research and Development Cost

Research and Development is by far the most costly aspect of drug development. Although R & D costs are extreme, in the US, the federal government offers a number of incentives and assistance programmes to pharmaceutical companies (Viscusi, et al., 1995).

The research-based pharmaceutical industry invests a higher percentage of sales in R&D than most other industries (US CBO, 1994). The R&D/sales ratio for the US research-based industry has increased from 11.9 percent in 1980 to 21.2 percent in 1997 (PhRMA, 1997). However, because of the long lag between R&D and sales, a point-in-time R&D/sales ratio is downward biased as an estimate of the fraction of total costs that is accounted for by R&D. The sales in the denominator pertain to several cohorts of drugs currently on the market, whose R&D occurred many years earlier; conversely, the R&D expenditure in the numerator aggregates the one-year expenditures for several different cohorts that will generate sales over several future decades. To estimate R&D as a fraction of total cost, the stream of costs over the life cycle of a drug, from discovery through launch and sales, must be expressed in discounted present value at a common date. Applying this calculation to the date of launch, R&D accounts for roughly 30 percent of total costs (Danzon, 1997).

The appropriate methodology for measuring the R&D cost per new drug approved was pioneered by Hansen (1979), using company-specific data for a cohort of drugs. DiMasi et al., (1991) extend this approach to estimate R&D costs for drugs introduced from 1980 through 1984. The average successful NCE incurred $73m of preclinical testing expense and $53m during clinical testing, excluding amortization of failures and cost of capital.

(ii) Costs of Pharmaceutical Regulation

An extensive literature has attempted to quantify the social and private costs and benefits of regulatory requirements for proof of efficacy, in particular, the 1962 US Amendments. Most research focused on costs, in particular, the decline in the number of new drug introductions, longer delays for NCEs that ultimately do reach the market, higher input cost and capitalization cost per successful NCE due to larger and longer clinical trials, and shortened period of patent life - all of which coincided with the 1962 Amendments.

Measurement of benefits has been even more elusive, because it requires comparing the actual rate of new drug introductions to the counterfactual rate that would have occurred, had the Amendments not been passed.

Grabowski, Vernon and Thomas (1978) reported that the number of NCEs fell from 233 in the five-year period 1957-1961 to 93 in 1962-1966 and 76 in 1967-1971. Some decline would be consistent with the intent of the legislation, if some of the prior

introductions were ineffective. However, the percentage of total ethical drug sales accounted for by new NCEs declined roughly in proportion to the number of drugs, from 20.0 percent in 1957-1961 to 5.5 percent in 1967-1971. This tends to refute the argument that only the most insignificant drugs were eliminated. Several studies (Baily, 1972; Peltzman, 1973; Wiggins, 1981) have attempted to estimate the contribution of the Amendments to this dramatic decline in new drug introductions.

Bailey (1972) estimates a production function of new drugs and concludes that input costs per NCE increased more than three-fold after 1962. Peltzman estimates a demand pull model to predict new drugs for the post-1962 period based on pre-1962 relationships. The author attributed all the difference between predicted and actual number of NCEs to regulation. However, this is an assumption rather than a tested proposition since he does not explicitly control for other possible contributing factors.

Grabowski, Vernon and Thomas (1978) attempted to identify the marginal contribution of regulation, controlling for other possible contributing factors, including the depletion of new product opportunities; the thalidomide tragedy that may have made manufacturers and physicians more risk averse, hence reduced demand for new drugs; and pharmacological advances that may have raised R&D costs independent of regulation. Their strategy is to compare trends in NCE discoveries in the US relative to the UK, an appropriate comparator country because of its strong and successful research-based pharmaceutical industry. This provides a quasi-natural experiment because the UK did not adopt efficacy requirements until 1971 and its 1963 safety

requirements were statistically unrelated to the flow of new discoveries. Grabowski et al. find that research productivity, defined as number of NCEs per (lagged) R&D expenditure, declined six-fold between 1960-61 and 1966-1970 in the US, compared to a threefold decline in the UK, and that the 1962 US Amendments increased the cost per new NCE by a factor of 2.3. The authors concluded that these differentials are plausibly attributable to regulation, since the UK would have been equally affected by exogenous changes in scientific opportunities and testing norms and by any thalidomide-related change in demand. Using the UK as a benchmark provides a conservative estimate because changes in the US, as the largest single pharmaceutical market, would influence incentives for innovative R&D for all firms, regardless of country of domicile, and hence could have contributed to the decline in discovery rates in the UK. Several studies have examined the role of regulation in increasing delay for drugs that ultimately do reach the market.

Dranove and Meltzer (1994) estimated that the average time from a drug's first worldwide patent application to its approval by the FDA rose from 3.5 years in the 1950s to almost 6 years in the 1960s and 14 years in the mid-1980. Wardell (1973) and Wardell and Lasagna (1975) report that the US lagged behind each major European country in new drug introductions for various new drugs sold in the US in the late 1960s. Comparing the US and Britain for the period 1962-1971, they find that more drugs were launched earlier in Britain than the US. The US had 59 product-years of prior availability compared to 120 in Britain. Of single country drugs, 77 were

exclusive to Britain while 21 were confined to the US. The authors attributed these differences to the increased stringency of FDA regulations.

Other studies provide further support for the hypothesis that the 1962 Amendments delayed the introduction of new drugs into the US. Grabowski and Vernon (1978) compare introduction dates in the US and the UK for drugs discovered in the US between 1960 and 1974. The proportion of drugs introduced first in the US declined significantly between the periods 1960-1962 and 1972-1974, while the proportion introduced later in the US increasing significantly. The authors conclude that increased regulatory scrutiny in the US caused multinational companies to introduce new products abroad before their US launch. Similarly, Grabowski (1980) finds that many more drugs were introduced first in Europe despite most being discovered in US research laboratories or by US-based firms, with the lag increasing over time.

Wiggins (1981) extended the evidence by using differences in average FDA approval times across therapeutic categories. He finds large and significant effects of the 1962 Amendments, particularly on R&D cost per new product introduced, with some additional depressing effect on research expenditures and significant variation across therapeutic categories.

However, in a study of new product introductions between 1956 and 1976, by therapeutic category, he finds that the overall decline is dominated by a few therapeutic

classes for which regulatory stringency appears to be less important than other, non-regulatory factors in the decline in new product introductions.

The cost in foregone consumer welfare from delay or elimination of new drugs remains a current issue for different reasons in different countries. In the US, concern has focused on regulatory delay in approval of promising therapies for life-threatening diseases and other conditions that lack effective alternative therapies, such as AIDS. The economic argument is that the costs of delay are higher; hence the optimal risk-benefit trade-off is different if no alternative therapy exists. Since the mid-1970s the FDA has attempted to accelerate approval of such critical drugs, under pressure from Congress, consumer groups and the pharmaceutical industry. Early studies (by, for example, Wiggins, 1981) concluded that the drug lag for 'important therapeutic advances' was similar to that for all new chemical entities. More recently, Dranove and Meltzer (1994) conclude that, beginning in the 1950s; more important drugs - especially drugs that proved to be successful in the marketplace - have been developed and approved more rapidly than less important drugs. This differential appears to reflect actions of drug companies, as much as regulatory priority setting. Moreover, for their period 1950-1986 the trend towards longer average development and approval times implied that even drugs two standard deviations above the mean level of importance took longer to reach the market. One interesting feature of the Dranove and Meltzer study is the use of a comprehensive set of ex post measures of drug importance, including citations in medical textbooks, in medical journals, and in subsequent patent applications; the extent of worldwide introduction; and US sales. To the extent that

these ex post measures of importance are noisy measures of ex ante forecasts of importance, their estimates of differential delay are understated.

These findings that, since the 1962 Amendments, delay in approval for important drugs has increased less than for more minor drugs, and that firm strategies can significantly influence delay, implies that estimates of the average drug lag due to the 1962 Amendments may overestimate the social costs of the regulation-induced delay. On the other hand, if it is costly for firms to accelerate approval, then the measure of total social costs should include these added expenditures as well as the pure delay-induced costs.

The fact that approval time continued to lengthen through the 1980s and that this is not confined to the US suggests either that, other countries have experienced similar regulatory factors or that other factors such as common clinical factors may play an important role. Recent evidence suggests some convergence. Although Dranove and Meltzer (1994) find that approval times have lengthened in the US, their data indicate some narrowing of the gap between the US and other countries at the end of their period. Schweitzer, Schweitzer and Guellec (1996), using a sample of drugs approved in the US between 1970 and 1988, conclude that there were no significant differences in approval between the US and the G-7 countries, but that Switzerland was consistently quicker. These different findings may reflect differences in time period, methodology or sample. They may also reflect real changes in firms' optimal timing of launch in different countries. In particular, with increasing interdependence between markets, due

to parallel trade and regulatory use of international price comparisons, the incentive of firms is to delay launch in countries with relatively low prices that may become a ceiling for prices in other countries.

(iii) Manufacturing

Actual manufacturing and packaging costs are very small compared to other costs. A prescription that is priced at $50 may only contain 50 cents worth of ingredients. But drug companies stress that efforts to link prices to manufacturing costs are misguided, because of the extreme R&D costs.

Several studies have attempted to estimate the pharmaceutical industry's cost of capital, as a critical input in estimates of the cost and profitability of R&D. The cost of capital determines the interest cost on R&D funds invested and the discounted present value of life-time revenue flows. Using standard finance models such as the capital asset pricing model (CAPM), the conclusion is generally that the pharmaceutical industry is of average risk, with a beta approximately equal to one, a nominal cost of capital of roughly 15 percent or 10 percent in real terms in 1990 (for example, Grabowski and Vernon (1993); Myers and Shyam-Sunder (1996) and references cited therein). Although the industry is often perceived as highly risky because the success of any individual drug candidate is highly uncertain, such risks are readily diversifiable.

However, Myers and Shyam-Sundar (1996) pointed out the sequential nature of investment in R&D amplifies risk. Investing in R&D is equivalent to investing in

compound lotteries and compound call options. Both beta and the opportunity cost of capital are higher for early stage R&D projects than for later stages. By implication, the average cost of capital is higher for smaller companies that have several early-stage projects but no final products, than for large companies that have a diversified portfolio of products at various stages of the life cycle of development and commercialization.

(iv) Advertising cost

In addition to the billions of dollars pharmaceutical companies spend on sales and marketing to physicians, pharmaceutical companies spent an estimated $1.9 billion on direct-to-consumer **(**DTC) advertising in 1999. Prior to the 1990s, DTC advertisements of prescription drugs were severely restricted; prior to 1997, advertising had to be accompanied by all of the fine print that would normally go on a label and package insert. But in August, 1997, the FDA relaxed restrictions on DTC advertising, leading to a boom in television and radio ads (and advertising spending).

In addition to adding directly to pharmaceutical company costs, direct-to-Consumer advertising is a significant reason America's drug spending has increased. Consumers either try a drug where they would have used nothing (such as allergy medicines), or consumers ask for more expensive drugs by name, rather than purchasing a less expensive drug, (Burton, 1998).

The pharmaceutical industry’s large expenditures on advertising and promotion have been controversial in both the economic literature and the policy debate, with concern

over both magnitude and form. Critics question the social value of these large promotional expenditures and charge that they lead to increased market power and higher prices. The alternative view is that promotion provides information to physicians and consumers, which are necessary for the effective use of the products. Considerable research has focused on determining the competitive effect of promotional expenditures in the pharmaceutical industry.

An early proponent of the anti-competitive hypothesis, Walker (1971) argued that large promotion expenditures raise entry barriers and increase market power, by requiring new entrants to make large outlays in order to attract attention to new products. The alternative view is that advertising may enhance competition by facilitating the introduction of new products and new firms. Schwartzman (1975) finds that more innovative firms spend larger sums on promotion. Telser (1975) finds that the extent of new entry into a therapeutic class is positively related to promotional intensity.

However, this positive correlation between research and selling intensity, at the level of either the firm or the therapeutic class, does not prove that the effect of advertising is to enhance competition. Clearly the two may be simultaneously determined and both causally related to such unobservable factors as technological advance and market potential.

Leffler (1981) estimated a model across therapeutic categories with selling effort as the dependent variable and the number of new products introduced as the primary

explanatory variable. The author found a significant positive effect, which was interpreted as suggesting that informative advertising of pharmaceuticals may be substantial. The author also found evidence, however, that advertising of established pharmaceutical products accomplishes 'reminder' and 'habit-formation' purposes by finding significant coefficients on variables which indicate therapeutic categories in which he hypothesizes that the returns from non-informative, repetitive advertising are relatively high. These results suggest that the impact of advertising is multidimensional and that the net effect on competition may differ, depending on the circumstances.

The distinction drawn by Leffler between the 'persuasion' and 'information' roles of pharmaceutical promotion is extended by Hurwitz and Caves (1988) in a study of promotional expenditures for a sample of drugs that went off-patent and their generic competitors. Their interest was in the scope of rent-seeking in manufacturers' promotion outlays. They note that the social costs generated by rent-seeking behavior must be weighed against the efficiency advantages of sellers as suppliers of product information demanded by buyers. Their results indicate that the leader's (the original patent holder) market share increases significantly with its own sales promotion, independent of the amount of goodwill generated before it went off-patent, although these past investments are also important. In addition, the leader's share diminishes with generic outlays. The leader's price premium significantly increases the generics' share of advertising, although the implied sensitivity is small in the short run. They conclude that there are both information and rent-seeking functions of pharmaceutical promotion.

2.3 Conditions affecting the production cost in the pharmaceutical industry

(i) Industry Structure and Productivity: Regulation or Technology?

Government regulation has had a significant impact on industry structure. In the US, the 1938 Federal Food, Drug, and Cosmetic Act restricted the sale of some drugs to prescription, leaving only less potent drugs available for direct over-the-counter (OTC) demand by consumers. The fact that insurance coverage is restricted in many countries to prescription drugs and that physician agency is an issue only for prescription drugs has distinguished the prescription sector from the OTC sector. The 1962 Amendments, enacted to promote safety and efficacy, further differentiated the research-based industry. Several studies have examined the effects of regulation and other factors on industry structure and economies of scale in R&D. Temin (1980) examines the impact of regulatory and technological change on the structure of the US pharmaceutical industry using firm level data from 1948 to 1973.

Major technological advances in the postwar period dramatically increased the number and therapeutic potential of new drugs. Temin finds that the size of drug firms increased dramatically during this period with much of the growth concentrated in large rather than small firms.

Grabowski and Vernon (1976, 1977) suggested that regulation-induced increases in cost and risks of R&D create scale economies that result in the concentration of innovation in large firms. They also hypothesize that this concentration would lead to higher

market shares and higher prices for drugs that do obtain FDA approval, due to the reduction in the number of close competitors. Their empirical findings support the first hypothesis, showing an increasing proportion of innovations concentrated in large firms and increasing concentration ratios of innovational output. However, they find no evidence to support the second hypothesis: concentration of sales in the industry did not increase and competition from generic and non-patented products prevented prices from rising.

The relationship between research productivity and firm size is further examined by Thomas (1990). Despite the decline in the annual number of NCE introductions following the 1962 Amendments, levels of real R&D expenditures rose each year from 1960 to 1980. Thomas shows that the decline in NCE introductions around 1962 was concentrated in the smallest firms, many of which dropped out of innovation. Using productivity trends in the UK as a control to isolate the effects of regulation in the US, Thomas estimates the 'direct effects' of regulation on individual firms and the 'indirect effects' resulting from the asymmetric impact of the regulation on small and large firms. In contrast to Grabowski and Vernon, he concludes that the sales gains due to reduced competition from smaller firms more than offset the reduction in research productivity for large firms.

Thomas (1996) extended the argument that strict safety and efficacy regulation in the US and UK led to a shakeout of smaller, less innovative firms and concentration of innovative effort in larger firms. This, together with relatively free pricing policies, may

have contributed to the preeminence of these two countries in developing innovative products, by forcing the development of the necessary skills. Thomas argues that the much less stringent efficacy regulation in France and Japan has sheltered weak domestic firms and hence contributed to the failure of these countries to develop skills necessary to compete in the global pharmaceutical marketplace. The price regulatory systems in these two countries, which depress prices over the life of a drug, create incentives for firms to focus R&D efforts on a large number of new drugs in order to get frequent price increases, rather than invest in fewer, truly innovative drugs that achieve global penetration (Danzon, 1997).

More recently, the structure of the pharmaceutical industry has been undergoing fundamental change. Horizontal mergers have combined some of the largest firms, ostensibly to further exploit potential economies of scale, scope and risk-pooling. Other large firms have integrated forward into distribution, with the acquisition of pharmacy benefit management companies. The stated rationale for this strategy is to gain access to information and possibly leverage to gain sales advantage. The long-term value of both the horizontal and vertical integration strategies remains to be determined, compared to the alternative of devoting the same resources to R&D. It is also plausible that the optimal strategy is different for different firms, depending on their other assets and capabilities.

At the same time, the biotechnology revolution has dramatically increased the importance of small firms in discovery research and related development of new tools

for enhancing R&D productivity, for example, through rational drug design. In the 1980s a very small number of successful biotech firms developed their functional scope to become fully integrated pharmaceutical companies, similar in structure to the traditional chemical-based firms. However, theory and evidence for the 1990s indicate a higher degree of specialization and mutual dependence between small and large firms. Most small firms now specialize in discovery, relying on large firms for development and marketing expertise where regulatory interactions and economies of scale play a greater role. Conversely, although large firms still have in-house R&D activities, they also draw extensively on discoveries - tools and target compounds - that are in-licensed from smaller firms. The extent and form of alliances between small firms, particularly biotech, and large firms varies, in part reflecting the particular expertise of large firms.

However there is virtually universal recognition that small firms have a key role to play and that most large firms cannot compete effectively in the R&D race without taking advantage of the developments offered by small firms.

An important implication of this mutual dependence is that it is now almost impossible - and perhaps a meaningless task - to attempt to estimate returns to scale in R&D productivity. Since all firms draw on technologies developed by other firms through licensure and other sharing arrangements, any attempt to allocate specific new drugs to specific firms in order to count the number of new drugs per firm is at risk of error because most drug innovation employs inputs developed by several other firms, in addition to the firm that ultimately takes it through the regulatory process.

(ii) Competition and Regulation

The pharmaceutical industry is structurally competitive, with low overall concentration. Although concentration within specific therapeutic categories is greater, the market is contestable in the long run, however, since there are no barriers to entering the process of research and discovery by established or new firms, as evidenced by the large number and high rate of turnover of start-up companies. It is incorrect to infer that entry would take 12 years (the mean time from discovery to approval for new drugs). Competitive entry is initiated long before a promising innovative compound for a new indication or with a new mode action reaches the market. Competitor firms can obtain information on the drug candidates under development by other firms in the industry, from patent filings and regulatory filings with the FDA. The techniques of rational drug design make it increasingly easy for competitors to develop similar but chemically distinct compounds to a promising new compound under development. Thus the pioneer may not necessarily be the first to reach the market and even if it is, follower compounds that are close therapeutic substitutes now enter the market within months. The SSRIs (selective seratonin reuptake inhibitors) and statins (HMG CoAse Reductase inhibitors) illustrate the rapid speed of imitative entry.

2.4 Modelling of optimal production cost

Herrmann (2006) described the history of production scheduling in manufacturing facilities over the last one hundred (100) years. According to the author, understanding the ways that production scheduling has been done is critical to analyzing existing production scheduling systems and finding ways to improve upon them. The author

covered not only the tools used to support decision-making in real-world production scheduling, but also the changes in the production scheduling systems. The author extended the work to the first charts developed by Gannt (1973), to advance scheduling systems that rely on sophisticated algorithms. Through these findings, the author was able to help production schedulers, engineers, and researchers understand the true nature of production scheduling in dynamic manufacturing systems and to encourage them to consider how production scheduling systems can be improved even more. The author did not only review the range of concepts and approaches used to improve production scheduling, but also demonstrated their timeless importance.

Lodree and Norman (2006) summarized research related to scheduling personnel where the objective is to optimize system performance while considering human performance limitations and personnel well-being. Topics such as work rest scheduling, job rotation, cross-training, and task learning and forgetting were considered. For these topics, mathematical models and best practices were described.

Pfund and Scott (2006) discussed scheduling and dispatching in one of the most complex manufacturing environments - wafer fabrication facilities. These facilities represent the most costly and time-consuming portion of the semiconductor manufacturing process. After a brief introduction to wafer fabrication operations, the results of a survey of semiconductor manufacturers that focused on the current state of the practice and future needs were presented. They presented a review of some recent dispatching approaches and an overview of recent deterministic scheduling approaches.

2.5 Benefits of production scheduling to Management

Production scheduling helps manufacturers to create the most optimal schedules, while meeting a number of important priorities, including increased production efficiency, that is, running like-products together to reduce mild changes and clean-out time, process change-over-time reduction, inventory reduction, in that, fewer inventories are needed to fill time sensitive orders when capacity can be accurately predicted, accurate delivery date quotes which creates customer loyalty and satisfaction. Others are: supply chain optimization, material requirements plan (MRP) to ensure that the necessary materials for orders is on hand or ordered on time, reduction in scheduling effort by arranging an optimal schedule per the constraint, labour load leveling to reduce labour spikes and declines by projecting schedule into the future, real time information to view the jobs that are currently running in order to allow customer services to see the capacity available; and identification and reduction in bottlenecks, are some of the benefits of production scheduling.

CHAPTER THREE

METHODOLOGY

3.0 Introduction

This chapter describes a field study in which a quantitative model is used to model the production problem of a manufacturing firm as a balanced transportation problem.

Methodology is about procedures or techniques of investigation, that is, the set of techniques used in one piece of research. This may include procedures such as: research design, area of study, population, sample and sampling technique, instrument for data collection, method of data collection and proposed method of data analysis. It is all about the methods used in the study of the research. Methodology is essential in gathering relevant information, thereby giving effective and reliable representation.

3.1 Research Design

Research design is the plan for the study, which mentions specifically the type of research being undertaking. For the purpose of this course, the researcher decided to conduct an action research. An action research is an applied research in which the researcher applies the concepts, models and knowledge acquired to diagnose a local problem and finding solution to it in a local setting.

It is possible to categorize different research method approaches into two main categories depending on how they are conducted; quantitative research methods and

qualitative research methods. Merriam (1994) stated that, information brought by words is qualitative while information brought by figures is quantitative.

According to Patel and Davidson (1991), quantitative research methods are methods for analyzing numeric information in the form of statistical methods, while qualitative research methods, on the other hand, are methods used for analyzing other information, such as interpretations of text. Though the two methods can be used to analyze data and information gotten from the research, they both have their differences. The main difference between the two research methods is that quantitative research methods transform the information into numbers and amounts, whereas qualitative research methods use the researcher's interpretation of information which cannot or should not be translated into numbers or amounts. The difference between quantitative and qualitative research lies in the procedure involved in investigation. The quantitative technique is an approach which seeks to inquire into an identified problem, based on testing the theory measure with numbers and analyzing the data using statistical techniques. The main objective of the quantitative technique is to find out if a theory can be generalized.

A qualitative research on the other hand is aimed at understanding a social or human problem from multiple perspectives and it is mostly conducted in a natural setting.

In this work, the researcher used statistical techniques to convert the production problem of ECL into transportation problem in order to determine a model for

optimality which could be used by other manufacturing concerns facing similar problems. The researcher therefore adapted the quantitative research approach.

3.2 Sources of data collection

There are generally two sources from which data for research work could be collected. These are primary and secondary sources. Primary sources provide data that have not been worked on by earlier researchers. For example, data collected by the researcher from the field for the first time.

Secondary sources on the other hand provide data that have been used by earlier researchers or writers, like information picked from existing literature or research work. Though there have been earlier works on production schedules, on the specific case of Ernest Chemists Limited, no earlier work exist. For this reason, the researcher collected data from both primary and secondary sources for this study.

3.3 Area of study

The information and data needed for the analysis was collected from the Ernest Chemists Limited's manufacturing plant in Tema. An interview guide was designed to extract information on the company's regular and overtime production capacities, expected customer demands, monthly regular and overtime production costs, inventory at the beginning of the production year 2010 and storage cost, from the Production Manager.

3.4 Population

The population in a research comprises of the entire group of persons or institutions that have the characteristics that are of interest to the researcher. The population in this study is all pharmaceutical companies with manufacturing plants in Ghana. A compilation of pharmacy facilities in Ghana, in good standing; by the information management and research department of the pharmacy council (July, 2008), puts this figure at eleven (11).

3.5 Sample and Sampling Procedure

The sample unit in a research is the portion of the population from whom data for the research is collected. In this work, the researcher used a sample size of 10% of the population of eleven (11). The researcher decided to adopt the non-probabilistic sampling procedure in choosing the sample, instead of the probabilistic, which requires randomization or unbiased. This is because; this is an action research work, which requires the researcher to diagnose a problem in his local setting.

3.6 Method of data collection

In collecting the pertinent data for the research work, the researcher used the purposive sampling method, which allows the researcher to contact the key individuals who can give the required information for the study.

Purposive, also known as judgmental sampling method is a non- randomized sampling method, in which the selection of the sample is based on the subjective judgment of the researcher, that, those selected are the key people who can give the information required

for the study. An interview guide was designed, as a data collection instrument, to extract the required information, from the Production Manager of ECL.

3.7 Method of Data Analysis

The problem of balancing costs of regular and/or overtime production and storage to minimize the total cost of meeting given sales requirements can be set up as a transportation problem. The transportation problem received this name because many of its applications involve determining how to optimally transport goods. However, some of its important applications such as production scheduling actually have nothing to do with transportation.

This chapter is focused on the development of an algorithm for solving the production problems that has been modeled as a balanced transportation problem. Statistical software, QM for windows software, was used to solve and analyse the data collected for the study.

3.8 Modeling the Problem

The production problem involves the manufacturing of a single product, which can either be shipped or stored. The cost of production and the storage cost of each unit of the products are known. Total cost is made of total production cost plus total storage cost. Storage cost is the cost of carrying one unit of inventory for one time period. The storage cost usually includes insurance cost, taxes on inventory, and a cost due to the possibility of spoilage, theft or obsolescence.

3.8.1 Mathematical formulation of the production problem

The underlying assumptions of the mathematical formulation are:

(i) Goods produced cannot be allocated prior to being produced.

(ii) Goods produced in a particular month are allocated to the demand in that month or the months ahead.

The production problem is modeled as a balanced transportation problem as follows:
since production takes place periodically, we consider the time periods in which production takes place as sources $S_1, S_2,\ldots,S_n$ and the time periods in which units will be shipped as destinations $W_1, W_2 ,\ldots,Wm$. The production capacities a_i at source Si are taken to be the supplies in a given period i and the demands at the warehouse W_j is d_j. The problem is to find a production schedule, which will meet all demands at minimum total cost, while satisfying all constraints of production capacity (supply) and demands.

Let c_{ij} be the production cost per unit during the time period i plus the storage cost per unit from the time period i until time j. Let x_{ij} denote the number of units to be produced during time period i from Si for allocation during time period j to W_j then for all i and j, $xij \geq 0$ (since the number of units produced cannot be negative). i = 1,2 ,...., m and j = 1,2 ,..., n.

This is shown on the table 3.1 below:

Table 3.1: Modelling the production problem

	Destination										
Source	W_1		W_2		W_3		. . .	W_m		Supply
S_1	$X_{1,1}$	$C_{1,1}$	$X_{1,2}$	$C_{1,2}$	$X_{1,3}$	$C_{1,3}$	. . .	$X_{1,m}$	$C_{1,m}$	a_1
S_2	$X_{2,1}$	$C_{2,1}$	$X_{2,2}$	$C_{2,2}$	$X_{2,3}$	$C_{2,3}$	. . .	$X_{2,m}$	$C_{2,m}$	a_2
S_3	$X_{3,1}$	$C_{3,1}$	$X_{3,2}$	$C_{3,2}$	$X_{3,3}$	$C_{3,3}$	. . .	$X_{3,m}$	$C_{3,m}$	a_3
.										.
.										.
.										.
S_n	$X_{n,1}$	$C_{n,1}$	$X_{n,2}$	$C_{n,2}$	$X_{n,3}$	$C_{n,3}$	. . .	$X_{,n,m}$	$C_{n,m}$	a_i
Demand	d_1		d_2		d_3		. . . .	d_j		

Source: Amponsah, 2009

For each *i*, the total amount of commodity produced at *Si* is: $\sum_{i-1}^{n} xij$

We shall consider a set of *n* supply points from which a unit of the product is produced. Since supply point S_i can supply at most a_i units in any given period, we have:

$$\sum_{i-1}^{n} x_{ij} \leq a_i, i = 1,2,...n$$

We shall also consider a set of *m* demand points to which the products are allocated. Since demand points W_j must receive d_j units of the shipped products, we have:

$$\sum_{j-1}^{n} x_{ij} \geq d_j, j = 1,2,...m$$

Since units produced cannot be allocated prior to being produced, C_{ij} is prohibitively large for $i>j$ to force the corresponding x_{ij} to be zero or if allocation is impossible between a given source and destinations, a large cost of m is entered.

The total cost of production then is: $\sum_{i-1}^{m}\sum_{j=1}^{n} c_{ij}x_{ij}$

The objective is to determine the amount of allocation from a source to a destination such that the total production costs are minimized.

The model is thus:

Minimize

$$\sum_{i-1}^{m}\sum_{j=1}^{n} c_{ij}x_{ij} \qquad 3.1$$

Subject to:

$$\sum_{j-1}^{n} x_{ij} \le a_i,\ j = 1,2,...n \textit{ (Supply Constraints)} \qquad 3.2$$

$$\sum_{i-1}^{m} x_{ij} \ge d_j,\ i = 1,2,...m \textit{ (Demand Constraints)} \qquad 3.3$$

$X_{ij} \le 0$, i=1, 2,… *m*; j = 1, 2,…, *n* (non-negativity constraints) 3.4

Constraint (3.2) stipulates that the amount of goods transported from each source cannot exceed the available supply.

Constraint (3.3) stipulates that the amount of goods transported to each destination must meet or exceed the required demand.

The non-negativity constraint (3.4) ensures that all goods transported must be non-negative.

e production scheduling model was originally formulated by Hitchcock (1941),but, it was also considered independently by Koopmans (1947).

3.8.2 The modified distribution method (MODI)

The formulation above is solved using a method known as the Modified Distribution Method (MODI). An Initial Basic Feasible Solution (IBFS) is required before the application of the MODI. The IBFS can be obtained by the Northwest corner rule, Vogel's approximation method or the Least cost method. The solution obtained under each of the three methods is not optimal. The Vogel's Approximation Method provides the IBFS which is close to optimal and thus performs better than the Northwest Corner or the Minimum Cost Method (Dantzig and Wolfe,1951).

For this reason, the researcher used the Vogel's Approximation Method in determining the IBFS for this work. The IBFS and the MODI will be implemented by the QM software. MODI aids in obtaining the optimal solution and is established by the following theorem.

(i) Theorem:

The theorem states that if we have a basic feasible solution (B.F.S.) consisting of (m+n–1) independent positive allocations and a set of arbitrary numbers u_i and v_j (j =1, 2,..,n, i = 1,2,..,m) such that $C_{rs} = u_r+v_s$ for all occupied cells (basic variables), then, the evaluation corresponding to each empty cell (non-basic variables) (i, j) is given by:

$c_{ij} = c_{ij} - (u_i + v_j)$.

Once the multipliers u_i and v_j are determined, the relative cost coefficients corresponding to the non-basic variables (unoccupied cells) can be determined easily (Amponsah, 2009).

(ii) Test for optimality:

The following procedure is followed in order to test for optimality:

(i) start with IBFS consisting of (m+n-1) allocations in independent cells.

(ii) determine a set of (m+n-1) numbers, u_i (i = 1,2,…,m) and v_j (j = 1,2,…,n) such that for each occupied cell (r,s) $c_{rs} = u_r + v_s$.

(iii) calculate cell evaluations (unit cost difference), $c_{ij,}$ for each empty cell (i,j) by using the formula: $\bar{c}_{ij} = c_{ij} - (u_i + v_j)$

(iv) examine the matrix of cell evaluation c_{ij} for negative entries and conclude that

(i) if all $\bar{c}_{ij} > 0$ implies Solution is optimal and unique.

(ii) if all $\bar{c}_{ij} \geq 0$ with at least one $\bar{c}_{ij} = 0$ implies Solution is optimal and alternate

(iii) if at least one $\bar{c}_{ij} < 0$ implies Solution is not optimal.

In this study, the researcher used the QM software to obtain both the IBFS and optimality; and to solve the production problem. This follows in the next chapter.

3.9 Profile of Ernest Chemists Limited

Ernest Chemists started business in 1986 as a sole proprietorship and in 1993 became a limited liability. The company is the brainchild of Ernest Bediako Sampong, a pharmacist by profession. As a mere one-shop business in 1986, Ernest Chemists has

grown very rapidly into a large pharmaceutical entity. Ernest Chemists has three business structures; trading, manufacturing and export. The company represents some of the world's leading pharmaceutical brands and operates an extensive network of distribution channels throughout the country. Inventory management is coordinated from a newly built warehouse in Accra. With the goal of establishing itself as a major player in the pharmaceutical industry in Africa, the company in 2001 setup its own manufacturing plant in Tema (Ghana) equipped with modern machinery and equipment. In furtherance of its goals and objectives, a new penicillin plant is under construction to ensure production activities are properly segregated to prevent the incidence of cross contamination. The company's export development programme which came on stream in 2004 with direct export to Cote d'lvoire, Senegal, Burkina Faso and Nigeria to mention but a few, saw the opening of its first foreign subsidiary in Freetown, Sierra Leone in September 2009. On the local scene, the company has thirteen wholesale and pharmacy retails.

3.9.1 Corporate Identity

Mission- Contributing to the healthcare needs of Africa through our determination to provide quality and affordable medicines.

Vision - We will achieve a leadership role in the healthcare business in West Africa and be counted among the ten largest indigenous African pharmaceutical companies by the year 2015.

Values – Ernest Chemists business practices are guided by corporate values based on integrity, customer driven excellence, people centeredness and visionary leadership.

Objectives

- To source products and raw materials from reputable organizations that will help the company offer top quality products at affordable prices
- To engage in continuous improvement of customer service and internal processes
- To make our products more available and accessible to all our targets.
- To be among the ten largest indigenous African pharmaceutical companies by the year 2015.

3.9.2 Products

ECL's manufacturing plants is designed to produce tablets including coated tablets, capsules, oral liquids and suspensions for pediatric use, medicines for external use such as liniments and disinfectants and powders in sachets for oral rehydration therapy. This translates into such class of medicine as analgesics, anti-malarial, anti-helmintics, antacids, disinfectants, and antibiotics and other anti-microbial agents, anti-hypertensive, vitamins and minerals, etc .The company has been granted license by Seven Seas (UK) to bottle its cod liver oil at its plant at Tema.

3.9.3 Divisions

a. Trading

ECL is the largest pharmaceutical trading firm in Ghana with an extensive network of distribution channels nationwide. Ernest Chemists adopts a multi-faceted approach in the distribution of its products with the goal of cutting down lead-time in reaching

customers/consumers.

ECL uses prequalified independent pharmaceutical distributors, retail pharmacies and chemical sellers to augment our warehouses, wholesales and pharmacies in reaching the customer/consumer. Government medical stores, hospitals, clinics and private health facilities are key partners to our business.

ECL's expansion programme is on course with a view to adding new wholesales and pharmacies to the network. ECL's objective is to get closer to the customer, thereby reduce the cost of doing business with us.

b. Manufacturing

ECL's pharmaceutical manufacturing plant is situated in the Heavy Industrial Area of the harbour city of Tema; about twenty minutes drive from Accra. The manufacturing plant is equipped with modern machinery and equipment for pharmaceutical production. All production activities are clearly segregated to avoid the incidence of cross contamination of one product by another.

Environmental control measures have been instituted to ensure that the activities of the company's manufacturing plant do not adversely affect our surroundings. In the same vein, equipment such as air- conditioners, dehumidifiers, dust extractors and a modern water treatment plant have been installed to ensure that external environmental influences that may adversely affect the quality of our products are eliminated. Other facilities installed include a well equipped laboratory for testing in-coming raw

materials, in-process and finished products, a warehouse for the storage of finished products and raw materials and staff canteen.

In total, the plant covers an area of about 3,000 square meters working floor space. On single shift basis, the manufacturing plant has the capacity to produce 400 million tablets, 100 million capsules, 300,000 litres or 3,200,000 bottles of oral liquids (disinfectants, liniments, liquid soap, etc) and 750,000 bottles of suspension in dry powder form for pediatric use per annum. A penicillin plant is currently under construction to ensure that manufacturing activities are segregated to avoid cross-contamination.

c. Export

In line with the company's vision to be counted among the top ten indigenous African pharmaceutical companies, Ernest Chemists has undertaken several business trips to some African countries. ECL has also participated in international trade exhibitions in a number of African countries. With the results achieved so far, we are confident that Ernest Chemists is poised to increase its reach and corporate profile within West Africa and beyond.

Sierra Leone- ECL opened its first foreign subsidiary in Freetown, the capital of Sierra Leone in September 2009. This investment is showing promises.

Nigeria- Ernest Chemists is gaining a foot-hold in the Nigerian market and has completed the registration of some of its brands in the country.

Senegal and Cote D'ivoire- Ernest Chemists participates in the international tendering programmes of these two countries.

There are plans to enter other Africa countries in the near future. In fact, ECL derives fulfillment from its growing capacity to bring quality and affordable medicines to other Africa countries.

3.9.4 Human Resources

The human resource policy of ECL ensures a blend of young and old professionals with a wealth of experience in diverse areas. ECL staff strength has risen from an initial figure of four (4), to over four hundred (400) employees. This is made of pharmacists, chemists, biochemists, engineers, laboratory technologists, marketing and sales personnel, administrators, accountants and other auxiliary personnel.

The company maintains an open door policy that encourages initiative and participatory decision making. Training is a crucial aspect of their manpower development. It is in line with its continuous effort to achieve efficiency and consequently deliver quality goods and services to its customers. The health and safety of ECL staff is of utmost importance to the company. Periodically, employees undergo medical examination and training in Industrial Safety and Good Manufacturing Practices.

3.9.5 Corporate Social Responsibility

Ernest Chemists makes allocation in its annual budget to meet its corporate social responsibility consistently. ECL does its best to satisfy requests that it receives from

society such as schools, health institutions, sports and the general community. ECL's CSR activities include:

(i) supported the Local Organizing Committee in Hosting Africa Hockey Cup of Nations Ghana 2009

(ii) regular sponsor of Pharmaceutical Council Of Ghana programmes

(iii) platinum Sponsor of National Quality Awards 2002

(iv) contributed to Rotary Club of Accra programmes

(v) supports and contributes to Kwahu South District development programmes.

CHAPTER FOUR

DATA PRESENTATION AND ANALYSIS

4.0 Introduction

This chapter is focused on data presentation and analysis, using statistical tables created by the QM software; and the discussion of findings upon the application of the optimal production schedule developed, for the production of a single product of the firm – the Big Joe pain reliever.

4.1 Data collection and analysis

The firm's capacity data (production plan), in cartons, for the financial year 2010 is given in Table 4.1. Inventory at the beginning of January, 2010 is 697,952 cartons. The cost per carton of the product in regular and overtime shifts production are GH¢12.00 and GH¢18.00 respectively, and the unit cost of storage is GH¢9.60 per month.

4.1.1 Scheduling formulation

The formulation takes into account the unit cost of production plus the storage cost C_{ij} (the cost per carton is GH¢12.00), the supply a_i at source Si and the demand d_j at destination Wj, for all i, j = (1, 2,...., 12).

Table 4.1: Capacity Data (cartons)

MONTH	ESTIMATED DEMAND	REGULAR SUPPLY	OVERTIME SUPPLY	TOTAL SUPPLY
January	58163	47870	19637	67507
February	47870	46979	14094	61073
March	52330	29227	12689	41916
April	29227	35735	13540	49275
May	48805	25624	14577	40201
June	25624	24500	35128	59628
July	56867	52158	13391	65549
August	64470	51194	6653	57847
September	51194	57427	18210	75637
October	67811	47295	14189	61484
November	47295	37783	9557	47340
December	47039	52195	15659	67854
TOTAL	596695	507987	187324	695311

Source: Field data, 2011

The problem is:

Minimize

$$\sum_{i=1}^{12}\sum_{j=1}^{12} c_{ij}x_{ij}$$

Subject to:

$\sum_{i=1}^{12} x_{ij} \le a_i, i = 1,2,...,12$ *(Supply Constraints),* and

$\sum_{i=1}^{12} x_{ij} \ge d_j, j = 1,2,...,12$ *(Demand Constraints).*

The objective is to determine the amount of x_{ij} allocated from source *i* to a destination *j* such that the total production cost

$\sum_{i=1}^{12}\sum_{j=1}^{12} c_{ij}x_{ij}$, is minimized.

The solution to the scheduling formulation was then found by using the QM software. The QM implements the MODI to solve the production scheduling formulation.

4.1.2 Using QM to obtain the BFS and the optimal solution

The QM is a windows package, which can be used to obtain the optimal solution to a production scheduling problem. Before using the QM software, the researcher created an initial table. This is given in Table 4.2.

Each cell in Table 4.2 contains the cost per carton of the product plus the storage cost. For example, in cell C2,2 (Jan-reg., Feb) the cost is GH¢12.00 whereas in the second cell C2,3 (Jan-reg., March) the cost is 21.6 (i.e., 12+9.6 = 21.60). A high cost of 10000 is put in cells where production is not feasible. For example in the cell C4,1 (Feb-reg., Jan), the cost is 10000. This is because the company cannot produce in the month of February to meet a demand in January and so a high cost is allocated to that effect.

The IBFS and the optimal solution to the problem are given in Table 4.3 and 4.4 respectively. The IBFS gives the initial allocations of production resources necessary to meet a given demand. Each cell (usually called the occupied cell) contains the respective allocations for each of the periods during the financial year. A cell with no allocation is called an unoccupied cell or an empty cell.

Table 4.2: Initial table the QMS software uses to generate results

Data													
	Jan	Feb	March	April	May	June	July	Aug	Sept.	Oct	Nov	Dec	Supply
Inventory	9.6	10,000	10,000.	10,000.	10,000.	10,000.	10,000.	10,000.	10,000.	10,000.	10,000.	10,000.	697,952
Jan-regular	10,000.	12	21.6	31.2	40.8	50.4	60.	69.6	79.2	88.8	98.4	108.4787	47870
Jan-o/time	18.	10,000	10,000.	10,000.	10,000.	10,000.	10,000.	10,000.	10,000.	10,000.	10,000.	10,000.	19,637
Feb - regular	10,000.	10,000	12.	21.6	31.2	40.8	50.4	60.	69.6	79.2	88.8	89.4	46,979
Feb - overtime	10,000.	18	10,000.	10,000.	10,000.	10,000.	10,000.	10,000.	10,000.	10,000.	10,000.	10,000.	14,094
Mar.- regular	10,000.	10,000	10,000.	12.	21.6	31.2	40.8	50.4	60.	69.6	79.2	88.8	29,227
Mar.- overtime	10,000.	10,000	18.	10,000.	10,000.	10,000.	10,000.	10,000.	10,000.	10,000.	10,000.	10,000.	12,689
April - regular	10,000.	10,000	10,000.	10,000.	12.	21.6	31.2	40.8	50.4	60.	69.6	79.2	35,735
April-overtime	10,000.	10,000	10,000.	18.	10,000.	10,000.	10,000.	10,000.	10,000.	10,000.	10,000.	10,000.	13,540
May - regular	10,000.	10,000	10,000.	10,000.	10,000.	12.	21.6	31.2	40.8	50.4	60.	69.6	25,624
May- overtime	10,000.	10,000	10,000.	10,000.	18.	10,000.	10,000.	10,000.	10,000.	10,000.	10,000.	10,000.	14,577
June - regular	10,000.	10,000	10,000.	10,000.	10,000.	10,000.	12.	21.6	31.2	40.8	50.4	60.	24,500
June- overtime	10,000.	10,000	10,000.	10,000.	10,000.	18.	10,000.	10,000.	10,000.	10,000.	10,000.	10,000.	35,128
July - regular	10,000.	10,000	10,000.	10,000.	10,000.	10,000.	10,000.	12.	21.6	31.2	40.8	50.4	52,158
July - overtime	10,000.	10,000	10,000.	10,000.	10,000.	10,000.	18.	10,000.	10,000.	10,000.	10,000.	10,000.	13,391
Aug.- regular	10,000.	10,000	10,000.	10,000.	10,000.	10,000.	10,000.	10,000.	12.	21.6	31.2	40.8	51,194
Aug- overtime	10,000.	10,000	10,000.	10,000.	10,000.	10,000.	10,000.	18.	10,000.	10,000.	10,000.	10,000.	6,653
Sept. - regular	10,000.	10,000	10,000.	10,000.	10,000.	10,000.	10,000.	10,000.	10,000.	12.	21.6	31.2	57,427
Sept- overtime	10,000.	10,000	10,000.	10,000.	10,000.	10,000.	10,000.	10,000.	18.	10,000.	10,000.	10,000.	18,210
Oct. - regular	10,000.	10,000	10,000.	10,000.	10,000.	10,000.	10,000.	10,000.	10,000.	10,000.	12.	21.6	47,295
Oct.- overtime	10,000.	10,000	10,000.	10,000.	10,000.	10,000.	10,000.	10,000.	10,000.	18.	10,000.	10,000.	14,189
Nov. - regular	10,000.	10,000	10,000.	10,000.	10,000.	10,000.	10,000.	10,000.	10,000.	10,000.	10,000.	12.	37,783
Nov- overtime	10,000.	10,000	10,000.	10,000.	10,000.	10,000.	10,000.	10,000.	10,000.	10,000.	18.	10,000.	9,557
Dec- regular	10,000.	10,000	10,000.	10,000.	10,000.	10,000.	10,000.	10,000.	10,000.	10,000.	10,000.	10,000.	52,195
Dec-overtime	10,000.	10,000	10,000.	10,000.	10,000.	10,000.	10,000.	10,000.	10,000.	10,000.	10,000.	18.	15,659
Demand	58,163.	47,870	52,330.	29,227.	48,805.	25,624.	56,867.	64,470.	51,194.	67,811.	47,295.	47,039.	

Source: QM for Windows

Table 4.3: Basic Feasible Solution (BFS) to the scheduling problem generated by the QM software

PRODUCTION PROBLEM													
Optimal cost = GH¢7,808,011	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept.	Oct	Nov	Dec	Dummy
INVENTORY	58,163.												639,789.
JAN – Regular		47,870.											
JAN -Overtime													19,637.
FEB – Regular			46,979.										
FEB - Overtime		0.											14,094.
MARCH - Regular				29,227.									
MARCH - Overtime			5,351.										7,338.
APRIL - Regular					35,735.								
APRIL - Overtime				0.									13,540.
MAY - Regular						989.	18,976.	5,659.					
MAY - Overtime					13,070.								1,507.
JUNE - Regular							24,500.						
JUNE - Overtime						24,635.							10,493.
JULY - Regular								52,158.					
JULY - Overtime							13,391.						
AUGUST - Regular									51,194				
AUGUST - Overtime								6,653.					
SEPT. - Regular										57,427			
SEPT. - Overtime									0.				18,210.
OCT. - Regular											47,295.		
OCT. - Overtime										10,384			3,805.
NOV. - Regular												37,783.	
NOV- Overtime											0.		9,557.
DEC- Regular													52,195.
DEC-Overtime												9,256.	6,403

Source: QM for Windows

Table 4.4: Optimal solutions to the production scheduling problem generated by the QMS software

	Jan	Feb	March	April	May	June	July	Aug	Sept.	Oct	Nov	Dec	Dummy
Inventory	58,163.	[9982]	[9982]	[9982]	[9982]	[9982]	[9972.4]	[9962.8]	[9982]	[9982]	[9982]	[9982]	639,789.
Jan - Regular	[9996.4]	47,870.	[9.6]	[19.2]	[28.8]	[38.4]	[38.4]	[38.4]	[67.2]	[76.8]	[86.4]	[96.478]	[6]
Jan –O/T	[8.4]	[9982]	[9982]	[9982]	[9982]	[9982]	[9972.4]	[9962.8]	[9982]	[9982]	[9982]	[9982]	19,637.
Feb - Regular	[9996.4]	[9988]	46,979.	[9.6]	[19.2]	[28.8]	[28.8]	[28.8]	[57.6]	[67.2]	[76.8]	[77.4]	[6]
Feb – O/T	[9990.4]	0.	[9982]	[9982]	[9982]	[9982]	[9972.4]	[9962.8]	[9982]	[9982]	[9982]	[9982]	14,094.
March - Regular	[9996.4]	[9988]	[9988]	29,227.	[9.6]	[19.2]	[19.2]	[19.2]	[48]	[57.6]	[67.2]	[76.8]	[6]
March –O/T	[9990.4]	[9982]	5,351.	[9982]	[9982]	[9982]	[9972.4]	[9962.8]	[9982]	[9982]	[9982]	[9982]	7,338.
April - Regular	[9996.4]	[9988]	[9988]	[9988]	35,735.	[9.6]	[9.6]	[9.59999]	[38.4]	[48]	[57.6]	[67.2]	[6]
April – O/T	[9990.4]	[9982]	[9982]	0.	[9982]	[9982]	[9972.4]	[9962.8]	[9982]	[9982]	[9982]	[9982]	13,540.
May - Regular	[9996.4]	[9988]	[9988]	[9988]	[9988]	989.	18,976.	5,659.	[28.8]	[38.4]	[48]	[57.6]	[6]
May – O/T	[9990.4]	[9982]	[9982]	[9982]	13,070.	[9982]	[9972.4]	[9962.8]	[9982]	[9982]	[9982]	[9982]	1,507.
June - Regular	[10006]	[997.6]	[9997.6]	[9997.6]	[9997.6]	[9997.6]	24,500.	[0]	[28.8]	[38.4]	[48]	[57.6]	[15.6]
June – O/T	[9990.4]	[9982]	[9982]	[9982]	[9982]	24,635.	[9972.4]	[9962.8]	[9982]	[9982]	[9982]	[9982]	10,493.
July - Regular	[10015.6]	[10007.2]	[10007.2]	[10007.2]	[10007.2]	[10007.2]	[9997.6]	52,158.	[28.8]	[38.4]	[48]	[57.6]	[25.2]
July – O/T	[10000]	[9991.6]	[9991.6]	[9991.6]	[9991.6]	[9991.6]	13,391.	[9972.4]	[9991.6]	[9991.6]	[9991.6]	[9991.6]	[9.6]
August - Regular	[9996.4]	[9988]	[9988]	[9988]	[9988]	[9988]	[9978.4]	[9968.8]	51,194.	[9.6]	[19.2]	[28.8]	[6]
August – O/T	[10009.6]	[10001.2]	[10001.2]	[10001.2]	[10001.2]	[10001.2]	[9991.6]	6,653.	[0001.2]	[10001.2]	[10001.2]	[10001.2]	[19.2]
Sept. - Regular	[9996.4]	[9988]	[9988]	[9988]	[9988]	[9988]	[9978.4]	[9968.8]	[9988]	57,427.	[9.6]	[19.2]	[6]
Sept. – O/T	[9990.4]	[9982]	[9982]	[9982]	[9982]	[9982]	[9972.4]	[9962.8]	0.	[9982]	[9982]	[9982]	18,210.
Oct. - Regular	[9996.4]	[9988]	[9988]	[9988]	[9988]	[9988]	[9978.4]	[9968.8]	[9988]	[9988]	47,295.	[9.6]	[6]
Oct. – O/T	[9990.4]	[9982]	[9982]	[9982]	[9982]	[9982]	[9972.4]	[9962.8]	[9982]	10,384.	[9982]	[9982]	3,805.
Nov. - Regular	[9996.4]	[9988]	[9988]	[9988]	[9988]	[9988]	[9978.4]	[9968.8]	[9988]	[9988]	[9988]	37,783.	[6]
Nov- O/T	[9990.4]	[9982]	[9982]	[9982]	[9982]	[9982]	[9972.4]	[9962.8]	[9982]	[9982]	0.	[9982]	9,557.
Dec- Regular	[9990.4]	[9982]	[9982]	[9982]	[9982]	[9982]	[9972.4]	[9962.8]	[9982]	[9982]	[9982]	[9982]	52,195.
Dec-O/T	[9990.4]	[9982]	[9982]	[9982]	[9982]	[9982]	[9972.4]	[9962.8]	[9982]	[9982]	[9982]	9,256.	6,403.

Created by QM for Windows

The solution in Table 4.4 is the optimal solution i.e. the Table 4.4 gives the allocations which minimize the total cost of production. This is so because according to the MODI, if all the factors c_{ij} calculated for the empty cells are either negative or zero, then the solution is optimal.

The firm's production plan will have incurred a cost of GH¢9,467,676.00 for producing a total of 695311 i.e. cost per unit of production multiplied by the total goods produced for the whole year (12(507987) +18(187324)).

The overall minimum production cost from January – December 2010 is given by the relation: $\sum_{jan.}^{Dec.,2010}(NxNP)+(OT\times OP)$, Where, N = Normal time rate, NP= Normal time production, OT = Overtime rate, OP = Overtime Production.

The optimal solution gave the final total cost of production as follows:

9.6(58163) + 21.6(18976) + 31.2(5659) + 12(47870 + 46979 + 29227 +35735 +989+ 24500 +52158 + 51194 + 57427 + 47295 + 37783) + 18(5351+ 13070 + 24635 + 13391 + 6653 + 10384 + 9256) = **GH¢7,808,011.20.**

The company, therefore, could have reduced total production cost by GHS 1,659,665.00 (17.53%), going by the above optimal schedule, i.e,

GH¢ 9,467,676.00 - GH¢ 7,808,011.20.

The Optimal solution to the production problem generated by the QM software is summarized in Table 4.5.

The S_i with i = 1, 2,...,12 represents the monthly supplies and the D_j with j = 1, 2,…,12 also represents the monthly demands. From the optimum production schedule above, the allocation S_1 to D_1 means use the production in January, 2010 to meet the demand in

the same month of January and similarly from S_2 to D_2 also means use the production in the month of February to satisfy the demand in February. The allocations continue till the end of the year. Dummy demands are only created to balance the production problem and so all their allocations do not count.

4.2 Discussion of results

The optimum production schedule presented in Table 4.5 gives the amount of the product to be allocated to satisfy consumer demand during each period of the financial year. The allocations have been done with the sole objective of minimizing cost.

The optimal solution gives the allocation that minimizes the total cost of production. On the production schedule, there is an allocation of 58163 cartons from December, 2009 inventory to January, 2010. That is, in order for the company to make profits or minimize cost, it has to allocate 58163 of the goods produced in December, 2009 to meet the demand in the month of January, 2010. This allocation means that 639789 cartons produced and put into inventory in December, 2009 could not have been necessary in meeting the demand in January, 2010. Also in the month of January, 47870 cartons of goods produced in that month were used to satisfy the demand in February. This allocation completely depleted the goods produced in the month of January. The schedule continues to give the various allocations until the financial year comes to an end.

Table 4.5: Summary of the optimum production schedule generated by the QM software

(untitled) Solution				
From: Si	To: Dj	Shipment	Cost per unit	Shipment cost
INVENTORY	JAN	58,163.	9.6	558,364.8
INVENTORY	Dummy	639,789.	0.	0.
JAN - Regular	FEB	47,870.	12.	574,440.
JAN -Overtime	Dummy	19,637.	0.	0.
FEB - Regular	MARCH	46,979.	12.	563,748.
FEB - Overtime	FEB	0.	18.	0.
FEB - Overtime	Dummy	14,094.	0.	0.
MARCH - Regular	APRIL	29,227.	12.	350,724.
MARCH - Overtime	MARCH	5,351.	18.	96,318.
MARCH - Overtime	Dummy	7,338.	0.	0.
APRIL - Regular	MAY	35,735.	12.	428,820.
APRIL - Overtime	APRIL	0.	18.	0.
APRIL - Overtime	Dummy	13,540.	0.	0.
MAY - Regular	JUNE	989.	12.	11,868.
MAY - Regular	JULY	18,976.	21.6	409,881.6
MAY - Regular	AUG	5,659.	31.2	176,560.8
MAY - Overtime	MAY	13,070.	18.	235,260.
MAY - Overtime	Dummy	1,507.	0.	0.
JUNE - Regular	JULY	24,500.	12.	294,000.
JUNE - Overtime	JUNE	24,635.	18.	443,430.
JUNE - Overtime	Dummy	10,493.	0.	0.
JULY - Regular	AUG	52,158.	12.	625,896.
JULY - Overtime	JULY	13,391.	18.	241,038.
AUGUST - Regular	SEPT.	51,194.	12.	614,328.
AUGUST - Overtime	AUG	6,653.	18.	119,754.
SEPT. - Regular	OCT	57,427.	12.	689,124.
SEPT. - Overtime	SEPT.	0.	18.	0.
SEPT. - Overtime	Dummy	18,210.	0.	0.
OCT. - Regular	NOV	47,295.	12.	567,540.
OCT. - Overtime	OCT	10,384.	18.	186,912.
OCT. - Overtime	Dummy	3,805.	0.	0.
NOV. - Regular	DEC	37,783.	12.	453,396.
NOV- Overtime	NOV	0.	18.	0.
NOV- Overtime	Dummy	9,557.	0.	0.
DEC- Regular	Dummy	52,195.	0.	0.
DEC-Overtime	DEC	9,256.	18.	166,608.
DEC-Overtime	Dummy	6,403.	0.	0.

Created by QM for Windows

For a solution to the production problem to exist, the total demand should be equal to the total supply. The total supply according to Table 4.1 is 695311 cartons and the total demand is 596695. Since the total supply is greater than the total demand, a dummy or fictitious demand of 98616 cartons (i.e., 695311 - 596695) is created to balance the production problem with a cost per unit of zero.

The company had a production of 67507 cartons of the product in the month of January and 67854 in the month of December. However, the optimum schedule revealed that the company should produce only 47870 in the month of January and 9256 in the month of December. The allocations in the dummy columns are not taken into consideration.

Since any unused capacity was to be shipped to the dummy demand point, it is clear from the above table that, overtime productions in January, February, April, September and November could not have been necessary to meet the demand for the year.

Again, the production of a huge inventory of 639,789 cartons that was brought forward from the previous year, as well as the overtime production of 7,338 cartons, out of a total of 12,689 produced in March and 1,507, 10,493, 3,805 and 6,403 cartons, out of a total of 14,577, 35,128, 14,189 and 15,659 produced in May, June, October and December respectively, could also not have been necessary in meeting the demand for the year.

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.0 Introduction

Many production managers or production schedulers go through the process of creating optimum production schedules in an intuitive manner. They obtain these schedules using little or no mathematics which provides a more scientific way of obtaining the optimum schedule. The usage of the scheduling mathematical model to optimize a production schedule is important since production schedulers cannot rely on intuition alone.

5.1 Summary

Optimum Production scheduling, the subject of this thesis, is both an essential and intangible part of the organization and coordination of production activities in an organization. Intangible, because the implementation of scheduling techniques in practice is still scarce, despite many efforts from both academia and practitioners. The research described in this thesis attempts to achieve the following objectives:

(i) to identify the major production problem(s) at ECL,

(ii) to identify the determinants of production cost of ECL,

(iii) to use quantitative model to estimate the minimum production cost of Big Joe pain reliever

(iv) to identify the benefits of knowing the optimum production cost to the management of

A survey of the available literature on the role of techniques and humans in the area of production scheduling shows that techniques that originate from the operations research and the artificial intelligence research community suffer from a number of serious drawbacks that have hampered implementation of these techniques in practice.

To set the stage for the body of the research, a descriptive case study was carried out in a pharmaceutical manufacturing company. In this case, a quantitative model was used to study the production problems of the firm and to convert it into a balanced transportation problem that would make it easy to come out with an optimum production schedule which when implemented, could help the firm to meet its demands at minimum costs.

In this study, the researcher used a quantitative method to model the production problems of the case company as a balanced transportation problem and solved it by using the Vogel's Approximation method to determine the Initial Basic Feasible Solution (IBFS) and then improved the IBFS to obtain optimality by using the Modified Distribution Method (MODI).

The final optimum schedule for the firm was arrived at by feeding the Quantitative Manager (QM) for windows software with empirical data collected by the researcher from the firm.

It was observed that most of the firm's production activities for the year under review could not have been necessary to meet its demand for the year.

5.2 Conclusion

The modelling of the production problem as a balanced transportation problem and its specialized methods of solution such as the Northwest corner rule, the Least cost method and the Vogel's approximation method developed by Dantzig and Wolfe (1951), which are modifications of the parent simplex algorithm have proven worthwhile in obtaining the optimum schedule in this study.

The QM was used to solve the scheduling formulation. Ordinarily, the production plan of the firm would have yielded a total production cost of GHS 9, 467,676.00, but the optimal production plan or schedule gave a total production cost of GHS 7,808,011.00, resulting in a reduction in production cost of GHS 1,659,665.00, which translates into a reduction of 17.53% in cost.

This clearly shows that the firm had serious problems with scheduling of its production activities, resulting in high cost of production for the firm.

This finding is important because the decrease of GHS 1, 659,665.00 (i.e. 9, 467,676.00 - 7,808,011.00), in the total cost of production is significant. Furthermore, the optimal solution demonstrated how the reduction will be achieved, that is using demand estimates as production targets and not production capacities, as was observed in this

project work. This was observed to be the major production problem of the case company.

5.3 Recommendation

The application of the model showed how the monthly allocations of resources should be done in order to reduce the cost of production.

It also showed which months the stocks available should be allocated to so that they do not pile up unnecessarily and ultimately reduce the cost of production.

Also, the company is able to produce to meet its entire demand using regular working time period. This means that overtime work should be considered only when demand rises above the regular production capacity.

The researcher, therefore, recommends the use of the model to the Management of Ernest Chemists Limited and all manufacturing firms, to determine their optimum level of production necessary to meet a given demand at a minimum cost.

REFERENCES

Abernathy, F. H. et al, (1995), *Harvard Center for Textile Apparel Research Annual Progress Report.*

Amponsah, S.K., (2009). Lecture Notes, *"Optimization Techniques 1"*. Institute of Distance Learning. Department of Mathematics, Kwame Nkrumah University of Science and Technology, Kumasi.

Amponsah, S. K. et al, (2011), *Research Journal of Applied Sciences, Engineering and Technology* 3(2): 74-80, Available from www.maxwellsci.com/print/rjaset/v3-74-80.pdf. (Accessed: 3/5/2011).

Anthonisse, J.M., Lenstra, J.K., & Savelsbergh, M. (1988). Behind the screen: DSS from an OR point of view. Decision Support Systems, 4, 413ñ419.

Armstrong, Brian M. (2002). *Investors' Ultimatum. Pharmaceutical Executive*. Retrieved March 14, 2011

Baily, Martin N. (1972), 'Research and Development Costs and Returns: The U.S. Pharmaceutical Industry', *80 Journal of Political Economy*, 70-85.

Baker, K.R. (1974). *Introduction to scheduling and sequencing*. New York: Wiley.

Brucker, Peter, *Scheduling Algorithms*, Fourth Edition, 2004, Springer-Verlag, Berlin.

Burton T. M., (1998), "Hard to Swallow--America's Soaring Drug Costs--Bested Interests: Why Generic Drugs Often Can't Compete Against Brand Names--Lower Prices Aren't Enough to Overcome Demand for 'New and Improved,'" *The Wall Street Journal, Nov. 18, 1998, p. A1*.

Cassandras, C. G., (1993), *Discrete Event System: Modeling and Performance Analysis* (Irwin and Aksen Associates).

Coburn, F.G., *"Scheduling: the coordination of effort,"* in Organizing for Production and Other Papers on Management 1912-1924, Mayer, I., Ed., Hive Publishing, pages 149-172, 1981.

Comanor, William S. (1986), 'The Political Economy of the Pharmaceutical Industry', *24 Journal of Economic Literature*, 1178-1217.

Conway, R.N., Maxwell, W.L. & Miller, L.W. (1967). *Theory of scheduling*. Reading, MA: Addison-Wesley.

Dantzig, G.B. and P. Wolfe, (1951). Decomposition principle for linear programming. *J. Oper. Res.*, 8:101-111

Danzon, Patricia M. (1997), Price Regulation in the Pharmaceutical Industry: National vs. Global Interests, Washington, DC, *The American Enterprise Institute Press.*

Dawande, M., 1. Kalagnanam, HS. Lee, C. Reddy, S. Siegel, and M. Trumbo, (2004), "The slab-design problem in the steel industry," Interfaces, Volume 34, "Number 3", pages 215-225.

Dessouky, M.I., Moray, N., & Kijowski, B. (1995). *Strategic behavior and scheduling theory. Human Factors,* 37(3), 443-472.

Devitt, Blake (2003). Executive Prophesies Vision for the Future. *Pharmaceutical Executive*. Retrieved March 14, 2011

DiMasi, Joseph A., Hansen, Ronald W., Grabowski, Henry G. and Lasagna, Louis (1991), 'The Cost of Innovation in the Pharmaceutical Industry', *10 Journal of Health Economics,* 107-142.

Dranove, David and Meltzer, David (1994), 'Do Important Drugs Reach the Market Sooner?' 25 Rand Journal of Economics, 402-423.

Gantt, H.L., (1973). Work, Wages and Profits. Hive Publishing, New York.

Grabowski, Henry G. (1980), *Drug Regulation and Innovation*

Grabowski, Henry G., Vernon, John M. and Thomas, Lacy G., II (1978), 'Estimating the Effects of Regulation on Innovation: An International Comparative Analysis of the Pharmaceutical Industry', *21 Journal of Law and Economics*, 133-163.

Grabowski, Henry G. and Vernon, John M. (1976). 'Structural Effects of Regulation on Innovation in the Ethical Drug Industry', in Masson, R.T. and Qualls, P.D. (eds), Essays on Industrial Organization in Honor of Joe S. Bain, Cambridge, MA, Lippincott, Ballinger 181-205.

Grabowski, Henry G. and Vernon, John M. (1977). 'Consumer Protection Regulation in Ethical Drugs', *67 American Economic Review*, 359-64.

Hansen, Ronald W. (1979), 'The Pharmaceutical Development Process: Estimates of Current Development Costs and Times and the Effects of Regulatory Changes', in Chien, R.I. (ed.), *Issues in Pharmaceutical Economics*, Lexington, MA, Lexington Books. 151-187.

Herrmann, J.W., (2006). A History of Production Scheduling. Chap. 1, Handbook of Production Scheduling, Springer, New York.

Herrmann, J.W., (2004), Information flow and decision-making in production scheduling, 2004 *Industrial Engineering Research Conference*, Houston, Texas, May 15-19, 2004.

Hitchcock, F.L., (1941). The distribution of a product from several sources to numerous localities. *J. Math. Phys*., 20: 224-230.

Ho, J.K.K., & Sculli, D. (1997). The scientific approach to problem solving and decision support systems. *International Journal of Production Economics,* 48(3), 249ñ257.

Hurtubise, Stephanie, and Claude Olivier, and Ali Gharbi. "Planning Tools for Managing the Supply Chain." *Computers & Industrial Engineering 46* (2004): 763–779.

Hurwitz, Mark A. and Caves, Richard E. (1988), 'Persuasion or Information? Promotion and the Shares of Brand Name and Generic Pharmaceuticals', *31 Journal of Law and Economics,* 299-320.

Interview conducted by C. Kesler with a senior IT director (name withheld per company policy) on March 7, 2003.

Koopmans, T.C., (1947). Optimum utilization of the transportation system. *Proceedings of the international statistical conference,* Washington D.C.

Kreipl, Stephan, and Pinedo M., "Planning and Scheduling in Supply Chains: An Overview of Issues in Practice." *Production and Operations Management 13,* no. 1 (2004): 77–92.

Leffler, Keith B. (1981), 'Persuasion or Information? The Economics of Prescription Drug Advertising', *24 Journal of Law and Economics,* 45-74.

Lodree, E. J. Jr. and Norman, B.A., (2006). *"Scheduling Models for Optimizing Human Performance and Well-Being"* in Handbook of Production Scheduling, Springer, New York. Chapter 12. Aurum University and University of Pittsburgh.

Lopez, P., and Roubellat, F., (2008), "*Statement of Production Scheduling".* Chapter 1. LAAS-CNRS, Toulouse, France

MacNiece, E.H., *Production Forecasting, Planning, and Control*, John Wiley & Sons, Inc., New York, 1951

McKay, K. N., and Wiers, V. C.S., Practical Production Control: a Survival Guide for Planners and Schedulers, J. Ross Publishing, Boca Raton, Florida, 2004. Co-published with APICS.

Merriam, S. B. (1994). Learning and life experience. The connection in adulthood. In J. D. Sinnott (Ed.), *Handbook of adult lifespan learning* (pp. 74-89).Westport, CT: Greenwood Publishing Group, Inc.

Myers, Steward C. and Shyam-Sunder, Lakshmi (1996), 'Measuring Pharmaceutical Industry Risk and the Cost of Capital', in Helms, Robert B. (ed.), *Competitive Strategies in the Pharmaceutical Industry,* Washington, DC, The American Enterprise Institute Press, 208-237.

Overby, Stephanie (2002). They Want a New Drug. *CIO*. Retrieved March 14, 2011 fromhttp://www.cio.com/archive/101502/drug.html–(5) Seget, Steven (2002).Ibid.(p. 18).

Patel, R. & Davidson, B. (1991). *research bases. To plan, implement and report of an investigation*. New York: University Pr

Peltzman, Sam (1973), 'An Evaluation of Consumer Protection Legislation: The 1962 Drug Amendments', 8 *Journal of Political Economy,* 1049-1091.

Pfund, M.E. and J.M. Scott, (2006). *Semiconductor Manufacturing Scheduling and Dispatching*. Chap. 9, Handbook of Production Scheduling, Springer, New York.

Pharmaceutical Research and Manufacturers of America (PhRMA) (1997), *1997 Industry Profile,*Washington, DC.

Pinedo, M. (1992). Scheduling. In G. Salvendy (Ed.), *Handbook of Industrial Engineering* (2nd edition) (pp. 2131-2153). Chichester: Wiley-Interscience.

Pinedo, Michael, and Xiuli Chao, *Operations Scheduling with Applications in Manufacturing and Services*, 1999, Irwin McGraw Hill, Boston.

Scherer, Frederic M. (1993), 'Pricing, Profits and Technological Progress in the Pharmaceutical Industry', *7 Journal of Economic Perspectives*, 97-115.

Schwartzman, David (1975), *The Expected Return from Pharmaceutical Research, Washington*, DC, The American Enterprise Institute Press.

Schweitzer, Stuart O., Schweitzer, Maurice E. and Guellec, Marie S. (1996), 'Is There a U.S. Drug Lag? The Timing of New Pharmaceutical Approvals in the G-7 Countries and Switzerland', 53 *Medical Care Research and Review*, 162-178.

Seget, Steven (2002). *Pharmaceutical Innovation: An Analysis of Leading Companies and Strategies*. Reshaping the Value Chain (p. 19). London: DataMonitor, PLC.

Telser, Lester (1975), 'The Theory of Supply with Applications to the Ethical Pharmaceutical Industry', *18 Journal of Law and Economics*, 449-478.

Temin, Peter (1980), *Taking Your Medicine: Drug Regulation in the United States*, Cambridge, MA, Harvard University Press.

Thomas, Lacy Glenn, II (1990), 'Regulation and Firm Size: FDA Impacts on Innovation', *21 RAND Journal of Economics*, 497-517.

Thomas, Lacy Glenn, II (1996), *'Industrial Policy and International Competitiveness in the Pharmaceutical Industry'*, in Robert B. Helms (ed.), *Competitive Strategies in the Pharmaceutical Industry*, Washington, DC, The American Enterprise Institute Press, 107-129.

US Congressional Budget Office (CBO) (1994), *An Analysis of the Administration's Health Proposal*, Washington, DC, Government Printing Office.

Vollmann, T.E., Berry, W.L., & Whybark, D.C. (1988). *Manufacturing planning and control systems.* Homewood, IL: Irwin.

W. Kip Viscusi, et al., *Economics of Regulation and Antitrust*, M.I.T. Press (2nd Ed., 1995), Chapter 24.

Walker, Hugh E. (1971), *Market Power and Price Levels in the Ethical Drug Industry, Bloomington,* University of Indiana Press.

Wardell, William M. (1973), '*Introduction of New Therapeutic Drugs in the United States and Great Britain: An International Comparison'*, 14 Clinical Pharmacology Therapeutics, 773-790.

Wardell, William M. and Lasagna, Louis (1975), *Regulation and Drug Development*, Washington, DC, American Enterprise Institute Press.

Wiggins, Steven N. (1981), 'Product Quality Regulation and New Drug Introductions: Some New Evidence from the 1970s', *63 Review of Economics and Statistics,* 615-619.

APPENDIX

KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY, KUMASI

INSTITUTE OF DISTANCE LEARNING

TOPIC: OPTIMUM PRODUCTION SCHEDULE, CASE STUDY: ERNEST CHEMISTS LIMITED.

INTERVIEW GUIDE FOR INTERVIEWING THE PRODUCTION MANAGER OF ERNEST CHEMISTS LIMITED

This interview guide is designed purposely to assist the researchers carry out an investigation on the above topic. The researchers believe that such research information, which would be treated with the uttermost confidentiality that it deserves, to a large extent will help them come out with recommendations which will be beneficial to the Ernest Chemists Limited, in designing the appropriate production model for the allocation of the optimum level of production necessary to meet a given demand at a minimum cost.

1. Where is your production plant located?
2. Do you have enough workers, working at the plant?
3. How many shifts do you run in a day?
4. Do you produce at full capacity?
5. Are you able to meet all your demand?
6. Do you run overtime shifts?
7. How much does it cost you to produce a carton of your Big joe pain reliever in normal shift?
8. What about in overtime shift?
9. How much does it cost to keep a carton in inventory for a month?

10. What are your expected production capacities for both regular and overtime shifts, for 2010?
11. Is there any opening stock from December, 2009 production for both shifts?
12. How many in each case?
13. What about the actual demand for the same period?
14. Do you usually record surpluses in production?
15. Does it have any effect(s) on your prices?
16. Would you embrace a solution to your production problems (if any), and would management be willing to implement it?