KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY, KUMASI

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OPTIMAL PRODUCTION SCHEDULE: A CASE STUDY OF PIONEER FOOD CANNERY LIMITED

BY

STEPHEN OPOKU (B.ED MATHEMATICS)

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DECLARATION

I hereby declare that this submission is my own work towards the MSc and that, to the best of my knowledge, it contains no material previously published by another person 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.

STEPHEN OPOKU (PG6323411)		
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Student Name & ID	Signature	Date

Certify by:

PROF. S. K AMPONSAH		
--	-------------------------	--------------------
Supervisor(s) Name	Signature	Date

Certified by:

PROF. S. K. AMPONSAH		
--	-------------------------	--------------------
Head of Dept. Name	Signature	Date

Certified by:

PROF. I. K DONTWI		
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Dean, IDL	Signature	Date

ABSTRACT

Production scheduling is a decision-making process that is used in manufacturing and service industries to achieve efficiency and minimize production cost. This study presents a production scheduling problem and its optimal solution for Pioneer Food Cannery, a manufacturing firm based in Tema, Ghana. The objective of the study is to determine the quantity of goods to produce in a given time period that will minimize total production cost of the company. A capacity data for one financial year was collected from the company for the study. The production problem was modeled as a transportation problem and the QM software for windows was used to solve the problem to optimality. The results showed that the firm could have reduced the production cost for the year under review and still meets its demands. It is recommended to the management of Pioneer Food Cannery Limited to use the model to determine its optimum level of production necessary to meet a given demand at a minimum cost.

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DEDICATION

This work is dedicated to my wife Ms Grace Abbam and my daughter Juliet Opoku Amankwah for the love and support they gave during the writing of this thesis.

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CHAPTER ONE

INTRODUCTION

1.0 Introduction

The main objective of every production company is to make profit to keep the company running. A number of factors should be considered to realize this objective. These include satisfaction of customer demands, timely delivery of goods and services among others. To achieve these, the company should have at its disposal technological expertise and competent management to bring on board the current trend of managerial skills and the needed technology. It is advisable for a company to prepare a production plan based on scientific methods to give a clear direction as to how the production process should be carried out. These are all deliberate attempts to minimize production cost and maximize profit for the company.

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 as 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 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 freight scheduling problems. In the past two decades, technological advancements, international competitions and market dynamics have brought a major impact to the manufacturing 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).

According to Kreipl 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 measured is often or time unit. 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.

The difference between industrial planning and industrial scheduling can be viewed in terms of resolution. While the industrial planning deals with the task of finding plans for longer period of time where activities are assigned to departments etc., the industrial scheduling deals with the task of finding detailed schedules for individual machine for shorter period of time. From this point of view, scheduling can be seen as a "high resolution short term planning". (Bartak, 1999).

Production scheduling and Control entail the acquisition and allocation of limited resources to production activities so as to satisfy customer demands over a specified time frame. As such, planning and control problems are inherently optimization problems, where the objective is to develop a schedule or plan that meets demand at minimum cost or that fills the demand that maximizes profit subject to constraints.

Production scheduling and planning may be defined as the technique of foreseeing every step in a long series of separate operations; each step to be taken at the right time and in the right place and each operation is to be performed in maximum efficiency. It helps entrepreneurs to work out the quantity of material, manpower, machine and money required for pre-determined level of output in a given period of time. With the current global markets and global competition, pressures are placed on manufacturing organizations to compress order fulfillment times, meet delivery commitments consistently and also maintain efficiency in operations to address cost issues (McCarthy, 2006). It is in respect of this that many manufacturing facilities find it expedient to generate and update production schedules, which are plans that state when certain controllable activities (example, processing jobs by resources) should take place. In manufacturing systems with a wide variety of products, processes and production levels, production schedules can enable better coordination to increase productivity and minimize operating costs.

A production schedule can identify resource conflicts, control the release of jobs to the shop, and ensure that required raw materials are ordered in time. A production schedule can determine whether delivery promises can be met and identify time periods available for preventive maintenance. A production schedule gives shop floor personnel an explicit statement of what should be done so that supervisors and managers can measure their performance. In practice, production scheduling has become part of the complex flow of information and decision-making that forms the manufacturing planning and control system. This decision-making system enhances production scheduling (Herrmann, 2006).

Wight (1984) identified priority and capacity as the two key problems in production scheduling. In other words, what should be done first? and who should do it?. He defined scheduling as establishing the timing for performing a task and observes that in manufacturing firms, there are multiple types of scheduling, including the detailed scheduling of a shop order that shows when each operation must start and complete. (Cox et al., 1992) defined detailed scheduling as the actual assignment of starting and / or completion dates to operations or groups of operations to show when these must be done if the manufacturing order is to be completed on time. They note that this is also known as operation scheduling, order scheduling and shop scheduling.

Scheduling is an important tool for manufacturing and engineering, where it can have a major impact on the productivity of a process. In manufacturing, the purpose of scheduling is to minimize the production time and costs, by telling a production facility what ton to make, when, with which staff, and on which equipment. Thus, the production scheduling aims to maximize the efficiency of the operation and reduce costs.

1.1.1 Factors of Production

We cannot discuss production without taking into consideration the factors that affect production. Factors of production are the inputs or resources that are used in the production process. Factors of production are grouped into six categories. These are Raw materials, Machinery, Labour services, Capital, Land and Entrepreneur. For the purpose the study, we shall discuss the three main factors of production which are land, capital and labour.

Land

Daly (1997) defined land as everything in the universe that is not created by human beings. It includes more than the mere surface of the earth. Air, sunlight, forests, earth, water and minerals are all classified as land. This is to say that land comprises all naturally occurring resources. This underpins the fact that land is a passive factor of production. Labour uses capital on land to produce wealth.

Land is not created by mankind but it is a gift of nature. So, it is called as natural factor of production. It is also called as original or primary factor of production. Normally, land means surface of earth. But in economics, land has a wider meaning. Land includes earth's surface and resources above and below the surface of the earth. It includes the following natural resources:-

(i) On the surface (e.g. soil, agricultural land, etc.)

(ii) Below the surface (e.g. mineral resources, rocks, ground water, etc.)

(iii) Above the surface (e.g. climate, rain, space monitoring, etc.)

Though all factors are required for production, land puts foundation for production process. Starting point of production process is an acquisition of land. So, it is a primary factor (kalyan-city.com, 2011).

Labour

In order to satisfy our needs and desires, human beings must do something with the natural resources; they must exert themselves to transforming the natural recourses to products of value and this human exertion in production is called labour. Labour refers to the human energy and mental skills used to produce economic goods. It is the generic name given to all the various productive services provided by human beings, including physical effort, skills, intellectual abilities and applied knowledge. In economics, labour is a measure of the work done by human beings (Wikipedia, 2011).

Labour is an ability to work. Labour is a broad concept because it includes both physical and mental labour. Labour is a primary or human factor of production. It indicates human resource. Labour cannot be stored. Once the labour is lost, it cannot be made up. Unemployed workers cannot store their labour for future employment. It is easy to calculate production cost of a commodity produced in an industry. But cost of producing a labour is a vague concept because it includes expenses incurred by parents on education of their children and other expenses incurred on them right from their birth date. It is impossible to estimate all such costs accurately. Other factors like land and capital are passive, but labour is an active factor of production. Being a human being, this factor has its own feelings, likes and dislikes, thinking power, etc. We can achieve better quality and level of production, if land and capital are employed properly in close association with Labour. So without labour, we cannot imagine the smooth conduct of production (kalyan-city.com, 2011).

Capital

To an economist, capital has several meanings - including the finance raised to operate a business. But normally the term capital means investment in goods that can produce other goods in the future. Capital refers to the machines, roads, factories, schools and office blocks which human beings have produced in order to produce other goods and services. A modern industrialized economy possesses a large amount of capital, and it is continually increasing. Increases to the capital stock of a nation are called investment (tutor2u.com, 2011).

Normally, capital means investment of money in business. But in economics money becomes capital only when it is used to purchase real capital goods like plant, machinery, etc. When money is used to purchase capital goods, it becomes Money Capital. But money in the hands of consumers to buy consumer goods or money hoarded doesn't constitute capital. Money by itself is not a factor of production, but when it acquires stock of real capital goods, it becomes a factor of production. Capital generates income. So, capital is a source and income is a result. E.g. refrigerator is a capital for an ice-cream parlour owner. But profits which he gets out of his business is his income. Capital helps in increasing level of productivity and speed of production (kalyan-city.com, 2011).

1.1.2 Problems Facing the Manufacturing Industry in Ghana

The manufacturing sector in Ghana contributes significantly to the development of the country. Notwithstanding its contributions, it is plague by the following constraints:

(i) **High cost of raw materials**: the upward surge of fuel prices in the country as a result of high global prices has significantly influenced the cost of production. Raw materials used are often imported and therefore any increment in fuel prices affects the transportation cost. Consequently, the cost of importing raw materials increases thus cost of production goes high causing the price of the finished product to go high as well. Manufacturers in the importing countries will end up producing at a low unit cost whereby enjoying a better competitive advantage in pricing.

(ii) **Power fluctuations**: Though Ghana is blessed with the Akosombo Hydroelectric Plant, power supplies in Ghana are not so dependable. When even there is a sudden cut in power supply, manufacturers have two options:-

- ✓ To use a generator; this consumes a lot of fuel making production costly
- ✓ Holding off all work while the day goes waste.

An investment towards the development of other alternative sources of power such as Solar and Biogas is very expensive and this serves as a deterrent to most manufacturing companies in the country.

(iii) **Labour Intensive**: The dilemma facing most manufacturing firms in Ghana today is choosing either capital intensive or labour intensive approach towards production. Firms who adopt the capital intensive approach tend to employ less manual workers but as a result would have to pay a high initial cost of purchase of machinery and installation. This, most manufacturing firms find it difficult doing. On the other hand, most companies are unable to buy heavy equipment and therefore prefer a more labour intensive approach, eventually, increasing the labour cost. Labour can be classified as either skilled or unskilled. Most firms take advantage of the unskilled since it is "cheap" source of labour. However, training for unskilled at a time of upgrade in technical know-how becomes a problem due to the cost involved.

(iv) **High taxes**: Since the setting of more industries can lighten unemployment issues in the country, government can give tax rebate to manufacturers to help the manufacturing firms make enough profit to employ more labour. It is unfortunate that many manufacturers complain of high taxes. Some pay taxes right from the harbour through the toll booth along the high ways to the daily, monthly and yearly collection of taxes and unaccounted royalties. Businesses pay value added taxes as well as unaccountable bribes to keep their businesses going and growing.

(v) **Availability of credit:** Big firms have the collaterals that the established banks may need to give them credit unlike the small firms. These inequalities affect the growth of the upcoming firms. More microfinance companies should come into the system so that the small firms can have access to credit facilities.

(vi) **Exchange rates:** According to Canales-Kriljenko (2003), exchange rate expectations are particularly important for the monetary policy decisions in emerging market economies (EMEs). The exchange rate has been a policy tool in EMEs to various degrees due to, for instance, relatively large exchange rate pass-through to domestic inflation or currency mismatches. With high inflation rate importers have to buy few foreign currencies with a lot of the Ghana-cedis, aggravating the inflationary situation. This result in high selling price on goods sold. Exchange rate should be pegged so that the economy can be fixed for a long time.

1.2 Statement of the problem

In an attempt to meet demands of customers, especially in a competitive market, companies try to put in place the necessary conditions to meet deadlines in order to be efficient. To achieve this objective, proper planning and scheduling cannot be underestimated. Planning and scheduling are decision-making processes that are used on a regular basis in many manufacturing and service industries. These forms of decision-making play an important role in procurement and production, in transportation and distribution, and in information processing and communication. The planning and scheduling functions in a company rely on mathematical techniques to allocate limited resources to the activities that have to be done. This allocation of resources has to be done in such a way that the company optimizes its objectives and achieves its goals.

Production problems involve a single product, which is to be manufactured, and units of the product can be either shipped or stored. Both production costs and storage costs are known. The objective is to determine a production schedule which will meet all future demands at minimum total cost. The scheduling process interacts with the production planning process, which handles medium - term to long - term planning for the entire organization. This process intends to optimize the firm's overall product mix and long-term resource allocation based on inventory levels, demand forecasts and resource requirements.

Within the manufacturing set up, the challenge exist where production managers are unable to meet customers' orders or demand on time. Unfortunately, many manufacturers have ineffective production scheduling systems. They produce goods and ship them to their customers, but they use a broken collection of independent plans that are frequently ignored, periodic meetings where unreliable information is shared, expediters who run from one crisis to another, and ad-hoc decisions made by persons who cannot see the entire system. Production scheduling systems rely on human decision makers, and many of them need help dealing with the swampy complexities of real-world scheduling (McKay and Wiers, 2004).

1.3 Objective of the study

The study seeks to establish an efficient production schedule that will minimize total production cost of a manufacturing firm based in Tema. The main objective of the study is to determine the quantity of goods to produce in a given time period.

1.4 Justification of the study

This study looks into the optimum production of goods at minimum cost. It seeks to address the issue of efficiency in the production sector. The outcome of the study will advise firms on when to produce and when not to. The work will reveal the market demand of the product and the capacity of the firm to meet that demand.

1.5 Methodology

Production problems may be converted into transportation problems by considering the time periods during which production can take place as sources, and time periods in which units will be shipped as destinations. In view of that, the transportation model was used for the study. A transportation problem is the problem of finding the minimum - cost distribution of a given commodity from a group of supply centers (sources) $i=1,\ldots,m$ to a group of receiving centers (destinations) $j=1,\ldots,n$. Each source has a certain supply (s_i) and each destination has a certain demand (d_j). The cost of shipping from a source to a destination is directly proportional to the number of units shipped. When total supply equals total demand, we have a balanced transportation problem.

$$\sum_{i=1}^{m} s_i = \sum_{j=1}^{n} d_j$$

When total supply exceeds total demand or vice-versa, we have an unbalanced transportation problem.

$$\sum_{i=1}^{m} s_i > \sum_{j=1}^{n} d_j$$

or

$$\sum_{i=1}^{m} s_i < \sum_{j=1}^{n} d_j$$

The production problem is basically the optimization of output subject to cost minimization. Annual production capacity of the company will be used as data for the study. Solutions to the problem shall be found by using the QMS software, a windows package.

1.6 Scope of the study

The study 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 – Pioneer Food Cannery limited in Tema. The study focuses on the production of one product only – Petit Navire.

1.7 Limitations of the study

The main limitation of the study was the unwillingness of the company to disclose full details of its production capacities and costs.

1.8 Organization of the study

The study consists of five chapters. Chapter one considered the background, statement of the problem and the objectives of the study. The justification, methodology, scope and limitations of the study were also put forward. In chapter two, we shall put forward adequate and relevant literature on production and transportation problem. Chapter three presents the research methodology of the study. Chapter four will focus on data collection and analysis. Chapter five, which is the last chapter of the study presents the summary, conclusions and recommendations of the study.

1.9 Summary

In this chapter, we looked at production and the factors that are needed for production. We also looked at an overview of the problems facing the manufacturing industries in Ghana and how to solve some of these problems. The next chapter reveals literature on production management and transportation problem.

CHAPTER TWO

LITERATURE REVIEW

2.0 Introduction

This chapter reviews literature related to this study. This was done with the expectation that relevant information would be obtained to help shape and enrich the study. Knowledge of what has been done on this topic is important in helping to clarify issues.

2.1 Canning: A Brief History

Canning dates back to the early 19th century. During the first years of the Napoleonic Wars, the French government offered a hefty cash award of 12,000 francs to any inventor who could devise a cheap and effective method of preserving large amounts of food. In 1809, a French confectioner and brewer, Nicolas Appert, observed that food cooked inside a jar did not spoil unless the seals leaked, and developed a method of sealing food in glass jars (Barbier, 1994). Thus, the inception of canning process was born. Following the end of the Napoleonic Wars, the canning process was gradually employed in other European countries and in the US.

Increasing mechanization of the canning process, coupled with a huge increase in urban populations across Europe, resulted in a rising demand for canned food. A number of inventions and improvements followed, and by the 1860s smaller machine-made steel cans were possible, and the time to cook food in sealed cans had been reduced from around six hours to thirty minutes (Fellows, 1999). Thus the canning industry had emerged and therefore issues of production and management were inevitable.

2.2 Production Scheduling

The objective of production scheduling is to arrive at the framework of manufacturing operations during the period planned. This framework should be designed to meet company goals filling customer requirements with minimum total cost. An aggregate scheduling is a valuable procedure that will determine the work force levels, overtime, and inventory levels with the objective of minimizing cost. Many aggregate strategic plans are available such as manipulation of inventory, production rate, subcontracting and hiring and overtime (Mouli et al., 2006).

Herrmann (2006) described the history of production scheduling in manufacturing facilities over the last one hundred (100) years. According to him, understanding the ways that production scheduling has been done is critical to analyzing existing production scheduling systems and finding ways to improve upon them. He covered not only the tools used to support decision-making in real-world production scheduling, but also the changes in the production scheduling systems. He extended the work to the first charts developed by Gannt (1973) to advance scheduling systems that rely on sophisticated algorithms. Through his findings, he 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.

Leandro et al., (2012) see production scheduling as a difficult task especially in a complex environment where capacity is usually limited. The authors presented and analyzed the development of a shop-floor scheduling system that uses Ant Colony Optimization (ACO) in a backward scheduling problem in a manufacturing scenario with single-stage processing, parallel resources, and flexible routings. They concluded that ACO is as efficient as branch-and-bound, however ACO executes faster.

Ben-Ewuah et al., (2012) conducted a study on oil sands mining and its relationship with waste disposal planning. They developed, implemented, and verified a theoretical optimization framework based on Mixed Integer Linear Goal Programming (MILGP) to address the problem. Their study presented an integration of mixed integer linear programming and goal programming in solving large scale mine planning optimization problems using clustering and pushback techniques. The authors found out that the MILGP model generated a smooth and uniform mining schedule that generates value and provides a robust framework for effective waste disposal planning. The results showed that mining progresses with an ore to waste ratio of 1:1.5 throughout the mine life, generating an overall net present value of $14,237M.

Lodree and Norman (2006) conducted a research relating to personnel scheduling, where the objective was to optimize system performance while considering human performance limitations and personnel well-being. They stated that the overall performance of a system was often directly related to how system personnel were scheduled. According to them, personnel are critical components of many systems. Properly considering human capability and the manmachine interface was essential in order to maximize system effectiveness. Topics such as work test scheduling, job rotation, cross training, and task learning and forgetting were considered.

In their attempt to improve production planning practice, Portougal and Robb (2000) identified four-factor classification of planning environments (planning level, production type, production strategy, and production cycle time). They put forward that scheduling theory is relevant but not in all settings. Based on extensive consulting experience in Australasia, they called for caution in applying scheduling theory. They suggested that while complex models are pertinent in some cases, more benefit often arises from establishing appropriate performance measures, planning periods, capacity negotiation processes, and uncertainty reduction measures.

Napaporn and Aussadavut (2012) conducted a research to find the minimum overall cost comprising of production setup cost, inventory holding cost, transportation cost and reorder cost. They developed the mixed integer linear programming model for an integrated decision of production, inventory and transportation planning problem. Their model was solved to optimality using CPLEX. Their results showed that the firm could generate the cost saving of 28.93% and reduce the number of trucks used approximately 49.88% by incorporating the direct shipment. They, however, observed that CPLEX takes large computation time, more than 10,000 seconds in many large size problems, to solve the problem optimally. They therefore suggested that in future research, a time-partitioning heuristic algorithm is used to efficiently solve the problem.

Hui and Lau (2003) proposed a model based on the minimization of inventory costs for small scale organizations. Their model was an interactive one characterized by its ability to cope with continuous changes in production and demand conditions. The model was built on the foundation of the Wagner-Whitin algorithm, and has incorporated factors of safety stock, economic batch quantity, production capacity and past forecast accuracy in inventory and production scheduling. The concluded that by using the model substantial savings can be achieved in inventory costs.

Dauzere-Peres et al., (2000) carried out an extensive study on continuous-time production control models in deterministic and stochastic environments. The solution methodology was usually based on either Hamilton-Jacobi-Bellman dynamic programming or the Pontryagin maximum principle. For linear costs and simple demand functions (constant, cyclic, etc), the optimal production can be obtained in a closed form. According to them, for more complicated cases, development of specific numerical procedures is required.

Dileep and Sumer (2007) presented a paper that dealt with a multi-machine, multi-product lot size determination and scheduling problem. The model developed considered not only the usual inventory-related operational cost, but also the costs that depend on under-or-over utilization of available men and machines. The solution minimizes the inventory and resource-related costs and not just inventory costs. A heuristic was developed to determine the solution from the model and to modify it, as necessary, to obtain a conflict-free, repetitive, and cyclic production schedule for an infinite horizon.

Dessouky and Kijowski (1997) undertook a study that addressed the problem of scheduling a single-staged multi-product batch chemical process with fixed batch sizes. A mixed integer nonlinear programming model was used to determine the schedule of batches, the batch size and the number of overtime shifts that satisfy the demanded minimum cost. A polynomial–time algorithm was used to solve the problem when the processing times of all batches are identical and the set up and cleaning times are sequence-independent. The solution procedure was based on recognizing that optimal fixed batch sizes were a member of a set whose cardinality was polynomial. Given the batch size, the problem was formulated as a simplex algorithm problem, which is an assignment problem.

Kumral (2010) conducted a study on production scheduling of open pit mines to determine the extraction sequence of blocks such that the net present value (NPV) of the mining project is maximized under capacity and access constraints. The author used a Robust Stochastic Optimization (RSO) approach to deal with the problem in a manner such that the solution is insensitive to changes in input data. The approach seeks a tradeoff between optimality and feasibility. He demonstrated the model on a case study and the findings showed that the approach can be used in mine production scheduling problems efficiently.

Bitran et al., (1982) studied production planning problems where multiple item categories were produced simultaneously. The items had random yields and were used to satisfy the demands of many products. These products had specification requirements that overlap. An item originally targeted to satisfy the demand of one product may be used to satisfy the demand of other products when it conforms to their specifications. Customers' demand must be satisfied from inventory hundred percent (100%) of the time. The authors formulated the problem with service constraints and provided near- optimal solution to the problem with fixed planning horizon. They also proposed simple heuristics for the problem solved with a rolling horizon. Some of the heuristics performed very well over a wide range of parameters.

Gavareshki and Zarandi (2008) presented a heuristic approach based on Shifting Bottleneck (SB) for large scale job shop scheduling problems. According to them, Sub-problem solution procedure and re-optimization are two important factors in SB approach that can increase computational efforts. Their study first presented a modified Schrage algorithm for single machine scheduling problems with heads and tails that is an effective sub-problem solution procedure. They then presented a heuristic approach for job shop scheduling that resolve re-optimization difficulties in SB. The results showed the superiority of their approach in comparison to SB in large scale problems especially in computational efforts. The authors, however, suggested that their approach can be a good initial seed in using search techniques.

2.3 Optimal Production Scheduling

The term optimization has been used in operations management, operations research, and engineering for decades. The idea is to use mathematical techniques to arrive at the best solution, given what is being optimized (cost, profit, or time, for instance). To optimize a manufacturing system means that the effort to find best solutions focuses on finding the most effective use of resources over time (Yu-Lee, 2000).

Hui et al., (2010) presented a paper that addresses the problem of optimizing production schedules of multiproduct continuous manufacturing facilities where a wide range of products are produced in small quantities, resulting in frequent changeovers. The authors investigated a real-world scheduling problem from the polyamide fiber plant which involved a sequencing of products. They formulated a simulated annealing model for the problem and the computational results showed that a satisfactory solution can be obtained in reasonable computation time. They also demonstrated the effectiveness and the applicability of the model from their case study.

Javanmard and Kianehkandi (2011) proposed Mixed Integer Linear Programming (MILP) model for the optimal production scheduling in a single milk production line. The model takes into account all the standard constraints encountered in production scheduling (material balances, inventory limitations, machinery capacity, labor shifts and manpower restrictions). The objective function that is minimized considers all major sources of variable cost that depend on the production schedule, i.e. changeover cost, inventory cost and labor cost. Their results shows that the model produces the complete production schedule for a selected future horizon, including the sequence of products that should be produced every day and the respective quantities and the inventory levels at the end of each day.

In their paper, “Optimal production scheduling for the dairy industry”, Doganis and Sarimveis (2008) presented a customized Mixed Integer Linear Programming (MILP) model for optimizing yogurt packaging lines that consist of multiple parallel machines. The model is characterized by parsimony in the utilization of binary variables and necessitates the use of only a small pre-determined number of time periods. The efficiency of their proposed model was illustrated through its application to the yogurt production plant of a leading dairy product manufacturing company in Greece.

Lakdere and Boushehri (2012) conducted a study on finding the optimal production schedule for an inventory model with time-varying demand and deteriorating items over a finite planning horizon. The problem was formulated as a mixed-integer nonlinear program with one integer variable. The optimal schedule was shown to exist uniquely under some technical conditions. They also showed that the objective function of the nonlinear obtained from fixing the integrality constraint is convex as a function of the integer variable. This in turn led to a simple procedure for finding the optimal production plan. The authors concluded that the model allows for the purchasing cost to vary with time, and therefore with fixed unit cost and no deterioration, the model is very effective.

Heluane et al., (2006) worked on how to address critical operational issues in the sugar cane industry. Their concern was to determining the optimal cyclic cleaning policy in the evaporation section and the corresponding optimum steam consumption profile of both evaporation and crystallization sections. A detailed Mixed Integer Nonlinear Programming (MINLP) performance model which includes the effect of fouling on the overall heat-transfer coefficient was considered by them. Their formulation was flexible enough to model multiple units (*M* units) and parallel (*N* lines) evaporator systems, as well as network arrangements arising from the combination of these basic cases. The results showed that significant savings of steam could be achieved just operating the evaporation section in a different way and with no additional investment needed.

Yang et al., (2000) studied the scheduling problem for two products on a single production facility. The objective was to specify a production and setup policy that minimizes the average inventory, backlog, and setup costs. The authors assumed that the production rate can be adjusted during the production runs and provided a close form for an optimal production and setup schedule. They verified the optimality of the obtained policy by combining Dynamic programming and Hamilton–Jacobi–Bellman equation. Their conclusion stated an effective use of the model.

Cheng et al., (1993) considered the problem of minimizing the cost due to talent hold days in the production of a feature film. They developed a combinatorial model for the sequencing of shooting days in a film shoot. A branch-and-bound solution algorithm and a heuristic solution method for large instances of the problem (15 shooting days or more) were developed and implemented on a computer. A number of randomly generated problem instances were solved to study the power and speed of the algorithms. The computational results revealed that the heuristic solution method is effective and efficient in obtaining near-optimal solutions.

In their paper, "Optimal production lot-sizing model considering the bounded learning case and shortages backordered", Zhou and Lau (1998) developed an optimal manufactured lot-sizing model under the consideration of learning and shortages. According to them the learning phenomenon conforms to the De Jong bounded learning curve. A one-dimensional search method was presented for determining the unique optimal production schedule, which minimizes the sum of labor and material costs, fixed set-up costs, the holding cost and the shortage cost per unit time. A numerical example used to illustrate the solution procedure and sensitivity analyses showed impeccable results.

Dimitrakopoulos and Ramazan (2008) agreed to the fact that production scheduling of open pit mines is an intricate, complex and difficult problem to address due to its large scale and the unavailability of a truly Optimal Net Present Value (NPV) solution, as well as the uncertainty in key parameters involved. They formulated a stochastic integer programming (SIP) model to provide a framework for optimizing mine production scheduling considering uncertainty. The SIP model allows the management of geological risk in terms of not meeting planned targets during actual operation, unlike the traditional scheduling methods that use a single orebody model and where risk is randomly distributed between production periods while there is no control over the magnitude of the risks on the schedule. The authors tested the SIP formulation in two cases, a gold and a copper deposit, and the results showed that the expected total NPV of the schedule using the SIP approach is significantly higher (10% and 25% respectively) than the traditional schedule developed using a single estimated orebody model.

2.4 Overtime and Productivity

Overtime refers to all hours worked in excess of the normal hours, unless they are taken into account in fixing remuneration in accordance with custom [Reduction of Hours and Work Recommendation, 1962 (No. 116)]. The definitions used in practice differ however. First, the threshold used for identification of overtime varies depending on institutional settings. It can be made up, for example, by the contractual working time, usual working time or statutory working time. Secondly, for some purposes (mainly for statistical ones), overtime does not necessarily need to be linked to compensation. Thus, many studies on overtime distinguish between paid and unpaid overtime (ILO, 2004). It can therefore be generalized that, overtime is the quantity of time someone works further than the regular working hours.

Taking a queue form the ILO working document, Ofori (2009), notes that the normal hours may be determined in several ways:

- By custom (what is considered healthy or reasonable by society),
- By practices of a given trade or profession,
- By legislation,
- By agreement between employers and workers or their representatives.

However, according to the ILO (2004), regulations on overtime commonly set two thresholds. First, the maximum standard working time (often called "normal hours"), marking the point above which working time is considered as overtime; second, the maximum total working time, including overtime. The limitations of working time and overtime can often be temporarily extended in the framework of flexible working time arrangements.

The ILO Hours of Work (Industry) Convention (No. 1) of 1919 introduced a maximum standard working time of 48 hours per week and eight hours per day as an international norm. In several exceptional cases, working time is allowed to exceed these limits, as long as daily working time remains not higher than ten hours, and weekly working time not higher than 56 hours. The European Union's Working Time Directive of 1993 sets the threshold of total working time, including overtime, at 48 hours per week on average over a 17-week period.

Most nations have overtime laws designed to dissuade or prevent employers from forcing their employees to work excessively long hours. These laws may take into account other considerations than the humanitarian, such as increasing the overall level of employment in the economy. One common approach to regulating overtime is to require employers to pay workers at a higher hourly rate for overtime work. Companies may choose to pay workers higher overtime pay even if not obliged to do so by law, particularly if they believe that they face a backward bending supply curve of labor (Ofori, 2009).

Bauer and Zimmermann (1999) revealed in a discussion paper that, sharing the available stock of work more fairly is a popular concern in the public policy debate. One policy proposal is to reduce overtime work in order to allow the employment of more people. In their paper, using Germany as a case study, it was shown that the group of workers with the highest risks of becoming unemployed, namely the unskilled, also exhibit low levels of overtime work. Those who work overtime, namely the skilled, face excess demand on the labor market. Since skilled and unskilled workers are largely complements in production, a general reduction in overtime will lead to less production and hence also to a decline in the level of unskilled employment.

Overtime achieves schedule acceleration by increasing the amount of hours worked by labor beyond the typical 40 hours worked per week. Past research indicated that labor productivity can be negatively impacted by overtime, causing problems such as fatigue, reduced safety, increased absenteeism, and low morale (Horner et al, 1985).

2.5 Optimal Solutions to the Transportation Problem

The transportation problem is a special class of the linear programming problem. It deals with the situation in which a commodity is shipped from sources to destinations. The objective is to determine the amounts shipped from each source to each destination that minimize the total shipping cost while satisfying both the supply limit and the demand requirements. The model assumes that the shipping cost on a given route is directly proportional to the number of units shipped on that route. In general, the transportation model can be extended to areas other than the direct transportation of a commodity, including among others, inventory control, employment scheduling and personnel assignment. (Mohammad, 2012)

Amponsah et al., (2011) conducted a study on production scheduling problem for a beverage firm based in Accra, in an attempt to cut down manufacturing cost and increase efficiency. According to them, the creation of an optimum production schedule requires the modeling of the scheduling problem as a balanced transportation problem. The scheduling formulation was solved by using QM software, a window's package. The results showed how the monthly allocations 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. Their results also suggested to the company that overtime or subcontracting is not necessary in reducing the cost of production. They therefore recommended the usage of the model to determine the optimum level of production to meet a given demand at a minimum cost.

Mouli et al., (2006) conducted a research to find a solution for finding an optimal production planning to minimize the total cost under the resource constraints taking overtime and subcontracting costs. A mathematical model was formulated and solved as a transportation problem. They proposed Genetic Algorithms (GA) to handle the constraints to obtain an optimal solution. A C++ codes were written to solve the problem. They tested the model in an automobile piston pins manufacturing company and proved to be very effective. They recommended that the proposed model could be extended for solving multi-period, multi-product and multi-objective problems by varying the mutation probabilities and crossover parameters suitably.

Abdallah and Mohammad (2012) wanted to find the best method for solving transportation problems. According to them, the main objective of transportation problem solution methods is to minimize the cost or the time of transportation. Most of the currently used methods for solving transportation problems are trying to reach the optimal solution, whereby, most of these methods are considered complex and very expansive in term of the execution time. They proposed the use of the best candidate method (BCM), in which the key idea is to minimize the combinations of the solution by choosing the best candidates to reach the optimal solution. Their results showed that applying the BCM in the proposed method obtains the best initial feasible solution to a transportation problem and performs faster than the existing methods with a minimal computation time and less complexity. They conclude that the BCM can be used successfully to solve different business problems of product distribution.

Zrinka et al., (2008) conducted a study in a petroleum industry where several plants at different locations produce a certain number of products for a large number of customers. Their objective was to find the production program for each plant as well as the transportation of products to customers for which the sum of the production and transportation costs is minimized given the condition that each customer can satisfy its demand for a given type of product from one plant only. They formulated two models of the general production-transportation problem, a mixed-integer programming problem and a bilevel mixed-integer programming problem to deal with the problem. They solved the problem using CPLEX 9.0 programming package and positive results were recorded.

Abdul et al., (2012) used a new method named ASM-Method for finding an optimal solution for a wide range of transportation problems, directly. According to them, the most attractive feature of this method is that it requires very simple arithmetical and logical calculation and it is very easy even for layman to understand and use. They add that the method is a much easier heuristic approach for finding an optimal solution directly with lesser number of iterations and very easy computations. They established numerical illustrations to show how the method can yield optimal solution by comparing their solution with that of the MODI. They concluded that the ASM-Method provides an optimal solution directly, in fewer iterations, for the transportation problems. They suggested that the method consumes less time and is very easy to understand and apply, so it will be very helpful for decision makers who are dealing with logistic and supply chain problems.

In a related study, Sudhakar et al., (2012) proposed zero suffix method for finding an optimal solution for transportation problems directly. Their method always gives optimal solution without disturbance of degeneracy condition. This requires least iterations to reach optimality, compared to the existing methods. They used numerical example to solve the problem to check the validity of the proposed method. In conclusion, they found the zero suffix method to provide an optimal value of the objective function for the transportation problem. According to them, the method carries systematic procedure, and very easy to understand. They suggested that the method can be extended to assignment and traveling salesman problems to get optimal solution.

Mohammad (2012) wanted to find out if the Zero Suffix Method and the ASM-Method for solving transportation problems actually give optimum solutions. According to him, these direct methods reveal optimal solution without disturbance of degeneracy condition. They find optimal solutions directly with lesser number of iterations and very easy computations. He used numerical examples to compare the two methods with the VAM-MODI process. The results showed that the two direct methods for finding optimal solution of a transportation problem do not present optimal solution at all times.

Jamal et al., (2012) were interested in conducting a study in a food industrial group which produces large quantities of sugar and distributes it to warehouses and customers. Their problem was to formulate a model to optimize transportation costs and reduce losses caused by the company. The authors proposed an integer linear model to optimize the travel of full loaded trucks taking into account respect of the group's peculiarities. They also studied a second integer linear model taking into account transportation and production costs and allowing the possibility of closing some plants. The third model was aimed to review the production capacity of each plant through a redeployment of its production lines. Their results indicated that the first model enabled the company to optimize its distribution by a reduction in transport costs of around 11% of global distribution cost. The second model suggested a closure of two plants in certain periods of the production process. The third model would reduce the annual transport costs of around 30% in comparison of current situation. They however concluded that the third model will require an investment or a relocation of production lines of the company.

Fegade et al., (2011) proposed the Separation Method which is based on zero point method for finding an optimal solution for transportation problem. The authors considered transportation cost, supply and demand in the intervals. They Used interval membership function to checked optimality of the solution. They compared the method with triangular membership function. They checked the feasibility of the proposed method with a numerical example and concluded that the separation method based on the zero point provides an optimal value of the objective function for the fully interval transportation problem. According to them, the method provides more options and can be served an important tool for the decision makers when they are handling various types of logistic problems having interval parameters.

Aramuthakannan and Kandasamy (2013) introduced a new approach to transportation problem namely, Revised Distribution method (RDI), for solving a wide range of such problems. The new method is based on allocating units to the cells in the transportation matrix starting with minimum demand or supply to the cell with minimum cost in the transportation matrix and then try to find an optimum solution to the given transportation problem. The proposed method is a systematic procedure, easy to apply and can be utilized for all types of Transportation problem with maximize or minimize objective functions. Their results showed that the method can be used for all kinds of transportation problems, whether maximize or minimize objective function.

Chandrasekhar et al., (2010) saw the Northwest Corner Rule Method and the Russell Method for finding Initial Basic Feasible solution (IBF) for transportation problems as having some drawbacks. According to them, the IBF obtained from the Northwest Corner Rule is far from the optimal solution. The IBF obtained using the Russell Method does not give enough number of entries to start the transportation simplex algorithm. These methods use chain reaction to obtain the optimal solution. As a result these problems become cumbersome and also take a long time to come to the optimal solution. They developed a new method called Putcha-Ali method for finding the IBF which is able to get the optimal value without using chain reaction. Their numerical examples showed that the use of this method for simplex transportation problems can be very helpful and easy.

2.6 Summary

In this chapter we put forward a brief history of canning and discussed related literature on production scheduling, optimal production scheduling, overtime and productivity, and optimal solutions to the transportation problem. The next chapter presents the research methodology of the study.

CHAPTER THREE

METHODOLOGY

3.0 Introduction

This chapter presents the research methodology of the study. We shall first put forward the profile of the company under study, Pioneer Food Cannery (PFC) Limited, and explain some of the terms relating to the production techniques.

3.1.0 Profile of Pioneer Food Cannery

Pioneer Food Cannery Limited is a private company categorized under Tuna Fish, Preserved and Cured and located in Tema, Ghana. It was established in 1975 and underwent a major expansion in 1993 under the leadership of Mr. Heinz in order to produce tuna loins as well as canned tuna. The main reason PFC is located in Ghana is the favourable tropical conditions of that part of the Atlantic Ocean (FAO declared fishing Zone 34). This makes the Gulf of Guinea one of the best feeding and breeding grounds for tuna species.

Pioneer Food Cannery was first established as a wholly - owned subsidiary of Mankoadze Fisheries Limited (MFL) and operated as a herring cannery. In 1976, Star-Kist International (KSI) South Africa, operating in Ghana since 1964 as a raw fish procurement base for Star-Kist Caribe, joined MFL in an equal partnership to process tuna for canning and export. PFC then operated for the next eleven years with various degrees of success.

In 1987, due principally to marketing disputes with MFL, increasing competition from Thailand; Star-Kist International withdrew support for the operation and canning production ceased. In October 1990, Star-Kist international re-opened PFC on an agreement with MFL in which all factory costs including fish were funded by SKI and PFC paid a per tonne fee to process loins. The Loining operation, initially involving the processing of two tones per day (with 15 employees) continued and expanded to approximately 50 tonnes per day in 1993 (with a total of 230 employees) (PFC, 2011).

In early 1993, it was recognized that new investment regulations of Ghana, combined with the terms of the Lome Convention (allowing, under certain conditions the duty-free export of tuna into the European Union (EU)), gave the ability to source and produce canned tuna at competitive costs. Star-Kist Foods Inc., through Star-Kist International S.A., bought out the joint venture partner with MFL, and began a major cannery capable of processing up to 90 tonnes per day. The new factory recommenced operations in January 1994 acquiring approval by the Local Competent Authority, Ghana Standards Board to export Tuna products to the EU.

Factory output as well as the number of employees has since risen rapidly, and further expansion efforts have resulted in PFC being capable of processing up to 200 tonnes of tuna per day. Employment levels may vary between 1100 and 1300 personnel depending on demand of operations. The company holds certifications to the British Retail Consortium (BRC) - Grade A and International Food Standard (IFS) – Higher Level. Following strategic review of its businesses, Mr. Heinz transferred ownership of the factory to the new holding company, MW Brands.

PFC produces pre-cooked and raw pack tuna packs in a range of can sizes. It exports branded and private label products (retail and Food service) mainly to the UK and other European countries. Products are also sold in the local market and other parts of Africa. Some of the brands include Star-Kist tuna, John West, Petit Navire, Mareblu, Tesco and ASDA.

Tuna is caught in the Atlantic and Pacific Oceans by Purse Seine or Pole and Line vessels and frozen on board. The Company owns a majority share in Tema Tuna Venture (TTV), a local fishing fleet based in Tema, which supplies around 60% of fish used by the factory. Fish is also supplied by other approved EU vessels. The fish is landed at the port in Tema and transferred in scows directly to the factory (PFC, 2011).

3.1.1 Corporate Identity of Pioneer Food Cannery

Vision

The vision of the company is to:

(i) Be recognized as the number one branded Seafood Company operating in the mass market, delivering the best range of innovative seafood products to our clients, while always insisting on the highest quality.

(ii) Deliver consistently best in class financial performance through the achievement of excellence in each segment of our integrated value chain.

(iii) Build the future on our learnings, on our capacity to anticipate future needs and opportunities, on the motivation of our employees and on our drive to succeed.

Mission

The mission of the company is to be:

(i) The leader within the global seafood business, as recognized by both consumers and stakeholders.

(ii) A company delivering genuine quality at the right price. This is achieved through high levels of competence derived from owning our own fishing boats, processing plants, premium brands and our commercial structure.

(iii) A unique company inspired and motivated by efficient processes, new products, marketing innovations but also by environmental concerns.

(iv) A company projecting growth ahead through a culture of curiosity and competitiveness.

Key Drivers

The key drivers of the company include the following:

(i) To drive the company through strategic understanding, and be the first to make the right decisions ahead of competition.

(ii) To develop and consolidate a unique recognized positioning for each of our brands and products.

(iii) To anticipate market trends by offering innovative premium products to our consumers that will deliver against their expectations.

(iv) To innovate new seafood segments out of ambient/canned; specifically explore opportunities in chilled.

(v) To optimize the ideal location of our plants in the middle of the richest fishing waters.

3.2 Terms and Techniques

Linear programming is a widely used model type that can solve decision problems with many thousands of variables. Generally, the feasible values of the decisions are delimited by a set of constraints that are described by mathematical functions of the decision variables. The feasible decisions are compared using an objective function that depends on the decision variables. For a linear program the objective function and constraints are required to be linearly related to the variables of the problem. The examples in this section illustrate that linear programming can be used in a wide variety of practical situations including Transportation Problems. We illustrate how a situation can be translated into a mathematical model, and how the model can be solved to find the optimum solution.

Jensen (2004) defines the major terminologies used in linear programming as follows:

(i) **Decision Variables:** Decision variables describe the quantities that the decision makers would like to determine. They are the unknowns of a mathematical programming model. Typically we will determine their optimum values with an optimization method. In a general model, decision variables are given algebraic designations such as $x_1, x_2, x_3, \ldots, x_n$. The number of decision variables is *n*, and x_j is the name of the j^{th} variable. In a specific situation, it is often convenient to use other names such a x_{ij} or y_k or *z(i,j)*. An assignment of values to all variables in a problem is called a solution.

(ii) **Objective Function:** The objective function evaluates some quantitative criterion of immediate importance such as cost, profit, utility, or yield. The general linear objective function can be written as $z = \sum_{j}^{n} c_j x_j = c_1x_1 + c_2x_2 + \cdots + c_nx_n$, where cj is the coefficient of the jth decision variable. The criterion selected can be either maximized or minimized.

(iii) **Constraints:** A constraint is an inequality or equality defining limitations on decisions. Constraints arise from a variety of sources such as limited resources, contractual obligations, or physical laws. In general, an LP is said to have m linear constraints that can be stated as $\sum_{j=1}^{n} a_{ij}x_j \begin{Bmatrix} \le \\ = \\ \ge \end{Bmatrix} b_i$, for $i = 1, \dots, m$. One of the three relations shown in the large brackets must be chosen for each constraint. The number a_{ij} is called a 'technological coefficient' and the number b_i is called the 'right-hand side' value of the i^{th} constraint. Strict inequalities (< and >) are not permitted. When formulating a model, it is good practice to give a name to each constraint that reflects its purpose.

(iv) **Simple Upper Bound:** Associated with each variable x_j, may be a specified quantity u_i, that limits its value from above; $x_j \le u_j$ for $j = 1, \dots, n$. When a simple upper is not specified for a variable, the variable is said to be unbounded from above.

(v) **Non-Negativity Restrictions:** In most practical problems the variables are required to be nonnegative; $x_j \ge 0$ for $j = 1, \dots, n$. This special kind of constraint is called a non-negativity restriction. Sometimes variables are required to be non-positive or, in fact, may be unrestricted (allowing any real value).

(vi) **Complete Linear Programming Model:** Combining the aforementioned components into a single statement gives:

Maximize or Minimize $z = \sum_j^n c_j x_j$

Subject to

$$\sum_{j=1}^n a_{ij} x_j \begin{Bmatrix} \leq \\ = \\ \geq \end{Bmatrix} b_i, \text{ for } i = 1, \ldots, m.$$

$$0 \leq x_j \leq u_j \text{ for } j = 1, \ldots, n.$$

The constraints, including non-negativity and simple upper bounds, define the feasible region of a problem.

(vii) **Parameters:** The collection of coefficients (c_j, a_{ij}, b_i, u_j) for all values of the indices i and j are called the parameters of the model. For the model to be completely determined all parameter values must be known.

3.3 The Production Problem

Production problem involves a single product which is to be produced over a number of successive time periods to meet pre-specified demands. Once manufactured, units of product 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. The underlying assumptions of the production problem 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 (Amponsah et al., 2011)

3.4 The Transportation Problem

The production problem can be modeled as a transportation problem as follows:

Since production takes place periodically, we consider the time periods in which production takes place as sources $S_1, S_2, \dots, S_n$ and the time periods in which units will be shipped as destinations $W_1, W_2, \dots, W_m$. The production capacities a_i at source S_i 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 and demands.

Let c_{ij} be the production cost per unit during the time period *i* plus the storage cost per unit from time period i until time period *j*. If we let x_{ij} denote the number of units to be produced during time period *i* from S_i for allocation during time period *j* to W_j then for all *i* and j, $x_{ij} \geq 0$ (since the number of units produced cannot be negative).

i = 1,2 ,...., m and j = 1,2 ,..., n

For each i, the total amount of commodity produced at S_i is:

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

We shall consider a set of m 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:

$$\sum_{j=1}^{n} x_{ij} \leq a_i \quad i = 1, 2, \dots, m \quad \dots\dots\dots\dots\dots\dots\dots. \quad (3.1)$$

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

$$\sum_{i=1}^{m} x_{ij} \geq d_j \quad j = 1, 2, \dots, n \quad \dots\dots\dots\dots\dots\dots\dots \quad (3.2)$$

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.

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 allocated from source to a destination such that the total production costs are minimized.

The model is thus:

Minimize

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

subject to:

$$\sum_{j=1}^{n} x_{ij} \leq a_i \quad i = 1, 2, \dots, m \quad (supply\ constraints) \quad \dots\dots\dots\dots\dots\dots \quad (3.3)$$

$$\sum_{i=1}^{m} x_{ij} \geq d_j \quad j = 1, 2, \dots, n \quad (demand\ constraints) \quad \dots\dots\dots\dots\dots\dots \quad (3.4)$$

$$x_{ij} \geq 0, \quad j = 1, 2, \dots, n \quad i = 1, 2, \dots, m$$

The non-negativity condition $x_{ij} \geq 0$ is added since negative values for any x_{ij} have no physical meaning.

Since the transportation problem is a linear programming, it can be solved by the Simplex Method. But because of its special nature, it can be solved more easily by special forms of the Simplex Method taking advantage of the special structure. These special methods are more efficient for the transportation problem than the parent Simplex Method.

3.4.1 The Balanced Transportation Problem

A transportation problem is said to be balanced if the total supply is equal to the total demand. This is represented in the following table:

Table 3.1 The Balanced Transportation Table

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

Source: Amponsah, 2009

There is a row for each source and a column for each destination. The supplies and the demands of these are shown for the right and below respectively of the rows and columns. The unit costs are shown in the upper right hand corners of the cells.

We observe that:

(a) The coefficient of each variable x_{ij} in each constraint is either 1 or 0.

(b) The constant on the R.H.S. of each constraint is an integer.

(c) The coefficient matrix A has a certain pattern of 1's and 0's.

It can be shown that by any LP problem with these properties has the following property: If the problem has a feasible solution then there exist feasible solutions in which all the variables are integers. It is this property on which the modification of the Simplex method that provides efficient solution algorithms is based.

We also note that m + n conditions

$$\sum_{i=1}^{m} x_{ij} = d_j, 1 \leq j \leq n \quad \dots\dots\dots\dots\dots\dots\dots \quad (3.5)$$

$$\sum_{j=1}^{n} x_{ij} = a_i, 1 \leq i \leq m \quad \dots\dots\dots\dots\dots\dots\dots \quad (3.6)$$

are not independent since

$$\sum_{j=1}^{n} d_j = \sum_{i=1}^{m}\sum_{j=1}^{n} x_{ij} = \sum_{i=1}^{m} a_i \quad \dots\dots\dots\dots\dots\dots\dots. \quad (3.7)$$

Thus the effective number of constraints on the balanced transportation problem is m+n-1. Hence we expect a basic feasible solution of the balanced transportation problem to have m+n-1 non-negative entries.

3.4.2 The Unbalanced Transportation Problem

The transportation problem is unbalanced if the total supply is not equal to the total demand. Thus,

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

The unbalanced problem is converted to a balanced problem in the following way:

If the total supply exceeds the total demand

If the total supply exceeds the total demand, we create a fictitious destination W_f whose demand is precisely the excess supply over demand and such that the unit cost of each source to the fictitious destination W_f is zero. This gives the following balanced problem:

Table 3.2 Total Supply Exceeds Total Demand

Source \ Destination	W_1	W_2	. . . .	W_m	W_f	Supply
S_1	$C_{1,1}$ $X_{1,1}$	$C_{1,2}$ $X_{1,2}$		$C_{1,m}$ $X_{1,m}$	0	a_1
S_2	$C_{2,1}$ $X_{2,1}$	$C_{2,2}$ $X_{2,2}$		$C_{2,m}$ $X_{2,m}$	0	a_2
. . . .						. . . .
S_n	$C_{n,1}$ $X_{n,1}$	$C_{n,2}$ $X_{n,2}$		$C_{n,m}$ $X_{n,m}$	0	a_i
Demand	d_1	d_2	. . . .	d_j		

If the total demand exceeds the total supply

If the total demand exceeds the total supply, create a fictitious source S_f whose capacity is precisely the excess of demand over supply and such that the unit cost from source to every destination is zero. This produces a balanced transportation problem of the type shown below:

Table 3.3 Total Demand Exceeds Total Supply

Source \ Destination	W_1	W_2	. . . .	W_m	Supply
S_1	$C_{1,1}$ $X_{1,1}$	$C_{1,2}$ $X_{1,2}$		$C_{1,m}$ $X_{1,m}$	a_1
S_2	$C_{2,1}$ $X_{2,1}$	$C_{2,2}$ $X_{2,2}$		$C_{2,m}$ $X_{2,m}$	a_2
. . . .					. . . .
S_n	$C_{n,1}$ $X_{n,1}$	$C_{n,2}$ $X_{n,2}$		$C_{n,m}$ $X_{n,m}$	a_i
S_f	0	0		0	
Demand	d_1	d_2	. . . .	d_j	

3.5 Solution of the Transportation Model

In applying the simplex method, an initial solution has to be established in the initial simplex tableau. This same condition must be met in solving a transportation model. In a transportation model, an initial feasible solution can be found by several alternative methods, including the northwest corner method, the minimum cell cost method, and Vogel's approximation method. There are also other unfamiliar methods including the Russell method and the Best Candidate method for finding the initial basic feasible solution. For the purposes of this study, we would discuss the Vogel's approximation method since that is what we shall use in the analysis.

3.5.1 Vogel's Approximation Method (VAM)

Vogel's approximation method is based on the concept of penalty cost. A penalty cost is the difference between the largest and next largest cell cost in a row or column. If a decision maker incorrectly chooses from several alternative courses of action, a penalty may be suffered (and the decision maker may regret the decision that was made). In a transportation problem, the courses of action are the alternative routes, and a wrong decision is allocating to a cell that does not contain the lowest cost. VAM allocates as much as possible to the minimum cost cell in the row or column with the largest penalty cost.

It follows the following steps to arrive at the initial basic feasible solution:

Step 1: Determine the penalty cost for each row and column.

Step 2: Select the row or column with the highest penalty cost (breaking ties arbitrarily)

Step 3: Allocate as much as possible to the feasible cell with the lowest transportation cost in the row or column with the highest penalty cost.

Step 4: Recompute the penalty costs in each row and column, leaving out cells already allocated.

Step 5: Repeat steps 1, 2, 3 and 4 until all supply and demand requirements have been met.

Remarks:

The Vogel's approximation method provides a basic feasible solution which is close to optimal or is optimal and thus performs better than the northwest corner or the minimum cost method. Unlike the northwest corner method, Vogel's approximation method may lead to an allocation with fewer than (m+n-1) non-empty cells even in the non-degenerate case. To obtain the right number of cells in the solution, we add enough zero entries to empty cells, avoiding the generation of circuits among the cells in the solution.

3.5.2 The Modified Distribution Method (MODI)

The initial basic feasible solution has to be improved to optimality. This optimal solution can be found by several alternative methods, including the stepping stone method and the modified distribution method. We have chosen to discuss the MODI method since that is what we shall use in the analysis.

The modified distribution method which aids in obtaining the optimal solution and is established by the following 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:

$$\bar{c}_{ij} = c_{ij} - (u_i + v_j)$$

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)

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 cells (r, s) $c_{rs} = u_r + v_s$

(iii) Calculate cell evaluations (unit cost difference) $\bar{c}_{ij}$ 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 $\bar{c}_{ij}$ for negative entries and conclude that

- If all $\bar{c}_{ij} > 0$ implies solution is optimal and unique.
- If all $\bar{c}_{ij} \geq 0$ with at least one $\bar{c}_{ij} = 0$ implies solution is optimal and alternate
- If at least one $\bar{c}_{ij} < 0$ implies solution is not optimal.

3.6 Degeneracy

In the process of solving the transportation problem, we may have a non-degenerate solution or degenerate solution. For any non-degenerate solution, the number of occupied cells must be equal to the number of supply and demand requirements minus 1. That is, number of rows plus number of columns minus 1 (m+n-1). Where this rule is not met the solution is Degenerate.

Failure to meet the test for degeneracy in the transportation problem is indicated in two ways:

(i) There may be an excessive number of unoccupied cells in a solution; the number of unoccupied cells is greater than the number of supply and demand requirements minus 1. This type of degeneracy arises only in developing the initial solution and is caused by an improper assignment or an error in formulating the problem. In such cases, one must modify the initial solution in order to get a solution which satisfies the rule of non-degeneracy.

(ii) There may be an insufficient number of unoccupied cells in a solution. Degeneracy of this type may occur either in the initial solution or in subsequent solutions. It is this type of degeneracy which requires special procedures to resolve. With an insufficient number of unoccupied cells in a solution, it would be impossible to trace a closed path for each unused cell, and with the MODI method it would be impossible to compute the row and column values.

To resolve degeneracy a zero allocation is assigned to one of the unused cells. Although there is a great deal of flexibility in choosing the unused cell for the zero allocation, the general procedure, when using the northwest corner rule, is to assign it to a cell in such a way that it maintains an unbroken chain of unused cells. However, where the Vogel's Method is used the zero allocation is carried in a least cost independent cell. An independent cell in this context means that a cell which will not lead to a closed-path on such allocation.

3.7 Summary

This chapter presented the company profile of Pioneer Food Cannery. We also discussed the production problem and the various methods of solving production problems. The next chapter will discuss data collection and its analysis, using the transportation problem approach and will shows how we can optimize the production plan of the Food cannery by using the Transportation model.

CHAPTER FOUR

DATA COLLECTION 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 Petit Navire.

4.1 Data collection and analysis

The firm's capacity data (production plan), in cartons, for the 2011 financial year is given in Table 4.1. A carton contains twenty-four pieces of the product. Inventory at the beginning of January, 2011 was 48,653 cartons. The cost per carton of the product in regular and overtime shift productions are GH¢30.80 and GH¢35.20 respectively, and the unit cost of storage is GH¢8.40 per month.

Table 4.1: Capacity data for the company (in cartons)

MONTH	ESTIMATED DEMAND	REGULAR SUPPLY	OVERTIME SUPPLY	TOTAL SUPPLY
January	60028	49735	21502	71237
February	59735	48844	15959	64803
March	54195	31092	14554	45646
April	41092	37600	15405	53005
May	50670	27489	16442	43931
June	47489	26365	36993	63358
July	58732	54023	15256	69279
August	66335	53059	8518	61577
September	53059	59292	20075	79367
October	69676	49160	16054	65214
November	49160	39648	11422	51070
December	48904	54060	17524	71584
TOTAL	659075	530367	209704	740071

4.1.1 Scheduling formulation

The formulation takes into account the unit cost of production plus the storage cost c_{ij}, the supply a_i at source s_i and the demand d_j at destination w_j for all i, j = (1, 2, ..., 12).

The problem is:

Minimize

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

Subject to:

$$\sum_{j=1}^{12} x_{ij} \leq a_i \quad i = 1, 2, \ldots, m \quad (supply\ constraints)$$

$$\sum_{i=1}^{12} x_{ij} \geq d_j \quad j = 1, 2, \ldots, n \quad (demand\ constraints)$$

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.

Thus, we minimize:

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

subject to the following supply constraints:

$$x_{1,1} + x_{1,2} + x_{1,3} + x_{1,4} + x_{1,5} + x_{1,6} + x_{1,7} + x_{1,8} + x_{1,9} + x_{1,10} + x_{1,11} + x_{1,12} \leq 71237$$

$$x_{2,1} + x_{2,2} + x_{2,3} + x_{2,4} + x_{2,5} + x_{2,6} + x_{2,7} + x_{2,8} + x_{2,9} + x_{2,10} + x_{2,11} + x_{2,12} \leq 64803$$

$$x_{3,1} + x_{3,2} + x_{3,3} + x_{3,4} + x_{3,5} + x_{3,6} + x_{3,7} + x_{3,8} + x_{3,9} + x_{3,10} + x_{3,11} + x_{3,12} \leq 45646$$

$$x_{4,1} + x_{4,2} + x_{4,3} + x_{4,4} + x_{4,5} + x_{4,6} + x_{4,7} + x_{4,8} + x_{4,9} + x_{4,10} + x_{4,11} + x_{4,12} \leq 53005$$

$$x_{5,1} + x_{5,2} + x_{5,3} + x_{5,4} + x_{5,5} + x_{5,6} + x_{5,7} + x_{5,8} + x_{5,9} + x_{5,10} + x_{5,11} + x_{5,12} \leq 43931$$

$$x_{6,1} + x_{6,2} + x_{6,3} + x_{6,4} + x_{6,5} + x_{6,6} + x_{6,7} + x_{6,8} + x_{6,9} + x_{6,10} + x_{6,11} + x_{6,12} \leq 63358$$

$$x_{7,1} + x_{7,2} + x_{7,3} + x_{7,4} + x_{7,5} + x_{7,6} + x_{7,7} + x_{7,8} + x_{7,9} + x_{7,10} + x_{7,11} + x_{7,12} \leq 69279$$

$$x_{8,1} + x_{8,2} + x_{8,3} + x_{8,4} + x_{8,5} + x_{8,6} + x_{8,7} + x_{8,8} + x_{8,9} + x_{8,10} + x_{8,11} + x_{8,12} \leq 61577$$

$$x_{9,1} + x_{9,2} + x_{9,3} + x_{9,4} + x_{9,5} + x_{9,6} + x_{9,7} + x_{9,8} + x_{9,9} + x_{9,10} + x_{9,11} + x_{9,12} \leq 79367$$

$$x_{10,1} + x_{10,2} + x_{10,3} + x_{10,4} + x_{10,5} + x_{10,6} + x_{10,7} + x_{10,8} + x_{10,9} + x_{10,10} + x_{10,11} + x_{10,12} \leq 65214$$

$$x_{11,1} + x_{11,2} + x_{11,3} + x_{11,4} + x_{11,5} + x_{11,6} + x_{11,7} + x_{11,8} + x_{11,9} + x_{11,10} + x_{11,11} + x_{11,12} \leq 51070$$

$$x_{12,1} + x_{12,2} + x_{12,3} + x_{12,4} + x_{12,5} + x_{12,6} + x_{12,7} + x_{12,8} + x_{12,9} + x_{12,10} + x_{12,11} + x_{12,12} \leq 71584$$

and the following demand constraints:

$$x_{1,1} + x_{1,2} + x_{1,3} + x_{1,4} + x_{1,5} + x_{1,6} + x_{1,7} + x_{1,8} + x_{1,9} + x_{1,10} + x_{1,11} + x_{1,12} \geq 60028$$

$$x_{2,1} + x_{2,2} + x_{2,3} + x_{2,4} + x_{2,5} + x_{2,6} + x_{2,7} + x_{2,8} + x_{2,9} + x_{2,10} + x_{2,11} + x_{2,12} \geq 59735$$

$$x_{3,1} + x_{3,2} + x_{3,3} + x_{3,4} + x_{3,5} + x_{3,6} + x_{3,7} + x_{3,8} + x_{3,9} + x_{3,10} + x_{3,11} + x_{3,12} \geq 54195$$

$$x_{4,1} + x_{4,2} + x_{4,3} + x_{4,4} + x_{4,5} + x_{4,6} + x_{4,7} + x_{4,8} + x_{4,9} + x_{4,10} + x_{4,11} + x_{4,12} \geq 41092$$

$$x_{5,1} + x_{5,2} + x_{5,3} + x_{5,4} + x_{5,5} + x_{5,6} + x_{5,7} + x_{5,8} + x_{5,9} + x_{5,10} + x_{5,11} + x_{5,12} \geq 50670$$

$$x_{6,1} + x_{6,2} + x_{6,3} + x_{6,4} + x_{6,5} + x_{6,6} + x_{6,7} + x_{6,8} + x_{6,9} + x_{6,10} + x_{6,11} + x_{6,12} \geq 47489$$

$$x_{7,1} + x_{7,2} + x_{7,3} + x_{7,4} + x_{7,5} + x_{7,6} + x_{7,7} + x_{7,8} + x_{7,9} + x_{7,10} + x_{7,11} + x_{7,12} \geq 58732$$

$$x_{8,1} + x_{8,2} + x_{8,3} + x_{8,4} + x_{8,5} + x_{8,6} + x_{8,7} + x_{8,8} + x_{8,9} + x_{8,10} + x_{8,11} + x_{8,12} \geq 66335$$

$$x_{9,1} + x_{9,2} + x_{9,3} + x_{9,4} + x_{9,5} + x_{9,6} + x_{9,7} + x_{9,8} + x_{9,9} + x_{9,10} + x_{9,11} + x_{9,12} \geq 53059$$

$$x_{10,1} + x_{10,2} + x_{10,3} + x_{10,4} + x_{10,5} + x_{10,6} + x_{10,7} + x_{10,8} + x_{10,9} + x_{10,10} + x_{10,11} + x_{10,12} \geq 69676$$

$$x_{11,1} + x_{11,2} + x_{11,3} + x_{11,4} + x_{11,5} + x_{11,6} + x_{11,7} + x_{11,8} + x_{11,9} + x_{11,10} + x_{11,11} + x_{11,12} \geq 49160$$

$$x_{12,1} + x_{12,2} + x_{12,3} + x_{12,4} + x_{12,5} + x_{12,6} + x_{12,7} + x_{12,8} + x_{12,9} + x_{12,10} + x_{12,11} + x_{12,12} \geq 48904$$

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

4.1.2 Using QM software to obtain the Optimal Solution

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

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

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	*Supply*
Inventory	8.40	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	***48,653***
Jan-regular	10,000	30.80	39.20	47.60	56.00	64.40	72.80	81.20	89.60	98.00	106.40	114.80	***49,735***
Jan-o/time	35.20	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	***21,502***
Feb-regular	10,000	10,000	30.80	39.20	47.60	56.00	64.40	72.80	81.20	89.60	98.00	106.40	***48,844***
Feb-o/time	10,000	35.20	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	***15,959***
Mar-regular	10,000	10,000	10,000	30.80	39.20	47.60	56.00	64.40	72.80	81.20	89.60	98.00	***31,092***
Mar-o/time	10,000	10,000	35.20	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	***14,554***
Apr-regular	10,000	10,000	10,000	10,000	30.80	39.20	47.60	56.00	64.40	72.80	81.20	89.60	***37,600***
Apr-o/time	10,000	10,000	10,000	35.20	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	***15,405***
May-regular	10,000	10,000	10,000	10,000	10,000	30.80	39.20	47.60	56.00	64.40	72.80	81.20	***27,489***
May-o/time	10,000	10,000	10,000	10,000	35.20	10,000	10,000	10,000	10,000	10,000	10,000	10,000	***16,442***
Jun-regular	10,000	10,000	10,000	10,000	10,000	10,000	30.80	39.20	47.60	56.00	64.40	72.80	***26,365***
Jun-o/time	10,000	10,000	10,000	10,000	10,000	35.20	10,000	10,000	10,000	10,000	10,000	10,000	***36,993***
Jul-regular	10,000	10,000	10,000	10,000	10,000	10,000	10,000	30.80	39.20	47.60	56.00	64.40	***54,023***
Jul-o/time	10,000	10,000	10,000	10,000	10,000	10,000	35.20	10,000	10,000	10,000	10,000	10,000	***15,256***
Aug-regular	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	30.80	39.20	47.60	56.00	***53,059***
Aug-o/time	10,000	10,000	10,000	10,000	10,000	10,000	10,000	35.20	10,000	10,000	10,000	10,000	***8,518***
Sep-regular	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	30.80	39.20	47.60	***59,292***
Sep-o/time	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	35.20	10,000	10,000	10,000	***20,075***
Oct-regular	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	30.80	39.20	***49,160***
Oct-o/time	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	35.20	10,000	10,000	***16,054***
Nov-regular	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	30.80	***39,648***
Nov-o/time	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	35.20	10,000	***11,422***
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	***54,060***
Dec-o/time	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	35.20	***17,524***
Demand	***60,028***	***59,735***	***54,195***	***41,092***	***50,670***	***47,489***	***58,732***	***66,335***	***53,059***	***69,676***	***49,160***	***48,904***	

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-regular, Feb) the cost is GH¢30.80 whereas in the next cell C2,3 (Jan-regular, March) the cost is GH¢39.20 (i.e., 30.80+8.40 = 39.20). A high cost of 10,000 is put in cells where production is not feasible. For example in the cell C4,1 (Feb-regular, Jan), the cost is 10,000. 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. Overtime production for the month is allocated to that same month since it is needed to meet the demand of that month.

Table 4.3 gives the optimal solution to the problem solved by the QM software. It gives the allocations which minimize the total production cost. The company's production plan for the 2011 financial year would have incurred a total of GH⊄ 24,125,569.60 for producing a total of 888,724 cartons of the product. That is,

$$8.4(48,653) + 30.8(530,367) + 35.2(209,704) = \boldsymbol{GH \not\subset\ 24,125,569.60}$$

Thus, unit cost of storage multiplied by inventory at the beginning of the year plus unit cost of regular production multiplied by total supply for regular production plus unit cost of overtime production multiplied by total supply for overtime production.

The optimal solution from Table 4.3 gave the final total cost of production as GH⊄ 20,044,660. That is,

$$8.4(48,653) + 30.8(49,735 + 48,844 + 30,552 + 33,688 + 10,496 + 26,365 + 54,023 + 53,059 + 59,292 + 49,160 + 39,648) + 39.2(540 + 13,199) + 47.6(3,912 + 3,794) + 35.2(11,375 + 10,000 + 5,351 + 10,540 + 16,442 + 36,993 + 15,256 + 8,518 + 10,384 + 9,256) = \boldsymbol{GH \not\subset\ 20,044,657.20}$$

Table 4.3 Optimal solution to the production scheduling problem generated by the QM software

Optimal Cost = GH¢ 20,044,660	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Dummy
Inventory	48,653												
Jan-regular		49,735											
Jan-o/time	11,375												10,127
Feb-regular			48,844										
Feb-o/time		10,000											5,959
Mar-regular				30,552	540								
Mar-o/time			5,351										9,203
Apr-regular					33,688		3,912						
Apr-o/time				10,540									4,865
May-regular						10,496	13,199	3,794					
May-o/time					16,442								
Jun-regular							26,365						
Jun-o/time						36,993							
Jul-regular								54,023					
Jul-o/time							15,256						
Aug-regular									53,059				
Aug-o/time								8,518					
Sep-regular										59,292			
Sep-o/time									0				12,075
Oct-regular											49,160		
Oct-o/time										10,384			5,670
Nov-regular												39,648	
Nov-o/time											0		11,422
Dec-regular													54,060
Dec-o/time												9,256	8,268

The company could have reduced total production cost by GH¢ 4,080,912.40 (16.9%) if the above optimal schedule was used. That is,

$GH \not\subset \ (24{,}125{,}569.60 - 20{,}044{,}657.20) = GH \not\subset \ 4{,}080{,}912.40$

Table 4.4 gives the summary of the optimal solution to the production problem generated by the QM software. From the summary table, the inventory at the beginning of the 2011 financial year was used to meet the demand in January. Regular production in January was used to cater for the demand in February. The allocations continue till the end of the year. However, overtime productions were used to meet the demands in that same month. Dummy demands are only created to balance the production problem and so all their allocations do not count.

Table 4.4 Summary of the optimum production schedule generated by the QMS software

From	To	Shipment	Cost Per Unit	Shipment Cost
Inventory	January	48,653	8.4	408,685.2
January - regular	February	49,735	30.8	1,531,838
January - overtime	January	11,375	35.2	400,400
January - overtime	Dummy	10,127	0	0
February - regular	March	48,844	30.8	1,504,395
February - overtime	February	10,000	35.2	352,000
February - overtime	Dummy	5,959	0	0
March - regular	April	30,552	30.8	941,001.6
March - regular	May	540	39.2	21,168
March - overtime	March	5,351	35.2	188,355.2
March - overtime	Dummy	9,203	0	0
April - regular	May	33,688	30.8	1,037,590
April - regular	July	3,912	47.6	186,211.2
April - overtime	April	10,540	35.2	371,008
April - overtime	Dummy	4,865	0	0
May - regular	June	10,496	30.8	323,278.8
May - regular	July	13,199	39.2	517,400.8
May - regular	August	3,794	47.6	180,594.4
May - overtime	May	16,442	35.2	578,758.4
June - regular	July	26,365	30.8	812,042
June - overtime	June	36,993	35.2	1,302,154
July - regular	August	54,023	30.8	1,663,908
July - overtime	July	15,256	35.2	537,011.2
August - regular	September	53,059	30.8	1,634,217
August - overtime	August	8,518	35.2	299,833.6
September - regular	October	59,292	30.8	1,826,194
September - overtime	September	0	35.2	0
September - overtime	Dummy	12,075	0	0
October - regular	November	49,160	30.8	1,514,128
October - overtime	October	10,384	35.2	365,516.8
October - overtime	Dummy	5,670	0	0
November - regular	December	39,648	30.8	1,221,158
November - overtime	November	0	35.2	0
November - overtime	Dummy	11,422	0	0
December - regular	Dummy	54,060	0	0
December - overtime	December	9,256	35.2	325,811.2
December - overtime	Dummy	8,268	0	0

4.2 Discussion of results

The optimal production schedule presented in Table 4.3 gives the amount of the product to be allocated to satisfy demands 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, the inventory at the beginning of the year was used to meet the demand in January. The regular supply in January was the same as the one in the previous plan but the overtime supply in January was reduced from 21,502 to 11,375. Again, the regular supply in February was the same as in the previous plan but the overtime supply in February was reduced from 15,959 to 10,000. The schedule continues to give the various allocations until the financial year comes to an end.

However, regular production in the month of March was used to meet demands in April and May. Regular production in April was also used to meet demands in May and July. Similarly, regular production in May was used to cater for demands in June, July and August. Another significant observation on the optimal schedule is that the overtime productions in the months of September and November were not necessary to arrive at the optimum cost.

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 740,071 cartons and the total demand is 659,075 cartons. Since the total supply exceeds the total demand, a dummy or fictitious demand of 80,996 cartons (i.e., 740,071 – 659,075) is created to balance the production problem with a cost per unit of zero. The allocations in the dummy column are not taken into consideration.

CHAPTER FIVE

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.0 Introduction

The objective of production scheduling is to arrive at the framework of manufacturing operations during the period planned. This framework should be designed to meet company goals filling customer requirements with minimum total cost. An aggregate scheduling is a valuable procedure that will determine the work force level, overtime and inventory levels with the objective of minimizing production cost.

5.1 Summary

The objective of the study was to design a production schedule that will determine the quantity of goods to produce in a given time period to minimize cost. A capacity data of a manufacturing firm for one financial year was collected and used for the study.

The production problem was modeled as a transportation problem and the QM software for windows was used to solve the problem to optimality. The analysis of the results showed that the firm could have reduced the production cost for the year under review and still meets its demands.

5.2 Conclusions

The modeling 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. The QM software was used to solve the scheduling formulation.

Ordinarily, the production plan of the firm would have yielded a total production cost of GH⊄ 24,125,569.60, but the optimal production schedule gave a total production cost of GH⊄ 20,044,657.20. This finding is important because the decrease of GH⊄ 4,080,912.40 (16.9%) is significant. Furthermore, the optimal solution demonstrated how the reduction will be achieved as shown in the analysis.

The application of the model showed how the monthly allocations 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. The company is also able to produce using regular working time period but will only consider overtime work when demand rises above the regular production capacity.

5.3 Recommendations

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.

Finally, the model is recommended to the management of Pioneer Food Cannery Limited to determine its optimum level of production necessary to meet a given demand at a minimum cost.

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APPENDIX

KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY, KUMASI

INSTITUTE OF DISTANCE LEARNING

TOPIC: OPTIMUMAL PRODUCTION SCHEDULE. CASE STUDY OF PIONEER FOOD CANNERY LIMITED

INTERVIEW GUIDE FOR INTERVIEWING THE PRODUCTION MANAGER OF PIONEER FOOD CANNERY LIMITED

This interview guide is designed purposely to assist the researcher carry out an investigation on the above topic. The researcher believes that such research information, which would be treated with the greatest confidentiality that it deserves, to a large extent will help me come out with recommendations which will be beneficial to the Pioneer Food Cannery 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. How many shifts do you run in a day?

3. Do you produce at full capacity?

4. Are you able to meet all your demands?

5. Do you run overtime shifts?

6. How much does it cost you to produce a carton of Petit Navire in normal shift?

7. What about in overtime shift?

8. How much does it cost to keep a carton in inventory for a month?

9. What are your expected production capacities for both regular and overtime shifts, for 2011?

10. Is there any opening stock from December, 2010 production for both shifts?

11. How many in each case?

12. Do you usually record surpluses in production?

13. Does it have any effect(s) on your prices?

14. Would you embrace a solution to your production problems (if any), and would management be willing to implement it?