KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY,

KUMASI

INSTITUTE OF DISTANCE LEARNING

OPTIMAL PRODUCTION PLANNING AND SCHEDULING, CASE STUDY: GUINNESS GHANA BREWERY LIMITED, KUMASI

BY

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A THESIS SUBMITTED TO THE INSTITUTE OF DISTANCE LEARNING, DEPARTMENT OF MATHEMATICS IN PARTIAL FULFILMENT OF THE REQUIREMENT FOR THE AWARD OF THE MASTER OF SCIENCE DEGREE IN INDUSTRIAL MATHEMATICS.

JUNE, 2014

DECLARATION

I hereby declare that this project work was fully undertaken by me under supervision and has not in part or whole been presented for another project.

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DEDICATION

To God, whom life and energy belongs.

To my father, Mr. Joseph Derkye whose motivation, love and support at different times in my life over many years has made the production of this project possible and all the help I needed especially school fees and pocket monies when I was not working. Even now he supports me in many ways.

No influence is as impressive as that of an exemplary life. Hard working and unbiased lecturers at the Mathematics Department of Kwame Nkrumah University of Science and Technology, especially the Head of Department Mr. F. K. Darkwah and my supervisor Dr. Osei Frimpong who is also my role model. I dedicate this project to the entire Mathematics Department of this University.

To my dearest wife Saviour Oforiwa Adoma, my daughter Doris Odei and my son JeLord Derkye Adom.

ACKNOWLEDGEMENT

I wish to express my profound gratitude and appreciation to my lectures, especially my supervisor Dr. Osei Frimpong, who have impacted knowledge into me over the years. There is no way I can pay them back for their good works done.

The success of any work of this nature normally depends to a large extent on the assistance of many people. Through Him, with Him and in Him, all things are done. I wish to express my profound thanks to God for his direction, protection, guidance and strength he has enabled me to carry out this research.

I wish also to render my unalloyed thanks to my wife and son Saviour Oforiwaa Adoma and Jelord Derkye Adom, whose invaluable assistance, patience, guidance, encouragement, positive criticisms and suggestions enabled me to carry out and complete this project successfully and timely.

Special thanks go to my parents, Mr. Joseph Derkye and Madam Comfort Nyarrmekye for their outstanding motivation and priceless support throughout my University and entire educational life.

I wish to take a moment and pay homage to those who truly believe in this project work especially my siblings.

Finally, I would like to extend my sincere gratitude to all whom in diverse ways contributed to the success of this work but whose names, time and space will not permit me to mention.

ABSTRACT

Effective production planning and scheduling is paramount to the success of every manufacturing company. Regardless of your manufacturing industry, finding the best way to purchase, allocate and utilize your production resources to efficiently satisfy your customers while minimizing cost is a constant challenge. But without the right production planning and scheduling solution, it is near impossible. With the aid of computer software, a new approach makes it easier to bring out the basic principles involve and lead to a simple solution with respect to the manual iterations.

This project seeks to avoid common problems such as high inventory levels, poor customer delivery times, low yield, high scrap and inefficient usage of capacity and production capabilities. With the use of TORA computer software, the company can use a tactical production planning to manage real-time interaction between sales, planning and production and maintain low inventory while promising realistic delivery dates to keep their customers satisfied to save money and resources.

The production was modelled as a balanced transportation problem and solved using computer software TORA to obtain the optimal production plan. The results from the analysis showed that overtime production is not necessarily throughout the year but should apply effective planning and scheduling to their production activities to ensure optimum output.

The main aim is to maximize profit and minimize cost in a more convenient approach than the tedious calculations of the three main methods, Northwest Corner Rule, Least Cost and the Vogel approximation method (VAM) involved in transportation.

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INTRODUCTION

1.0 Review

This chapter talks about the background of the study, the meaning and effects of the topic production planning and scheduling. It also talks about relevance and related quotations of other Authors. It explains, expands and reviews some of the sayings related to the topic mentioned.

1.1 Background Of The Study

For many manufacturers the task of meeting the ever rising demand and customer expectations and lowering production costs in an environment of more products, more complexity, more choice and competition is placing great stress on the effectiveness of their planning of activities in the production process. Organizations have already adopted solutions with vary degrees of planning and scheduling capabilities. Yet, operates executive acknowledge that these same systems are becoming out dated, lacking the speed, flexibility and responsiveness to manage their increasing complex production environment.

Effective production planning and scheduling is vital to the success of every manufacturing business. Regardless of your industry, finding the best way to purchase, allocate and utilize your production resources to efficiently satisfy your customers while minimizing costs is a constant challenge. But, without the right production planning and scheduling solution, it is near impossible.

The process of production planning is central to the success of any manufacturing company. In general terms, the production planning process involves generating a plan to satisfy customers in a manner that results in a reasonable profit. The specifics of the production plan should vary company to company, and industry to industry.

Sales and marketing staff input customer needs to production planning. These needs include requirements volume and timing, target service levels, target lead times, and prices.

Operations, management, and engineering staff identify the necessary resources to meet customer needs at an appropriate cost. These resources include (but are not limited to) machine and equipment time, tooling, labour, materials, and engineering support. The most effective production planning occurs when operations and sales / marketing work together to develop an achievable plan, rather than sales / marketing "throwing the plan over the wall".

Depending on the type of business and the similarities among items, you may want to aggregate demand into product families and use generic product bills of material and routings when production planning. In deep bill of material environments, you may also want to do Master Production Scheduling. In deep bill environments, you should explode bills as part of the production planning process. Although it can be done manually, historically, this bill of material explosion has been handled by the MRP (material requirements planning) module of the company's business.

The process of identifying resources necessary to support the production planning process historically has been called Capacity Planning. Depending upon the time frame involved and whether or not bills have been exploded, more specific terms used to describe the process include resource requirements planning, rough-cut capacity planning, or capacity requirements planning.

By their very nature, production planning and capacity planning can be extremely imprecise. For instance, far enough out on the time horizon, customer orders become sparse and need to be replaced with forecasts. While some companies are good at forecasting, there will always be some level of forecast inaccuracy.

However, production planning can really fall apart when load (or hourly requirements) of the production plan is mapped onto available capacity. While it should be quite easy to predict when capacity is available, estimating the timing of load is much more difficult. Timing difficulties are caused by the assumption of infinite capacity. In the real world capacity is finite. Work doesn't flow through manufacturing plants, but gets "hung up" at bottlenecks, and can wait in queue for extended periods of time. Furthermore, bottlenecks aren't static, but vary based on the changing capacity requirements of different product mixes.

How do current production planning and capacity planning methods account for bottlenecks? With static estimates of lead time that seek to approximate how long operations will wait in queue. What is the problem with these lead time estimates? Trying to model bottlenecks and queues that vary over time with static estimates just doesn't work.

If you input inaccurate lead times into the production planning process, capacity loads are going to be scheduled at the wrong point in time. Then work that is projected to hit a resource at a particular point in time will actually arrive earlier or later. Therefore, load may actually be significantly less than capacity at points in time where it is predicted to be greater, and vice versa. Since capacity can't always be added or subtracted instantaneously, there will be a mismatch of load and capacity, sometimes needlessly adding cost, and sometimes hurting the ability to satisfy customers.

Production planning is an important part of the process for manufacturing firms. The organization of production relies in general on the implementation of a certain number of basic functions, among which the scheduling function plays an essential role. Magee (1956) emphasized the interrelationships between these two important production management activities. Irrespective of organizational status, it is generally recognized that production scheduling and inventory management, or control, are closely interrelated. In theory, problems are frequently classified according to type of problems, example distribution, queuing or sequencing. However, real industrial problems often do not fit into rigid categories. Production scheduling is a unifying problem closely related to other areas within an organization such as sales, cost control, purchasing, capital budgeting and inventory management (Pounds, 1961).

Scheduling is the establishment of starting and finishing dates for productive activities (Rago, et al, 2003). Under certain conditions, scheduling may also determine the sequence of operations and/ or the assigned workload on certain equipment. For example, as the size of the scheduling matrix increases, (i.e., more orders to be assigned to a larger array of machines) the number of possible combinations of routings increases exponentially.

Scheduling concerns the allocation of limited resources to tasks over time. McKay (1995) explained " Production scheduling is concerned with the allocation of resources and the sequencing of tasks to produce goods and services.

Although allocation and sequencing decisions are closely related, it is very difficult to model mathematically the interaction between them. However, by using a hierarchical approach, the allocation and the sequencing problems can be solved separately. The allocation problem is solved first and its results are applied as inputs to the sequencing problem. The resource allocation problem can sometimes be solved using aggregate production planning techniques. To specify completely the input to the sequencing problem, the resulting detailed or item plan (also referred as the master schedule) has to be disaggregated. A breakdown by component parts can be obtained in a straightforward way by using Material Requirements Planning (MRP) systems. Although MRP continues to be popular in practice, many issues still need to be resolved to make it an effective production planning tool".

However, the accomplishment of the scheduling function should not generally imply that rank orders have been set or specific machine loads determined. The term scheduling is often used to describe the sequencing situation. Scheduling should be reserved for procedures which give the time of arrivals units requiring service. Sequencing is defined as determining the order in which items are processed. The scheduling of complex activities, particularly when job-process times are short, does not explicitly determine the order of work for manufactured items. Scheduling –sequencing problems are, therefore, concerned with determining both the time that the order processing is completed and the rank order, that is, the sequence of order processing.

Production scheduling has three goals or objectives. The first involves due dates and avoiding late completion of jobs. The second goal involves throughput times; the firm wants to minimize the time a job spends in the system, from the opening of a shop order until it is closed or completed. The third goal concerns the utilization of work centres. Firms usually want to fully utilize costly equipment and personnel. Often, there is conflict among the three objectives. Excess capacity makes for better due –date performance and reduces throughput time but wreaks havoc on utilization. Releasing extra jobs to the shop can increase the utilization rate and perhaps improve due-date performance but tends to increase throughput time.

Vollman et al., (1997) noted that the production schedule is derived from the production plan; it is a plan that authorized the operations function to produce a certain quantity of an item within a specified time frame. In a large firm, the production schedule is drawn in the production planning department, whereas, within a small firm, a production schedule could originate with a lone production scheduler or even a line supervisor.

There are fundamental differences in production planning and production scheduling. Planning models often utilize aggregate data; cover multiple stages in a medium –range time frame, in an effort to minimize total costs. Scheduling models use detailed information, usually for a single stage or facility over a short term horizon, in an effort to complete jobs in a timely manner. Despite these differences, planning and scheduling often have to be incorporated into a single framework, share information, and interact extensively with one another. They may also interact with other models such as forecasting models or facility location models.

Bartak (1999) stated that "the main difference is in the resolution of the resulting plan or schedule. While the industrial planning deals with the task of finding "rough" plans for longer period of time where activities are assigned to departments etc., the industrial scheduling deals with the task of finding detail 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".

A production schedule can determine whether delivery promises can be met and identify time periods available for preventive maintenance. Production schedule gives shop floor personnel an explicit statement of what should be done so that supervisors and managers can measure their performance.

- Minimize average flow time through the system.
- Maximize machine and /or worker utilization.
- Minimize setup times.

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.

Better coordination to increase productivity and minimizing operating costs. It should be noted that a major shift in direction has occurred in recent research on scheduling methods. Much of what was discussed was developed for job shops. As a result of innovations such as Computer Integrated Manufacturing (CIM) and Just-In-Time (JIT), new processes being established in today's firms are designed to capture the benefits of repetitive manufacturing and continuous flow manufacturing. Therefore, much of the new scheduling research concerns new concepts and techniques for repetitive manufacturing-type operations. In addition, many of today's firms cannot plan and schedule only within the walls of their own factory as most are an entity with an overall supply chain. Supply chain management requires the coordination and integration of operations in all stages of the chain. If successive stages in a supply belong to the same firm, then these successive stages can be incorporated into a single planning and scheduling model. If not, constant interaction and information sharing are required to optimize the overall supply chain.

A Production schedule can identify resource conflicts, control the release of jobs to the shop, ensure that required raw materials are ordered in time, determined whether delivery promises can be met, and identified time periods available for preventive maintenance (Fordyce, 2005).

Production scheduling and Control entails the acquisition and allocation of limited resources to production activities so as 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 entrepreneur 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 fulfilment 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 (Herrmann, 2006).

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 systems enhances production scheduling (Herrmann, 2006). Planned production is an important feature of both small and large industries.

Wight (1984) identified “priorities” 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.

Production scheduling tools greatly outperform older manual scheduling methods. These provide the production scheduler with powerful graphical interfaces which can be used to visually optimize real-time work loads in various stages of production and pattern recognition allows the software to automatically create scheduling opportunities which might not be apparent without this view into the data. For example, an airtime might wish to minimize the number of airport gates required for its aircraft, in order to reduce costs, and scheduling software can allow the planners to see how this can be done, by analyzing time tables, aircraft usage, or the flow of passengers.

Companies use both backward and forward scheduling to allocate plant and machinery resources, plan human resources, plan production processes and to purchase materials. Forward scheduling is planning the tasks from the date resources become available in order to determine the shipping date or the due date. Backward scheduling entails planning the tasks from the due date or required-by date to determine the start date and /or any changes in capacity required.

Production schedule is prepared on the basis of type of production process involved. It is very useful where single or few products are manufactured repeatedly at regular intervals. Thus, it would show the required quality of each product and the sequence of operation. Modern production techniques and organization can create many production abilities by which different production systems (with the quality of goods and production schedule) and different production costs are formulated. It is reasonable to develop a production system or schedule that can ensure production quality and schedule at minimum cost.

Production scheduling can be difficult and time-consuming. In a dynamic and stochastic manufacturing environment, managers, production planners and supervisors must not only generate high-quality schedules but also react quickly to unexpected events and revise schedules in a cost-effective manner. These events, generally difficult to take into consideration while generating a schedule, disturb the system, generating considerable differences between the predetermined schedule and its actual realization on the shop floor. Rescheduling is then practically mandatory in order to minimize the effect of such disturbances in the performance of the system.

There are certain firms or organizations, which have to produce commodities or items at certain intervals over a given period to ensure that together with what is held in inventory (storage), there is enough to meet all demands. Since storage space for inventoried items is limited, there is a limit to how much commodity that can be put in inventory. After production has taken place to meet demand for the current quarter or season, there is always a production cost incurred, together with a carrying, holding, set up inventory or storage cost.

Because production scheduling activities are common but complex, there exist many different views and perspectives of production scheduling. Three important perspectives have been identified and these are the problem-solving perspective, the decision making perspective, and the organizational perspective. Each perspective has a particular scope and its own set of assumptions. Different perspectives lead naturally to different approaches to improving production scheduling.

The problem-solving perspective holds the view that scheduling is an optimization problem that must be solved by moving tasks around a Gantt chart, searching for the optimal solution. A great deal of research effort has been spent developing methods to generate optimal production schedules. Typically, such papers formulated scheduling as a combinatorial optimization problem isolated from the manufacturing planning and control system in place. More generally, the ability to formulate the problem rigorously and to analyze it to find properties of optimal solutions has attracted a great deal of research effort.

In addition to exact techniques, Brucker (2004) used a variety of heuristics and search algorithms to find near-optimal solutions to these problems. Although there exist significant gap between scheduling theory and practice, some researchers have improved real-world production scheduling through better problem-solving (Daniels R. L. et al. , (2004). Gantt (1973), reacting to situations that he has observed ninety years ago, warned that the most elegant schedules created by planning offices becomes useless if they are ignored.

The second is the decision-making perspective, where the production scheduling objective is “to see to it that future troubles are discounted (Coburn, 1981). There are many types of disturbances that can upset a production schedule, including machine failures, processing time delays, rush orders, quality problems, and unavailable materials. Problems can be caused by sources outside the shop floor, including labour agreements and the weather. It is unlikely that such a wide variety of possible problems can ever be considered automatically, implying that computers will never completely replace human schedulers. Moreover, improving production scheduling requires that the schedulers manage bottle neck themselves), and take steps to handle future uncertainty (McKay and Wiers, 2004).

Scheduling decision support systems can be useful as well. As suggested by McKay and Wiers (2006) and Wiers (1997), the design of a scheduling decision support tool should be guided by the following concepts:

(a) The ability of the scheduler to directly control the schedule (called “transparency),
(b) The amount of uncertainty in the manufacturing system
(c) The complexity of the scheduling decision and
(d) How well-defined the scheduling decision is characterized by incompleteness, ambiguity, errors, inaccuracy, and possibly missing information.

The organizational perspective considers scheduling as part of the complex flow of information and decision-making that forms the manufacturing planning and control system (Herrmann, 2004; McKay et al., 1995). Such systems are typically divided into modules that perform different functions such as aggregate planning and material requirements planning (Hopp and Spearman, 1996). The organizational perspective, which is the most complete, views production scheduling as a system of decision-makers that transforms information about the manufacturing system into a production schedule (Herrmann, 2004).

In a manufacturing facility, the production scheduling system is a dynamic network of persons who share information about the manufacturing facility and collaborate to make decisions which jobs should be done and when. The information shared includes the status of jobs (also known as work orders), manufacturing resources (people, equipment and production lines), inventory (raw materials and work-in-process) tooling, and many other concerns. The persons in the production scheduling system may be managers, production planners, supervisors, operators, engineers, and sales personnel. They will use a variety of forms, reports databases and software to gather and distribute information, and they will use tacit or implicit knowledge that is stored in their memory.

Based on the above decision, it is clear that these three perspectives forms a hierarchy, with the problem-solving perspective at the lowest level, the decision-making perspective in the middle and the organizational perspective at the highest level.

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).

The main tool used to control product availability is the application of a production schedule. By using the beginning inventory and the sales forecast for a particular end item, a planner or manager can calculate the amount of products or goods needed per period to meet anticipated customer demands. The production problem for such organization or firm is the setting up a production and inventory schedule that minimizes the total production and storage costs while meeting all demands for the given period.

1.2 A Brief History Of Kumasi Brewery Limited. (K B L)

Guinness Ghana has three sites, namely Achimota, in Accra, Ahensan in Kumasi and Kaase also in Kumasi. Guinness Ghana Breweries Limited (GGBL) emerged out of a merger of Guinness Ghana Limited (GGL) and Ghana Breweries Limited (GBL). To understand the history of GGBL therefore it is necessary to provide separate information on GGBL and GBL prior to 2004, the year in which the merger process commenced.

1.2.1 Guinness Ghana Brewery Limited (GGBL)

Guinness Ghana Limited was incorporated as a private company in 1960 and was listed on the Ghana Stock Exchange in 1990. When it was incorporated, Guinness Ghana Limited was to manage the importation and marketing of Guinness Foreign Extra Stout in Ghana. The shareholders were Guinness Overseas Limited (67.5%) and Atalantaf, a Bermudan Company (32.5%). In 1971, a brewery was designed and constructed in Kaasi, Kumasi. Production commenced a year later on 11 November 1971 with an installed capacity of 100,000 hectolitres. By 1977, the brewery was producing at maximum capacity. In 1976 Government of Ghana by an Investment Policy Decree acquired 40% of the shareholding in the Company. Other shareholders were Guinness Overseas Limited (28.68%), Atalantaf Limited (16.32%), Individuals (12.72%), Institutions (1.18%) and Employees (1.10%). The shareholding structure changed again when Government of Ghana divested its holding in the 1990s.

In May 1995, Guinness Ghana invested 18 billion cedis to expand its packaging capacity and commissioned in July 1999 a 40 billion cedis fully automated brew house facility using state of the art brewing and process control technology. This process allows product testing at every stage of the brewing process, thus delivering world-class purity and excellence throughout. In November 2003, Guinness Ghana commissioned a second state of the art packaging line at a cost of 165 billion cedis.

Guinness Ghana initially produced Foreign Extra Stout only. In 1989 it introduced Malta Guinness, a non-alcoholic beverage that was later produced in other markets in Africa. By the close of 2003 the Company had a range of products covering stout beer, malt drinks and "ready-to-drink" market. In 2003 financial year Guinness Ghana produced 576,000 hectoliters of its products As at 31 December 2003, the Company had a volume share of 31.3% of the combined beer and "ready-to-drink" market and 72.7% of the malt drinks market (as per AC Nielson data)

As at 30th October 2009, the range of Guinness Ghana Brand products covering: Mini Star (24x1), Gordon Spark (24x1), Star Large (12x1), Malta Guinness Quench (24x1), Amstel Malta (24x1), Malta Guinness can (24x1), Malta Guinness (24x1), Malta Guinness Quench can (24x1,Gulder Large (12x1), Heineken can/bottle (24x1), Guinness FES (24X1), Star Draft 30L Keg, Smirnoff Ice (24x1), Guinness FES can (24x1), Alvaro (24x1), Smirnoff /J& B /Gordon's ata). Guinness Ghana Breweries Limited becoming a total beverage business by bringing the Diageo Spirit Brands into the GGBL portfolio. These branded products that is being imported and sold on behalf of other companies are Johnny Walker (Red or Black), Baileys/J&B.

1.2.2 Ghana Breweries Limited (GBL)

Ghana Breweries Limited was incorporated on 30th April, 1992 under its previous name, 'ABC Brewery Limited. On 26th October 1994, it acquired the assets of Achimota Brewery Company Limited, a state-owned enterprise operating at Achimota, Accra. In October 1997, Heineken International acquired 90% of the outstanding ordinary shares of ABC Brewery Limited and subsequently renamed the company Ghana Breweries Limited. Ghana Breweries than merged with Kumasi Brewery Limited, a brewing company established in May 1959, with effect from 1st January 1998. Before this merger, Heineken and its wholly owned subsidiary, Limba Ghana Limited, held 50.26% of the issued shares of Kumasi Brewery Limited.

In June 2003, Ghana Breweries underwent a capital restructuring exercise. Consequently the stated capital of the Company increased from Cedi 74.4 billion to cedi 144 billion. Heineken Ghanaian Holdings held 75.59% while institutional and individual investors held 24.41% of the Company's shares.

Ghana Breweries' range of product covered beer (lager), malt drinks and soft drinks. As at 31st December 2003, had a volume share of 39.5% of the combined beer and "ready -to-drink-" market and 23.3% of malt drinks marker (according to AC Nielson data).

1.2.3. Merger

In 2004 Guinness Ghana Limited and Ghana Breweries Limited began a merger process. Up to 2007 the two Companies transacted business together as two separate legal entities under the new name "Guinness Ghana Breweries Limited". The merger process ended when Guinness Ghana Breweries Limited acquired all the assets of Ghana Breweries Limited in 2008.

1.2.4 Suppliers

GGBL has System SAP that registered all its suppliers of goods and services. Its registered vendors and suppliers strictly to provide goods and services. Goods are ordered from the registered suppliers. Suppliers are typically selected based on the supplier's ability to meet quality, quantity, delivery, and right source of product, price and services. Where there existing more than two suppliers; each supplier will have to sent his or her quotation for particular order where upon consideration and deliberation by the procurement board the order is assigned to one with minimum quotation and with quality goods and services, product standard. For one to become GGBL supplier he or she must meet the following conditions:

Good Ethics and Human Right Management Records.

These includes, safe working environment, pay and working hours, Anti-corruption and bribery, Tax Royalty, Valid Vendors Registration certificate, Supplier financial standings, Verification indicating reliable source and reliable of goods and more.

1.2.5 **Manufacturing**:

The Kaase site operates at an installed and target capacity of eleven million hectoliters per annum. The site operates an ultra modern brewing department, a modern and highly automated Packaging unit and distribution operations.

In order to be able to beat the competition and gain market share, Guinness Ghana Breweries injected capital into its operations by investing modern equipment. These include tanks, Gas processing plant, refrigeration plant, a new brew house and an ultra modern Packaging Plant. The Packaging plant is highly automated. This investment is in line with the company's objective of achieving One million, one hundred thousand hectoliters of beer per annum. The packaging plant is well supported with back up spares and world-class maintenance practices.

The GGBL uses modern Brewery automated system to brewery and bottled its beverages. The manufacturing material inventory includes the ingredients, empty bottles, lids, crown corks and label. Drinks are brew and package at the packaging Hall. The finish products are then arranged in pallet and moved to the warehouse prior to be distributed to the Distributors.

1.2.6 Smirnoff (Alcoholic Drink)

Smirnoff is imported in about 130 countries of which Ghana is no exception. It is originated from Russia. The landmark in the history Smirnoff became the invention of the 'Moscow Mule' Cocktail. The cocktail structure included ginger, beer, Vodka Smirnoff and a slice of lime.

Smirnoff is pure, transparent vodka with surprisingly soft and gentle taste the first class grain spirit, special water and unique process of filtration by specially processed activated coal are the secrets of flavouring advantages and faultless quality of this drink created in the best traditions of the Russian and American manufacture of alcohol. The Alcohol by volume range is 35% - 50%.

1.2.7 Warehouse

Raw materials, semi-finished goods and finished are kept at the warehouse at Ahensan and Kaase store House.

Some of the transporters like Maesk have their own warehouse where they keep raw materials on behalf of GGBL .The goods are held in Maesk warehouse till request from GGBL to deliver goods for production.

1.2.8 Transportation

The distribution of raw materials, semi-finish and the finish product is outsourced to third party contractors. Thus GGBL operate in 3 party logistics, which ensures materials, and finished goods are delivered at the right time to the right place in accordance with the planning schedule and at a minimum cost. There few registered transporters that are responsible for loading, packing, off loading and movement of raw material from port to warehouse, movement of finished products from Production warehouse to distributors. The main transporters are JoonMore, Maesk, and DHL . The Maesk is the main distributor that clears Guinness goods from the Port and held it in their warehouse till Guinness Ghana Breweries make a request for goods to be used for production. The Logistics managers of Maesk send daily report to GGBL detailing the available stock in the inventory and goods used up. Based on the report that GGBL will determine to make re-order or replenish stock. To be become a GGBL distributor one has to tender and if meet the GGBL requirement you then be accepted as a registered transporters. The criteria for transporters selection are:

Goods in transit policy. The transporters must have good insurance package for all its fleet and truckload damage recover policy.

Maintenance planning schedule. Every transporter must have two weeks maintenance schedule

Driver. Transporters must have qualified and competent drivers who must be able to read and write.

Number of Fleet. At least every transporter must have 10 fleets including folk lifts.

1.2.9 Distribution:

Finished products are sold directly to registered distributors. The distributors are the main agent who sells to retailers. The practice of exclusive distribution where only specially registered or authorized distributors (typically at least 5 distributors per a region) is the order of the day. These distributors act as wholesalers that sell directory to the publics and so called "Beer Bars". The GGL has their set rules and regulation governing registration and selection of a Key Distributors. There are 5 key factors required for someone to become a GGBL Key Distributor. They are listed below:

Financial standing: The Company must be able to have both physical assets to proof as collaterals as well as cash of not less than 25 thousand Ghana cedis, must also have large warehouse and parking space, must have staffs for administration task, packaging and drivers, must also have a fleet of cars for his transportation needs.

Tax royalty

Risk free and easy accessibility to parking space to enable discharging, loading and packing of bottles.

The names of registered Distributors in Ashanti Region are Ricky, Blue Banana, Afuakwa, Kayad, Askus.

1.3 Statement Of The Problem.

Typical decisions include work force level, production lot sizes, assignment of overtime and sequencing of production runs. Optimization models are widely applicable for providing decision support in this context.

1.4 Objectives Of The Study

1. To find optimal solution to the transportation problem
2. To minimize production cost.
3. To maximize production profit

1.5 Methodology

Monitoring and engaging private sector companies, especially the large and powerful multinational companies, are enormous tasks in any country let alone a third world country. Engaging such companies effectively on their production plan and schedule is dependent on accurate and up-to-date information on their application of production standards/plans.

The process is fraught with problems among which is the lack of relevant information on the operations of these companies. Even where the information is available it is provided on a discretionary basis. The complexity of the task can be further appreciated when we take into account the fact that the decisions of multinationals are heavily influenced by their parent companies outside the country.

The problem of workers plan and schedule at Guinness Ghana Brewery Limited (GGBL) will be modeled as a transportation problem which can easily be solved using a simplex pivot method.

Simplex Pivots Method allows us to solve linear programming problems without restriction and its algorithm can be readily converted into computer program. Irrespective of the size of the variables, the simplex pivots method relies heavily on matrices and row operations which computer program can solve easily. These problems would be reduced to additions and subtractions. For this reason, it is desirable to formulate a production problem as balanced transportation problem using transportation algorithm to solve.

A computer software TORA and An excel solver will be used in solving and analysing the data to obtain the optimal solution.

The data will be collected at GGBL for the analysis. The overtime production and regular production plans and schedules for one year period will be considered, thus from the period of September 2011 to August 2012.

The information required for this project will be gathered from the internet, the libraries, and Journals.

1.6 Justification of the Study

A number of studies on production planning and scheduling problems have been carried out during the past years. This context will emphasize on production planning and scheduling, machine capacity problem and freight planning and scheduling problems.

The planning/scheduling is applied in procurement and production, in transportation and distribution and in information processing communication.

In manufacturing, the scheduling function coordinates the flow of parts and products through the system and balances the workload on machines and personnel, departments and the entire plant.

Again a production scheduling can identify resource conflicts, control the release of jobs to the shop, and ensure that required raw materials are ordered in time.

Moreover, scheduling reduce the workload of workers there by improving quality health of workers.

Lastly, schedulers become well vest in production problems there by researching into it to improve good production schedules.

1.7 Organization of the Study

This thesis consists of five chapters. The first chapter covers the introduction of the study and a brief history of Kumasi Brewery Limited, Kaase, Kumasi (KBL) In the second chapter, the literature review relevant to this research is considered. Chapter three discusses the methodology, appropriate model to be used and data collection. The fourth chapter deals with the computations procedure, data analysis and result. Chapter five which is the last chapter, deals with the conclusion and recommendation.

CHAPTER 2

2.0 REVIEW OF FUNDAMENTALS

This chapter will focus on studies carried out by researchers on production planning and scheduling in the construction, manufacturing, mining, food and beverage industries, among others. The chapter outlined and discussed the various research works and studies that were undertaken by researchers on single and multi-product system problems. It also outlined the various algorithms used in addressing production problems including linear and non linear programming methods. It again looked at overtime and inventory related-costs, and their implication on production in achieving optimality. Different production problems identified and models developed to minimize these production problems.

2.1 Production Planning Models

Models for production planning which do not recognize the uncertainty can be expected to generate inferior planning decisions as compared to models that explicitly account for the uncertainty. Any planning problem starts with a specification of customer demand that is to be met by the production plan. Excellent general references on production planning are Thomas and McClain (1993), Pantelides (1994), Ovacik et al. (1995), Production planning problem are one of the most interesting application for optimization tools using mathematical programming.

The idea of incorporating uncertainty, in mathematical models appears initially with Dantzig, well known as the father of linear programming (Dantzig, 1955). Vollmann el al. (1997), carried out their research over the following seven categories of production planning hierarchical production planning, aggragates production planning, material requirement planning, inventory management and supply chain planning. They also identified four modelling approaches conceptual, analytical, artificial intelligence and simulation models.

Womack and Jones (1996), in a related work, the application of lean production techniques in construction have been triggered by its success in manufacturing. A number of studies were conducted to date in order to refine the thinking process and to develop appropriate methods to implement lean construction. However, to our knowledge, no computer tools have yet been developed for field level-use.

Hopp et al (1996) have been implemented in clear documenting, updating and constantly reporting the status of all process flows to all involved, so each person knows what others do and understands the implications of quality of their own work on the quality of the process output. Work-plan stores all work planning information in a database and generates relative information from it.

Production planning is one of the important activities in a production factory. Production planning represents the beating heart of any manufacturing process. According to Guinery, J. E. and MacCarthy (2005), production planning usually fulfils its functions by determining the required capacities and materials for these orders in quantity and time.

Corbett et al. (1998), conducted a research on work-plan, that is, Database for work package and production scheduling, defined a work-plan as the first computer tool designed specifically to implement lean production philosophy in construction. According to them, work-plan guides the user step by step through the process of spelling out work packages, identifying constraints, checking constraints satisfaction, releasing work packages, and allocating resources; then at the end of the week, collecting field progress data and reasons for plan failure. This systematic approach helped the user create quality work plans and learn from understanding reasons for failure.

discuss the role of production planning department, including routing, dispatching (issuing shop orders) and scheduling. According to Stevenson (2009), in the decision making hierarchy, scheduling decisions are the final step in the transformation process before actual output occurs.

Wight (1984) puts the two key problems in the production scheduling as “priorities” and “capacity”. In other words, what should be done first? And who should do it? He observes that in manufacturing firms, there are multiple types of scheduling, including the detailed scheduling of shop order that shows when each operation must start and complete. A lot of researchers have done.

Bitran et al., (1992) 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. They 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.

Vollmann (1997) classified lot sizing problems with finite planning periods into two models- small bucket and big bucket models. Small bucket models have relatively short periods.

In the small bucket model, at most one type of item can be produced and one setup can incur on the machine during each time period. Examples of this type of model are the Discrete Lot Sizing Problem (DLSP), and Continuous Lot Sizing Problem (CLSP). In DLSP, production must be at capacity if a machine is used to produce an item. In CLSP, the amount of production can vary, but is limited by the capacity of a machine. The solution of the small bucket problem contains production sequence of items on the machine. On the other hand, the big bucket model has fewer, but longer period without restriction on the number of items or setups per period and machine. In large bucket model, many different items can be produced on the same machine in one time period. Examples of large bucket models are the Capacitated Lot Sizing Problem (CLSP), and the General Lot Sizing and Scheduling Problem (GLSP).

2.2 Production Scheduling Models

In scheduling, it is necessary to consider the setup time and cost. According to Bruce (2005), although Master Production Scheduling (MPS) has been studied and used by both academia and industries for quiet a long time, the real complexity involved in making a master plan when capacity is limited, when products have the flexibility of been made at different productions lines, and when performance goals are tight and conflicting has not yet been presented in a simple and practical way. He considered how to attain a given performance by balancing different objectives, such as maximizing service level, and minimizing inventory levels, risk of stock- outs, over time, and set up time.

McKay et al (1995) used a simulation model that showed that longer frozen intervals could lead to greater scheduling stability but at the expense of lower customer service level and higher total cost. In contrast, Sridharan and LaForge (1994), assumed a single product environment, stated that increasing the freezing interval does not result in a major loss in a customer service (as measure by product availability), but increased freezing does lead to higher end-item inventory. Although these authors have addressed some issues of MPS stability and its impact on product availability, they often assume a single item production environment with no capacity constraints.

Coburn (1981) said the objective function minimizes the sum of the total construction cost that occurs in all links of the system during all of the periods. Acting within the constraints and related costs, it was required to determine the crashing time for each activity, which will make the cost function a minimum.

Bixby et al (2006) presented a paper or an article 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 utilized of available men and machines. It penalizes overtime or idle time at any facility. The solution minimizes the inventory and resource-related costs and not just inventory costs. A heuristic is 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.

Chung and Krajewski (1986) demonstrated that in a hierarchical production scheduling framework for a rolling horizon Master Production Schedule (MPS), the product cost structure influences the optimal choice of frozen interval lengths. In a comparative study, Sridharan and LaForge (1989) found that freezing a portion of the Master Production Schedule produces lower lot-sizes cost and more stable schedule than using safety stock at the MPS level.

Cambell (1992), using three different method for determining safety stock requirement, concludes that as the length of frozen interval increases there could be a greater need for safety stock. Lin and Krajewski (1992) identified three MPS factors, namely, the length of the frozen interval, the re-planning interval, and the forecast window that could have a significant impact on the total system costs.

Sridharan and Berry (1990) showed that increasing the length of the frozen interval improves schedule stability but that also increases cost.

Vollmann (1997) conducted a research that dealt with real world conditions involving a case study of MPS stability for paint manufacturing. He found that under conditions of minimum batch-sizes and demand certainty, freezing the MPS leads to considerably high levels inventory and high cost during peak periods of demands. In addition, Zhao, Xie and Jiang (2001) provided a comprehensive analysis of lot-sizing choice and freezing of the MPS as related to stability. Both of these studies analysis MPS stability under conditions of finite capacity (FC), an important consideration in the real world of manufacturing. As noted, several previous studies of MPS stability under conditions of infinite capacity exist, however, Zhao, Xie and Jiang (2001) comment, "it is uncertain whether the result found under incapacitated systems can be applied to capacitated systems.

According to Gantt et al (1973), many decisions need to be made during the development of an MPS, such as; which product should be scheduled, in what quantity, and to which resources? Is over time needed? Should inventory be built for future periods? Should backlogging be considered? Clearly an MPS process depends on the combination of many different parameters. For this type of problem, it is extremely difficult to find a solution that satisfied all objectives involved simultaneously, mainly because of the great number of variables involved. It is known that finding an optimal MPS solution for industrial scheduling scenarios is time consuming despite nowadays computers being extremely fast. It is common, therefore, to use heuristics (metal-heuristics) to find good plans in reasonable computer time.

Senouci and Eldin, (1996) used methods such as Critical Path Method (CPM) and Programme Evaluation and Reviewed Techniques (PERT) to established a feasible and desirable relationship between the time and cost of project by reducing the target time and taken into account the cost of expediting. A number of graphical scheduling methods were developed for planning and scheduling of construction projects and these were the line of balance and vertical production methods. These techniques were neither suitable for the scheduling of linear projects or adequate for addressing typical challenge related to time-cost, trade-off.

Eppen and Martin, (1987). This formulation concerned the scheduling of the activities, which combined to make a project. The analysis requires a graphical illustration of the starting and ending times costs for each activity of the project are known. The linear programming formulation provided a means of selecting the least costly schedule for desired completion time.

Simpson (2005) in a recent paper said, Computer Integrated Manufacturing (CIM) had become the most practical production system. Nevertheless, some problems appear in the stage of scheduling that were affected by the complexity of the system. Especially, CIM was classified to be an on-line system that had to decide the production schedule within a very short period.

Wilson (2003) explained that, linear programming analysis may be utilized to maximize a linear function subject to a finite number of linear constraints. In constructing the model, the objective function was to minimize the overall cost in order to reduce the completion time of construction projects. By solving the linear programming problem, the crash schedule and the corresponding crash cost can be found.

Shapiro (1993) and Smith (1956) showed that, the scheduling problem was to dynamically decide whether the server should be idle or working, and in the latter case, to decide which stage of which process to serve next. The objective was to minimize the long run expected average cost, which included for holding work-in process inventory (which may differ by process type and service stage) and backordering and holding finished goods inventory (which may differ by product type). They assumed that the workstation must be busy the great majority of the time in order to satisfy customer demand, and approximate the scheduling problem by control problem involving Brownian motion.

Senouci and Eldin (1996) presented a dynamic programming formulation for the scheduling of non sequential or nonserial activities to determine the project time-cost profile which determines possible project duration and their minimum project total cost. The formulation considered the effects of interruptions, minimum project direct cost, and minimum project duration.

Elmaghraby and Pulat (1997) considered completion schedules on an arbitrary set of milestone events by developing an efficient algorithm to determine the project schedule which minimizes the sum of the total cost plus penalties for late completion. Another extension was by Moore et al., (1998) who used goal programme to consider multiple objectives, such as completion time, resources levelling and operation within a limited budget.

2.3 Integration of Production Planning and Scheduling

Production planning and scheduling belong to different decision making levels in process operation, they are also closely related since the result of planning problem is the production target of scheduling problem.

A lot of researchers have proposed production planning methods that incorporate scheduling sub models (Basset et al (1996); Grossman et al (1996). Maravelias and Sung (2008) and Shah (2005) reviewed the integration of medium term production planning with scheduling and went further to discuss the main solution strategies developed to solve the integrated models effectively. Lin et al (2002) presented a three level integrated model for medium term multi-stage production scheduling.

Yan et al (2007) hierarchically solved an integrated model. They first solved the production planning problem in the presence of aggregate capacity constraints to get the production amount and then use tabu-search to ensure feasibility at the lower level. Papageorgion and Pantelids (1996) proposed an integrated planning and scheduling model where each higher level time period is made up of cycles.

Grossman (2006) proposed an integrated planning and scheduling model for scheduling continuous task on a single machine. They used iteration method to solve the resulting model. Joly et al (2002) proposed an integrated model for a refinery. The planning problem defined refinery topology and operating points, while the scheduling problem managed crude oil unloading from pipe lines, transferring to storage tanks and charging into units. The integrated model was solved using the branch and bound method.

In production planning and scheduling, it is very necessary to consider various uncertainties which affects the production processes. In the real world, there are many forms of uncertainties that affect production processes. Galbraith (1973) defined uncertainty as the difference between the amount information required to perform a task and amount of information already possessed. Ho (1989) categorized uncertainty into two groups:

(i) Environmental uncertainty and

(ii) System uncertainty.

Environmental uncertainty includes uncertainties beyond the production processes such as demand uncertainty and supply uncertainty.

System uncertainty is related to uncertainties within the production processes, such as operation yield production lead time, failure of production system, quality and changes to product structure uncertainties etc.

Honkomp et al (1999), Sand and Engell (2004) discussed hierarchical approaches that employ rolling horizon method to address problems under uncertainty. In this study, various uncertainties affecting production processes are considered in solving the problem of production planning and scheduling.

In considering a linear programming algorithm for least cost, Selinger (1980) developed a dynamic programming model for linear project. His work ignored to incorporate the cost as decision variable in the optimization process. As an extension of the Selinger's work Russel and Caselton (1988) formalized a N-stage dynamic programming solutions into two state variable to determine the minimum project duration. In the optimization process, the developed model ignored the activities cost as a decision variable.

Reda (1990) developed a linear programming to identify minimum cost maintaining constant production rates and rates repetitive projects. This method could only be used for nontypical linear project and not applicable to construction activities were accomplished serially. In reality, most construction activities were accomplished concurrently while others were accomplished serially.

Applequist G (1997) proposed that, another serious shortcoming has been the computational time when changes of network logic are involved. Finally, the excessive or inappropriate use of computers especially in a moderately sized network is another major factor of such failures. Because of these major failings, such programs have led to dissatisfaction and found little acceptance in the construction industry.

Barany et.al,(1984) Increased sophistication in optimization techniques have led to examine the possibility of incorporating a time-cost trade –off within an optimization framework.

Cattrysse and Maes (1990) When changes in the network logic are involved, this method has advantage that decisions required of the decision maker are simple, and can handle a large data or alternatives. Thus optimization techniques have been developed to aid in the quick determination of the minimum cost for every possible value of project duration. Clearly, the use of optimization techniques incorporated with time-cost trade-off becomes an economic necessity and the objective of this research.

Floudas (1995) said, most construction managers are continually facing a situation in which they must take a decision whether to complete the project sooner than originally specified in the contract because of the clients request and/ or to optimize the cost of expediting. The plan duration is decreased by crashing all critical activities either by authorizing over time work or applying additional resources.

Ackoff (1963) said optimal schedule cost can be determined by try and error for small project, but realistic project consisting of many activities, such trial-and error becomes extremely tedious and impossible. A very limited number of computer programmes are available but far from perfect. Such programmes have a limited capacity to accept time-cost data and at a very high price. Other limitations of these programmes are that, the only data the computer can handle is the time-cost slope for individual activities.

Ballard and Howell, (1997) said, synchronizing and physically aligning all steps in the production process, so there is little wait time for people or machines, and virtually no staging of partially completed products. Work-plan tries to eliminate unnecessary wait time on site by helping its users screen work packages. Releasing work packages only when all the resources are ready allows the construction to be carried out with minimum chance of being interrupted. As a result, fewer partially-completed work packages are being assigned to crews on site.

Zipkin (1991), proposed that stopping the assembly line to immediately repair quality defects. While this usually is very disruptive for the process as a whole, there are several advantages to doing so; thus the flawed processing step can be corrected right away, before numerous other assemblies have undergone the same treatment, resulting in additional defects, and it is substantially easier and less costly to discover and repair a quality defect early on in a process rather than at the end, after an assembly has been completed.

Bensoussan et al., (1983) considered both discrete and continuous time production scheduling problems, and within the continuous-time frame work, they considered both continuous and impulse control formulations. Sethi and Zhang (1995), Maimon et al. ,(1998).

Hadjinicola and Kumar (2002) assumed that production costs vary linearly with product attributes and allowed for exchange rates, inventory costs and transportations in their analysis. However, the model does not include the supply segments of the supply chain, but considered only the end product manufacturing location for a set of markets.

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. For more complicated cases, development of specific numerical procedures is required.

An important development in the modeling of planning and scheduling in process manufacturing has been the State-task Network (STN) representation introduced by Kondili et al.,(1993). The STN frame work uses materials (states) and tasks as building blocks for the process description, with each task consuming and producing materials while using equipment. An enhancement to the STN representation is the Resource –Task Network (RTN) proposed by Pantelides (1994) which unifies the treatment of both equipment and materials as resources that are consumed (produced) at the start (end) of a task.

Wight et al., (1984) said in coproduction systems, in which multiple products were produced simultaneously in a single production run, were prevalent in many industries. Such systems typically produced a random quantity of vertically differentiated products. This product hierarchy enabled the firm to fill demand for a lower-quality product by covering a higher-quality product. In addition to the challenges presented by random yields and multiple products, coproduction systems often serve multiple customer classes that differ in their product valuations. Furthermore, the sizes of these classes are uncertain. Employing a utility-maximizing customer model, Brian et al, (2008) investigated the production, pricing, down-conversion, and allocation decisions in a two-class, stochastic-demand, and stochastic-yield coproduction system.

For the single-class case, down-conversion will not occur if prices are set optimally. In contrast, it shows that down-conversion can be optimal in the two-class case, even if prices were set optimally. They considered the benefit of positioning certain operational decisions, e.g., the pricing or allocation-rule decisions, until uncertainties were resolved.

They used the term recourse to denote actions taken after uncertainties have been resolved. They found that recourse pricing benefits the firm much more than either down-conversion or recourse allocation do, implying that recourse demand management is more valuable than recourse supply management. Special class of our model includes the single-class and tow-class random-yield newsvendor models.

Bomberger, E. (1966) , showed that the problem of balancing costs of overtime production and inventory storage to minimize the total cost of meeting given sales requirements can be set up as a transportation problem. Accordingly, Bowman suggested the use of the method of Charnes and Cooper for the solution.

Wolsey (1997), focusing on optimal control theory, extensive studies and analysis has been carried out on the production-inventory scheduling problems, using the optimal control methodology. The pioneering work by (Hwang et al., 1967) which modeled a simple problem of aggregate production planning in a continuous-time form had been acknowledged.

CHAPTER 3

METHODOLOGY

3.1 The Transportation Problem

Transportation method is a simplified version of the simplex technique that may be used to solve a type of linear programming problem. Because of its major application in solving problems involving several product sources and several destinations of products, this type of problem is frequently called the transportation problem. It obtains its name from its application to problems involving transporting products from several sources to several destinations.

3.1.1 Formulation

The Transportation Problem was one of the original applications of linear programming models. The story goes like this. A firm produces goods at m different supply centres. Label these $i = 1, 2, 3, ..., m$. The supply produced at supply centre i is S_i. The demand for the goods is spread out at n different demand centres. Label these $j = 1, 2, 3, ..., n.$ The demand at the j^{th} demand centre is D_j. The problem of the firm is to get goods from supply centres to demand centres at minimum cost. Assume that the cost of shipping one unit from supply centre i to demand centre j is C_{ij} and that shipping cost is linear. That means that if you shipped X_{ij} units from centre i to demand centre j, then the cost would be $c_{ij}x_{ij}$.

Where x_{ij} is the number of units shipped from supply centre i to demand centre j. The problem is to identify the minimum cost shipping schedule. The constraints are that you must (at least) meet demand at each demand centre and cannot exceed supply at each supply centre.

The cost of the schedule, by the linearity assumption, is given by

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

Figure out the constraints. Consider centre i. The total amount shipped out of supply centre i is $\sum_{j=1}^{n} x_{ij}$. x_{ij} is what you ship from i to j. From i you can ship to any demand centre $(j = 1, 2, 3, \ldots, n)$. The sum above just adds up the total shipment from supply centres i. This quantity cannot exceed the supply available, hence the constraint

$$\sum_{j=i}^{n} x_{ij} \le s_i \quad \text{for all} \quad i = 1, 2, 3, \ldots, m.$$

Similarly, the constraints that guarantee that you meet the demand at each of the demand centres look like: $\sum_{i=1}^{m} x_{ij} \ge D_j$ for all $j = 1, 2, 3, \ldots, n$.

The only way that the problem can be feasible is if total supply exceeds total demand

$\sum_{j=1}^{n} D_j \le \sum_{i=1}^{m} S_i$. If this equation did not hold, then there would be excess demand. There would be no way to meet all of the demand with available supply. If there is enough supply, then you should be able to convince yourself that you can satisfy the constraints of the problem that is , the problem is feasible unless there is excess demand. It is conventional to assume that the total supply is equal to total demand if so, that is, if $\sum_{j=1}^{n} D_j = \sum_{i=1}^{m} S_i$ then all of the constraints in the problem must hold as equations (that is, when total supply equals total demand, then a feasible transportation plan exactly meets demand at each demand centre and uses up all the supply at each supply centre). (In cases where there is excess supply, you can transform the problem into one in which supply is equal to demand by assuming that you can freely dispose of the extra supply)

After making the simplification that total supply equals total demand, we arrive at the standard formulation of the transportation problem. The problem provides m supplies S_i for $i = 1, 2, 3, ..., m$, n demands D_j for $j = 1, 2, 3, ..., n$ that satisfy $\sum_{j=1}^{n} D_j = \sum_{i=1}^{m} S_i$, and costs C_{ij} .

The objective is to find a transportation plan denoted by x_{ij} to solve:

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

subject to $\sum_{j=1}^{n} x_{ij} = S_i$ for all $i = 1, 2, 3, ..., m$.

and $\sum_{i=1}^{m} x_{ij} = D_j$ for all $j = 1, 2, 3, ..., n$.

In this problem it is natural to assume that the variables x_{ij} take on integer values (and non-negative ones). That is, you can only ship items in whole number batches.

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

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

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

Let x_{ij} represent the (unknown) number of units to be shipped from source i to destination j . Then the standard mathematical model for this problem is

Minimize:

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

Subject to:

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

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

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

where

m … number of sources (month of production)

n … number of destinations (month of distribution)

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

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

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

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

3.1.2 The Transportation Tableau

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

Table 3.1 The Transportation Tableau

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

3.2 Balanced Transportation Problem

If total supply equals to total demand, the problem is said to be a balanced transportation problem: that is $\sum_{i=1}^{m} a_i = \sum_{j=1}^{n} b_j$

3.2.1 Methods to find the Balanced Transportation Problem

If total supply equals to total demand, the problem is said to be a balanced transportation problem: that is $\sum_{i=1}^{m} a_i = \sum_{j=1}^{n} b_j$

Balancing a Transportation Problem if total supply exceeds total demand

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

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

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

3.3 The Solution Method

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

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

It involves

i. finding an initial, basic feasible solution;

ii. testing the solution for optimality;

iii. improving the solution when it is not optimal

iv. repeating steps (ii) and (iii) until the optimal solution is obtained.

3.3.1 Methods of Finding Initial Basic Feasible Solution for Transportation Problem.

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

There are three basic methods:

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

3.3.2 The Northwest Corner Method

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

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

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

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

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

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

3.3.3 The Least Cost Method

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

Step 1: find the decision variable with the smallest shipping cost $x_{ij.}$ Then assign x_{ij} its largest possible value, which is the minimum of s_i and d_j.

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

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

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

3.3.4 The Vogel's Approximation Method (VAM)

In addition to the northwest corner and intuitive lowest-cost methods of setting an initial solution to transportation problems, we introduce one other important technique – Vogel's approximation method (VAM). VAM is not quite as simple as the northwest corner approach, but it facilitates a very good initial solution – as a matter of fact, one that is often the optimal solution.

Vogel's approximation method tackles the problem of finding a good initial solution by taking into account the costs associated with each route alternative. This is something that the northwest corner rule did not do. To apply the VAM, we first compute for each row and column the penalty faced if we should ship over the second best route instead of the least-cost route.

The steps involved in determining an initial VAM solution are below

VAM step 1: For each row and column of the transportation table, find the difference between the two lowest unit shipping costs. These numbers represent the difference between the distribution cost on the best route in the row or column and the second best route in the row or column. (This is the opportunity cost of not using the best route)

VAM step 2: Identify the row or column with the greatest opportunity cost, or difference.

VAM step 3: Assign as many units as possible to the lowest cost square in the row or column Selected.

VAM step 4: Eliminate any row or column that has just been completely satisfied by the assignment just made. This can be done by placing Xs in each appropriate square.

VAM step 5: Recompute the cost differences for the transportation table, omitting rows or columns crossed out in the preceding step.

VAM step 6: Return to step 2 and repeat the steps until an initial feasible solution has been obtained.

3.4 Computing To Optimality

There are two methods, namely

- The stepping stone method
- The modified distribution method

These are initial basic feasible solution to compute to optimality.

3.4.1 The Steppingstone Method

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

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

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

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

3.4.2 The Modified Distribution Method (MODI)

The MODI method allows us to compute improvement indices quickly for each unused square without drawing all of the closed paths. Because of this, it can often provide considerable time savings over other methods for solving transportation problems.

MODI provides a new means of finding the unused route with the largest negative improvement index. Once the largest index is identified, we are required to trace only one closed path. This path helps determine the maximum number of units that can be shipped via the unused route.

In applying the MODI method, we begin with an initial solution obtained by using the north west corner rule or any other rule. But now we must compute a value for each row (call the values R_1 R_2 R_3 if there are three rows) and for each column ($K_1K_2K_3$) in the transportation table. In general, let $R_i =$ value assigned to row i

$K_j =$ value assigned to column j

$C_{ij} =$ cost in square ij (cost of shipping from source i to destination j)

The MODI method, it requires five steps:

1. To compute the values for each row and column, set $R_i + K_j = C_{ij}$ but only for those squares that are currently used or occupied. For example, if the square at the intersection of row 2 and column 1 is occupied, we set $R_2 + K_1 = C_{21}$.

2. After all equations have been written, set $R_1 = 0$.

3. Solve the system of equations for all R and K values.

4. Compute the improvement index for each unused square by the formula

   improvement index $\left(I_{ij}\right) = C_{ij} - R_i - K_j$.

5. Select the largest negative index and proceed to solve the problem as you did using the stepping-stone method.

Table 3.2

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

m … number of sources (months of production)

n … number of destinations (months of distribution)

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

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

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

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

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

3.5 Test for optimality

For each occupied cell (i,j) of the transportation tableau, compute a row index R_i and a column index K_j such that $C_{ij} = R_i + K_j$

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

Since there are (*m + n)* row and column in dices altogether,it follows that by prescribing an arbitrary value for one of them, we say $R_1 = 0$,we then solve the equations for the remaining

(m+n -1) unknowns R_i, K_j .

With all the R_i, K_j known, we compute for each unoccupied cell such that the evaluation factor e_{st} is computed as $e_{st} = C_{st} - R_s - K_t$

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

3.5.1 Improvement to optimality

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

3.5.2 If the total supply exceeds the total demand

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

3.5.3 If the total demand exceeds total supply

If the total demand exceeds 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 warehouse is zero (0).

3.6 How to Pivot a Transportation Problem

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

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

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

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

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

3.7 Degeneracy

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

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

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

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

3.7.1 How to Overcome Degeneracy

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

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

3.8 The Production Problem

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

for example transhipment problems permits shipments of goods from origins to transhipment nodes and on to destinations, from one origin to another origin, from one transhipment location to another, from one destination location to another and directly from origins to destinations.

The general linear programming model of a production problem is

Minimize

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

Subject to:

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

Origin nodes i …. …. (1)

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

Production nodes …. ….(2)

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

Destination nodes j …. ….(3)

Where

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

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

s_i = supply at origin node i

d_{ij} = demand at origin node j

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

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

Model

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

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

3.9 Conclusion

The transportation problem is only a special topic of the linear programming problems. It would be a rare instance when a linear programming problem would actually be solved by hand. There are too many computers around and too many LP software programs to justify spending time for manual solution. TORA Solver software will be used to analyze the data. (There are also programs that assist in the construction of the LP or TP model itself. Probably the best known is GAMS—General Algebraic Modeling System (GAMS-General, San Francisco, CA). This provides a high-level language for easy representation of complex problems.

CHAPTER 4

DATA ANALYSIS AND FINDINGS

4.1 INTRODUCTION

Guinness Ghana Brewery Limited (GGBL), Kumasi Kaase produces both alcoholic and non alcoholic beverages. The alcoholic beverages include Smirnoff, Guinness, Star, Gulder etc and the non alcoholic beverages include Malta Guinness, Malta Guinness Quench, Amstel Malta, Alvaro etc. Guinness Ghana Brewing Limited, Kaase Kumasi, being a production firm must determine the quantity of goods to produce during each of the next twelve month in order to meet given demand.

This chapter deals with data collection, data analysis and discussion, the discussion of the results obtained from production planning of GGBL. The data was obtained from GGBL Production unit; the cost of transporting goods involves fuel consumption of vehicle, cost of labour and maintenance. For equity and fairness, the transporting cost for their key distributers is uniform irrespective of the distance.

A short History of Smirnoff

Vodka Smirnoff is one of the most accredited and popular vodkas in the world. Smirnoff vodka brand has been promoted by the American Heublein company and it belongs now to the British Diageo Corporation. Today Vodka Smirnoff is imported in 130 countries. By the way, the most popular Vodka brand is of the Russian Origin. At first Smirnoff was a distillery factory founded in Moscow by Peter Arsenyevich Smirnov. The Vodka made under his management, was expensive, accredited and consequently didn't provoke traditional alcoholic violence. People were very much surprised, when learned that the name of the vodka originates not from a word " Smirniy " (Russian for "quiet ") but from the surname of inventor who contrived how to clear vodka of unpleasant, poisoning elements.

Brand history: In 1818 Ivan Smirnov founded a Merchant house in Moscow, but only his great nephew Pyotr Arsenyevich assingned the present scope to business. Warmed up by ambitions, he redeemed the shares of his cousin and reconstructed distillery. Pyotr Smirnoff has based the distillery factory in Moscow in 1860, under the trading name P. A. Smirnoff. The Vodka under trademark "Smirnoff", was allocated with excellent quality and gained authority soon among senior public.

The landmark in the history Smirnoff became the invention of the "Moscow mule" cocktail. The cocktail structure included ginger beer, Vodka Smirnoff and a Slice of lime. "Moscow mule" was served in a copper mug. This very "animal" confirmed Smirnoff Vodka as a favourite American drink of the end 40. Very soon Smirnoff became an integral part of "Bloody Mary","Screwdriver" and other well-known cocktails. So, having obtained an initial recognition in Russia, vodka came to other continents and became the most popular spirit in the world. Pure, transparent vodka with surprisingly soft and gentle taste, the first class grain spirit , special water and unique process of filtration by specially processed activated coal are the secrets of flavouring advantages and faultless quality of this drink created in the best traditions of the Russian and American manufacture of alcohol. Alcohol by volume is of the range 35% - 50% .

The data shows the production of Smirnoff from July 2011 to August 2012.

4.3 Computational Procedure and Data Analysis

The company brews and package the Smirnoff into bottles. The bottle contains one litre of Smirnoff and is packaged in cartons. A carton contains 24 bottles, each with total volume of 24 litres

Table 4.1 represent the company's production capacities and expected demands for one of its product, which is Smirnoff from September 2011 to August 2012.

Table 4.1 Production Capacity of Smirnoff (in litres)

Months	Demand	Regular Capacity	Overtime Capacity
September	107520	148320	2928
October	106080	124368	2496
November	102960	200400	4008

December	230400	128472	2544
January	205920	192576	3840
February	130320	158400	3168
March	182736	166008	3312
April	156864	141600	2832
May	120336	120360	2400
June	135360	122808	2448
July	92880	100416	2016
August	153360	122832	2448
Total	1724736	1726560	34440

source: Kumasi Brewery Limited, Production unit .

The first column deals with months within which the data were collected, thus from September 2011 to August 2012. The second column describes the demand amount that must be produced to meet the request made by their clients. The highest demand was recorded in the month of December. The lowest demand was recorded in the Month of July. The total demand and the average demand were 1724736 and 143728 respectively.

The third column shows the regular capacity which is the amount of Smirnoff produced during the normal working hours. The highest regular capacity was recorded as 200400 whiles the lowest regular capacity was recorded as 100416. The total regular production capacity was 1726560 with an average capacity of 143880.

The fourth column which is the overtime capacity is the amount of Smirnoff produced aside the normal working hours. The highest overtime capacity was 4008 and the lowest overtime capacity was 2016. The total overtime capacity was also recorded as 34440 with an average overtime capacity as 2870.

The production capacities and demands are converted to cartons in figures in Table 4.2 by dividing each of the figures in Table 4.1 by 24 litres to obtain the figures in Table 4.2

Table 4.2 Production Capacity (in Cartons)

Months	Demand	Regular Capacity	Overtime Capacity
September	4480	6180	122
October	4420	5182	104
November	4290	5353	167
December	9600	8350	106

January	8580	8024	160
February	5430	6600	132
March	7614	6917	138
April	6536	5900	118
May	5014	5015	100
June	5640	5117	102
July	3870	4184	84
August	6390	5118	102

Production cost of Smirnoff is made up of brewing materials, packaging materials cost and utilities. Production is carried out throughout the day i.e. 24 hours, in three shifts of 8 hours per shift. At the beginning of each month, the company must decide how many products should be produced during the current month.

The regular production cost per carton is GH¢200.10 and the overtime cost per carton is GH¢203.24. Thus, 1.57% increase of the regular production cost per carton. Generally, goods produced are not available for transport during time of production; they are sold during the following month. Those that are not sold within the expected month are added to inventory are carried forward at an average holding cost of GH¢0.25 per carton every month.

Current regular production cost per carton for the months July 2012 to August 2012 is GH¢200.10. For simplicity and uniformity, we assume that demand and capacity for the previous cost per carton from September 2011 to June 2012 are the same as the current cost per carton and that goods used during each month would be used to meet demand for the current month.

Since the company operates 24 hours a day by running shift, overtime is considered as being part of the regular working hours. By having employees work overtime during a month. The unit cost of overtime per carton is GH¢203.24.

The company has an inventory of 668 cartons as of the beginning of September 2011.

It was observed that, the company will incur an overall total regular production cost of GH¢ 14,410,401.60, an overtime cost of GH¢291,649.40 and inventory cost of GH¢ 133,833.80 during the production period. This means the grand total amount of production cost of GH¢14,835,884.80 will be incurred in producing 74119 cartons of Smirnoff to meet demands of its customers.

Applying the transportation problem to the resulting tableau, we solve the production problem using the transportation problem to minimize the sum of production and inventory cost during the next twelve month.

Computational Procedure

A Toshiba Satellite laptop was used for the data presentation and the analysis. The model was Rating 2.1 Windows Experience Index, Processor: Intel(R) Core(TM)2 CPU T5500 @ 1.66GHz: Installed memory (RAM) : 1.00GB (894 MB usable).

TORA Optimization System, Windows®-version 2.00, transportation model software was used to analyse the data.

Vogel's Approximation Method: Another way to find an initial solution.

Vogel's approximation method tackles the problem of finding a good initial solution by taking into account the costs associated with each route alternative. This is something that the northwest corner rule did not do. To apply the VAM, we first compute for each row and column the penalty faced if we should ship over the second best route instead of the least-coast route. The VAM is not quite as simple as the northwest corner approach, but it facilitates a very good initial solution-as a matter of fact, one that is often the optimal solution.

MODI (Modified Distribution) Method

The MODI is used to save the time over stepping stone method. It provides a new means of finding the unused route with the largest negative improvement index. Once largest index identified, we are required to trace only one path, just as with the stepping stone approach, this helps to determine the maximum number of unit that can be shipped by the best unused route.

Table 4.3 Transportation Model

TORA Optimization System, Windows®-version 2.00

Saturday, April 26, 2014 12:33

TRANSPORTATION MODEL -- ORIGINAL DATA

Title: GGBL PRODUCTION CAPACITY FOR ONE YEAR 2011-2012

	Name	D1 W1	D2 W2	D3 W3	D4 W4	D5 W5	D6 W6	D7 W7
S1	SEP (R	200.10	200.10	200.10	200.10	200.10	200.10	200.10
S2	SEP (O	203.24	203.24	203.24	203.24	203.24	203.24	203.24
S3	OCT (R	200.10	200.10	200.10	200.10	200.10	200.10	200.10
S4	OCT (O	203.24	203.24	203.24	203.24	203.24	203.24	203.24
S5	NOV (R	200.10	200.10	200.10	200.10	200.10	200.10	200.10
S6	NOV (O	203.24	203.24	203.24	203.24	203.24	203.24	203.24
S7	DEC (R	200.10	200.10	200.10	200.10	200.10	200.10	200.10
S8	DEC (O	203.24	203.24	203.24	203.24	203.24	203.24	203.24
S9	JAN (R	200.10	200.10	200.10	200.10	200.10	200.10	200.10
S10	JAN (O	203.24	203.24	203.24	203.24	203.24	203.24	203.24
S11	FEB (R	200.10	200.10	200.10	200.10	200.10	200.10	200.10
S12	FEB (O	203.24	203.24	203.24	203.24	203.24	203.24	203.24
S13	MAR (R	200.10	200.10	200.10	200.10	200.10	200.10	200.10
S14	MAR (O	203.24	203.24	203.24	203.24	203.24	203.24	203.24
S15	APR (R	200.10	200.10	200.10	200.10	200.10	200.10	200.10
S16	APR (O	203.24	203.24	203.24	203.24	203.24	203.24	203.24
S17	MAY (R	200.10	200.10	200.10	200.10	200.10	200.10	200.10
S18	MAY (O	203.24	203.24	203.24	203.24	203.24	203.24	203.24
S19	JUN (R	200.10	200.10	200.10	200.10	200.10	200.10	200.10
S20	JUN (O	203.24	203.24	203.24	203.24	203.24	203.24	203.24
S21	JUL (R	200.10	200.10	200.10	200.10	200.10	200.10	200.10
S22	JUL (O	203.24	203.24	203.24	203.24	203.24	203.24	203.24
S23	AUG (R	200.10	200.10	200.10	200.10	200.10	200.10	200.10
S24	AUG (O	203.24	203.24	203.24	203.24	203.24	203.24	203.24
Demand		**4480.00**	**4420.00**	**4290.00**	**9600.00**	**8580.00**	**5430.00**	**7614.00**

		D8 W8	D9 W9	D10 W10	D11 W11	D12 W12	D13 DummyD	**Supply**
S1	SEP (R	200.10	200.10	200.10	200.10	200.10	0.00	**6180.00**
S2	SEP (O	203.24	203.24	203.24	203.24	203.24	0.00	**122.00**
S3	OCT (R	200.10	200.10	200.10	200.10	200.10	0.00	**5182.00**
S4	OCT (O	203.24	203.24	203.24	203.24	203.24	0.00	**104.00**
S5	NOV (R	200.10	200.10	200.10	200.10	200.10	0.00	**5353.00**
S6	NOV (O	203.24	203.24	203.24	203.24	203.24	0.00	**167.00**
S7	DEC (R	200.10	200.10	200.10	200.10	200.10	0.00	**8350.00**
S8	DEC (O	203.24	203.24	203.24	203.24	203.24	0.00	**106.00**
S9	JAN (R	200.10	200.10	200.10	200.10	200.10	0.00	**8024.00**
S10	JAN (O	203.24	203.24	203.24	203.24	203.24	0.00	**160.00**
S11	FEB (R	200.10	200.10	200.10	200.10	200.10	0.00	**6600.00**
S12	FEB (O	203.24	203.24	203.24	203.24	203.24	0.00	**132.00**
S13	MAR (R	200.10	200.10	200.10	200.10	200.10	0.00	**6917.00**
S14	MAR (O	203.24	203.24	203.24	203.24	203.24	0.00	**138.00**
S15	APR (R	200.10	200.10	200.10	200.10	200.00	0.00	**5900.00**
S16	APR (O	203.24	203.24	203.24	203.24	203.24	0.00	**118.00**
S17	MAY (R	200.10	200.10	200.10	200.10	200.10	0.00	**5015.00**
S18	MAY (O	203.24	203.24	203.24	203.24	203.24	0.00	**100.00**
S19	JUN (R	200.10	200.10	200.10	200.10	200.10	0.00	**5117.00**
S20	JUN (O	203.24	203.24	203.24	203.24	203.24	0.00	**102.00**

S21	JUL (R	200.10	200.10	200.10	200.10	200.10	0.00	**4184.00**
S22	JUL (O	203.24	203.24	203.24	203.24	203.24	0.00	**84.00**
S23	AUG (R	200.10	200.10	200.10	200.10	200.10	0.00	**5118.00**
S24	AUG (O	203.24	203.24	203.24	203.24	203.24	0.00	**102.00**
Demand		**6536.00**	**5014.00**	**5640.00**	**3870.00**	**6390.00**	**1511.00**	

TRANSPORTATION MODEL -- TABLEAUS (Vogel's Method)

Title: GGBL PRODUCTION CAPACITY FOR ONE YEAR 2011-2012

Iteration 1: **ObjVal=379396.40**

	Name		D1 W1 v1=200.10	D2 W2 v2=200.10	D3 W3 v3=200.10	D4 W4 v4=200.10	D5 W5 v5=200.10	D6 W6 v6=200.10
S1	SEP (R	u1=0.00	200.10 **4480** 0.00	200.10 **1624** 0.00	200.10 0.00	200.10 0.00	200.10 0.00	200.10 0.00
S2	SEP (O	u2=0.00	203.24 -3.14	203.24 -3.14	203.24 -3.14	203.24 -3.14	203.24 -3.14	203.24 -3.14
S3	OCT (R	u3=0.00	200.10 0.00	200.10 **2796** 0.00	200.10 **2386** 0.00	200.10 0.00	200.10 0.00	200.10 0.00
S4	OCT (O	u4=0.00	203.24 -3.14	203.24 -3.14	203.24 -3.14	203.24 -3.14	203.24 -3.14	203.24 -3.14
S5	NOV (R	u5=0.00	200.10 0.00	200.10 0.00	200.10 **1904** 0.00	200.10 **3449** 0.00	200.10 0.00	200.10 0.00
S6	NOV (O	u6=0.00	203.24 -3.14	203.24 -3.14	203.24 -3.14	203.24 -3.14	203.24 -3.14	203.24 -3.14
S7	DEC (R	u7=0.00	200.10 0.00	200.10 0.00	200.10 0.00	200.10 **6151** 0.00	200.10 **2199** 0.00	200.10 0.00
S8	DEC (O	u8=0.00	203.24 -3.14	203.24 -3.14	203.24 -3.14	203.24 -3.14	203.24 -3.14	203.24 -3.14
S9	JAN (R	u9=0.00	200.10 0.00	200.10 0.00	200.10 0.00	200.10 0.00	200.10 **6381** 0.00	200.10 **1643** 0.00
S10	JAN (O	u10=0.00	203.24 -3.14	203.24 -3.14	203.24 -3.14	203.24 -3.14	203.24 -3.14	203.24 -3.14
S11	FEB (R	u11=0.00	200.10 0.00	200.10 0.00	200.10 0.00	200.10 0.00	200.10 0.00	200.10 **3787** 0.00
S12	FEB (O	u12=0.00	203.24 -3.14	203.24 -3.14	203.24 -3.14	203.24 -3.14	203.24 -3.14	203.24 -3.14

S13	MAR (R	u13=0.00	200.10 0.00	200.10 0.00	200.10 0.00	200.10 0.00	200.10 0.00	200.10 0.00
S14	MAR (O	u14=0.00	203.24 -3.14	203.24 -3.14	203.24 -3.14	203.24 -3.14	203.24 -3.14	203.24 -3.14
S15	APR (R	u15=-0.10	200.10 -0.10	200.10 -0.10	200.10 -0.10	200.10 -0.10	200.10 -0.10	200.10 -0.10
S16	APR (O	u16=0.00	203.24 -3.14	203.24 -3.14	203.24 -3.14	203.24 -3.14	203.24 -3.14	203.24 -3.14
S17	MAY (R	u17=0.00	200.10 0.00	200.10 0.00	200.10 0.00	200.10 0.00	200.10 0.00	200.10 0.00
S18	MAY (O	u18=0.00	203.24 -3.14	203.24 -3.14	203.24 -3.14	203.24 -3.14	203.24 -3.14	203.24 -3.14
S19	JUN (R	u19=0.00	200.10 0.00	200.10 0.00	200.10 0.00	200.10 0.00	200.10 0.00	200.10 0.00
S20	JUN (O	u20=0.00	203.24 -3.14	203.24 -3.14	203.24 -3.14	203.24 -3.14	203.24 -3.14	203.24 -3.14
S21	JUL (R	u21=0.00	200.10 0.00	200.10 0.00	200.10 0.00	200.10 0.00	200.10 0.00	200.10 0.00
S22	JUL (O	u22=0.00	203.24 -3.14	203.24 -3.14	203.24 -3.14	203.24 -3.14	203.24 -3.14	203.24 -3.14
S23	AUG (R	u23=0.00	200.10 0.00	200.10 0.00	200.10 0.00	200.10 0.00	200.10 0.00	200.10 0.00
S24	AUG (O	u24=0.00	203.24 -3.14	203.24 -3.14	203.24 -3.14	203.24 -3.14	203.24 -3.14	203.24 -3.14
	Demand		**4480**	**4420**	**4290**	**9600**	**8580**	**5430**

	D7 W7 v7=200.10	D8 W8 v8=200.10	D9 W9 v9=200.10	D10 W10 v10=200.10	D11 W11 v11=200.10	D12 W12 v12=200.10	D13 DummyD v13=0.00	**Supply**
S1	200.10 0.00	200.10 0.00	200.10 0.00	200.10 0.00	200.10 0.00	200.10 0.00	0.00 **76** 0.00	**6180**
S2	203.24 -3.14	203.24 -3.14	203.24 -3.14	203.24 -3.14	203.24 -3.14	203.24 -3.14	0.00 **122** 0.00	**122**
S3	200.10 0.00	200.10 0.00	200.10 0.00	200.10 0.00	200.10 0.00	200.10 0.00	0.00 0.00	**5182**
S4	203.24 -3.14	203.24 -3.14	203.24 -3.14	203.24 -3.14	203.24 -3.14	203.24 -3.14	0.00 **104** 0.00	**104**
S5	200.10 0.00	200.10 0.00	200.10 0.00	200.10 0.00	200.10 0.00	200.10 0.00	0.00 0.00	**5353**
S6	203.24 -3.14	203.24 -3.14	203.24 -3.14	203.24 -3.14	203.24 -3.14	203.24 -3.14	0.00 **167** 0.00	**167**
S7	200.10 0.00	200.10 0.00	200.10 0.00	200.10 0.00	200.10 0.00	200.10 0.00	0.00 0.00	**8350**
S8	203.24 -3.14	203.24 -3.14	203.24 -3.14	203.24 -3.14	203.24 -3.14	203.24 -3.14	0.00 **106** 0.00	**106**
S9	200.10 0.00	200.10 0.00	200.10 0.00	200.10 0.00	200.10 0.00	200.10 0.00	0.00 0.00	**8024**
S10	203.24 -3.14	203.24 -3.14	203.24 -3.14	203.24 -3.14	203.24 -3.14	203.24 -3.14	0.00 **160** 0.00	**160**
S11	200.10 **2813** 0.00	200.10 0.00	200.10 0.00	200.10 0.00	200.10 0.00	200.10 0.00	0.00 0.00	**6600**
S12	203.24 -3.14	203.24 -3.14	203.24 -3.14	203.24 -3.14	203.24 -3.14	203.24 -3.14	0.00 **132** 0.00	**132**
S13	200.10 **4801** 0.00	200.10 **2116** 0.00	200.10 0.00	200.10 0.00	200.10 0.00	200.10 0.00	0.00 0.00	**6917**
	203.24	203.24	203.24	203.24	203.24	203.24	0.00	

S14	-3.14	-3.14	-3.14	-3.14	-3.14	-3.14	138 0.00	138
S15	200.10 -0.10	200.10 -0.10	200.10 -0.10	200.10 -0.10	200.10 -0.10	200.00 5900 0.00	0.00 -0.10	5900
S16	203.24 -3.14	203.24 -3.14	203.24 -3.14	203.24 -3.14	203.24 -3.14	203.24 -3.14	0.00 118 0.00	118
S17	200.10 0.00	200.10 4420 0.00	200.10 595 0.00	200.10 0.00	200.10 0.00	200.10 0.00	0.00 0.00	5015
S18	203.24 -3.14	203.24 -3.14	203.24 -3.14	203.24 -3.14	203.24 -3.14	203.24 -3.14	0.00 100 0.00	100
S19	200.10 0.00	200.10 0.00	200.10 4419 0.00	200.10 698 0.00	200.10 0.00	200.10 0.00	0.00 0.00	5117
S20	203.24 -3.14	203.24 -3.14	203.24 -3.14	203.24 -3.14	203.24 -3.14	203.24 -3.14	0.00 102 0.00	102
S21	200.10 0.00	200.10 0.00	200.10 0.00	200.10 4184 0.00	200.10 0.00	200.10 0.00	0.00 0.00	4184
S22	203.24 -3.14	203.24 -3.14	203.24 -3.14	203.24 -3.14	203.24 -3.14	203.24 -3.14	0.00 84 0.00	84
S23	200.10 0.00	200.10 0.00	200.10 0.00	200.10 758 0.00	200.10 3870 0.00	200.10 490 0.00	0.00 0.00	5118
S24	203.24 -3.14	203.24 -3.14	203.24 -3.14	203.24 -3.14	203.24 -3.14	203.24 -3.14	0.00 102 0.00	102
	7614	6536	5014	5640	3870	6390	1511	

TRANSPORTATION MODEL OUTPUT SUMMARY

Title: GGBL PRODUCTION CAPACITY FOR ONE YEAR 2011-2012
Final Iteration No.: 15
Objective Value (minimum cost) =14379396.40

From	To	Amt Shipped	Obj Coeff	Obj Contrib
S1: SEP (REG)	D1: W1	4480	200.10	896448.00
S1: SEP (REG)	D2: W2	926	200.10	185292.60
S1: SEP (REG)	D10: W10	208	200.10	41620.80
S1: SEP (REG)	D12: W12	490	200.10	98049.00
S1: SEP (REG)	D13: DummyD	76	0.00	0.00
S2: SEP (OVE)	D13: DummyD	122	0.00	0.00
S3: OCT (REG)	D2: W2	3494	200.10	699149.40
S3: OCT (REG)	D3: W3	1688	200.10	337768.80
S4: OCT (OVE)	D13: DummyD	104	0.00	0.00
S5: NOV (REG)	D3: W3	2602	200.10	520660.20
S5: NOV (REG)	D4: W4	2751	200.10	550475.10
S6: NOV (OVE)	D13: DummyD	167	0.00	0.00
S7: DEC (REG)	D4: W4	6849	200.10	1370484.90
S7: DEC (REG)	D5: W5	1501	200.10	300350.10
S8: DEC (OVE)	D13: DummyD	106	0.00	0.00
S9: JAN (REG)	D5: W5	7079	200.10	1416507.90
S9: JAN (REG)	D6: W6	945	200.10	189094.50
S10: JAN (OVE)	D13: DummyD	160	0.00	0.00
S11: FEB (REG)	D6: W6	4485	200.10	897448.50
S11: FEB (REG)	D7: W7	2115	200.10	423211.50
S12: FEB (OVE)	D13: DummyD	132	0.00	0.00
S13: MAR (REG)	D7: W7	5499	200.10	1100349.90
S13: MAR (REG)	D8: W8	1418	200.10	283741.80
S14: MAR (OVE)	D13: DummyD	138	0.00	0.00
S15: APR (REG)	D12: W12	5900	200.00	1180000.00
S16: APR (OVE)	D13: DummyD	118	0.00	0.00
S17: MAY (REG)	D8: W8	5015	200.10	1003501.50
S18: MAY (OVE)	D13: DummyD	100	0.00	0.00
S19: JUN (REG)	D8: W8	103	200.10	20610.30
S19: JUN (REG)	D9: W9	5014	200.10	1003301.40
S20: JUN (OVE)	D13: DummyD	102	0.00	0.00
S21: JUL (REG)	D10: W10	4184	200.10	837218.40
S22: JUL (OVE)	D13: DummyD	84	0.00	0.00
S23: AUG (REG)	D10: W10	1248	200.10	249724.80
S23: AUG (REG)	D11: W11	3870	200.10	774387.00
S24: AUG (OVE)	D13: DummyD	102	0.00	0.00

Analysis of results generated from the transportation model output summary is presented above.

It was observed that level of demand at each destination has been determined and the total demand was given as 71940 cartons. Then also, the level of supply at each source has been determined and the total supply was given as 72016 cartons with 76 cartons of surplus which was assigned zero cost to signify balance transportation.

The 6180 cartons produced in September, 4480 cartons were shipped to destination one and 1624 cartons as inventory were shipped to destination two.

The total of 5182 cartons produced in October, 2796 cartons were shipped to destination two and 2386 cartons as inventory were shipped to destination three.

The total of 5353 cartons produced in November, 1904 cartons were shipped to destination three and the remaining 3449 cartons as inventory were shipped to destination four.

The demand in destination four was met by regular production of 6151 cartons in December and 3449 cartons inventory from November. In December, the total regular production was 8350 cartons, where 2199 cartons were used as inventory for destination five.

Destination five was partly satisfy by regular production amount of 6381 cartons in January, which produced a total of 8024 cartons, so the remaining 1643 cartons as inventory were shipped to partly satisfy the demand in destination six.

The 6600 cartons produced in February, 3787 cartons were shipped to destination six and 2813 cartons as inventory were shipped to destination seven.

The 6917 cartons produced in March, 4801 cartons were shipped to destination seven and the remaining 2116 cartons as inventory were shipped to destination eight.

The 5900 cartons produced in April, 4420 cartons were shipped to destination eight and 1480 cartons as inventory were shipped to destination nine.

Destination nine, demanded a total of 5014 cartons in that 3534 cartons came from regular production of May couple with the 1480 cartons from inventory.

Destination ten required a total of 5640 cartons, where 1481 cartons were came from May inventory and the remaining 4159 cartons from June. June, the total cartons of 5117, in that, what was left 958 cartons were added to inventory.

Destination eleven required a total of 3870 cartons. 958 cartons from inventory and 2912 cartons from July were used to satisfy destination eleven.

Destination twelve was partly satisfied by 1272 cartons from July production and 5118 cartons from August to make a total demand of 6390 cartons.

Limiting production to only the regular production time the company would be able to have an inventory of 76 cartons by the end of year which is enough to cushion any eventuality.

The implication of this finding showed that the company could have drastically reduced its total production and inventory cost by GH¢455898.40 or 3.07%. In actual fact, the company would have incurred an overall cost of GH¢ 14,835,884.80

4.3. Discussions

Real-time scheduling during which production can take place are the regular shifts and overtime shifts for each of the twelve months. The scheduler enables the company to create production schedules that define the optimal work sequence per resource in a specific timeframe. Since each of these twelve months periods becomes a source, we then add a thirteenth source, that is, the initial inventory, since it can also supply goods.

Almost each month source is appearing twice. The second appearance indicates leftover which adds up to inventory for the next month source. Almost each month source has more than necessary supply.

Costs associated with the initial inventory are future carrying cost only, since production costs and past carrying charges have already been incurred and cannot be minimized. The remaining cost entries are simply the production cost plus storage charges. Any unused overtime capacity will be "shipped" to dummy demand point or destination.

CHAPTER 5

SUMMARY, CONCLUSION AND RECOMMENDATION

5.1 Summary of Findings

The fact that companies are trying to avoid common problems such as high inventory levels, poor customer delivery times, low yield, high scrap and inefficient usage of capacity and production capabilities, is evident in the analysis drawn in the previous chapter. With efficient planning and scheduling, the company was able to reduce the production cost and inventory cost 3.07% by planning. As a result of tactical production planning, the company can manage real-time interaction between sales, planning and production, and maintain low inventory while promising realistic delivery dates to keep their customers satisfied to save more money and resources.

Furthermore, the three primary goals of production system were achieved. The first goal which involves due date, avoiding late completion of jobs and bottlenecks was achieved as unnecessary overtime production was avoided. Then the second goal which involves through put times was achieved as the time a job spent in a system was minimized. And also the third objective which concerns the utilization of work centre would also be achieved as costly equipment and personnel would be fully utilized in order to minimize production and inventory cost. With this, it can be showed that the transportation program used can be used to schedule production activities efficiently. This goes to support the fact that computerized production planning and scheduling tools outperform older manual planning and scheduling methods.

Due to software limitations, but especially the intense work required by the “master production schedulers do not include every aspect of production, but only key elements that have proven their control effectively, such as forecast demand, production costs, inventory costs, lead time, working hours, capacity, inventory levels, available storage, and part supply. The choice of what to model varies among companies and factories.

The study also revealed that efficient planning and scheduling system and control can facilitate the production processes in a number of ways. First and foremost, planning and scheduling system can result in optimum utilization of capacity. Thus companies, with the help of good production plan and schedule system, can schedule their task and production in a way to ensure that production capacities i.e., employees and machinery do not remain idle, they should be fully utilized and that there is no undue queuing up of task since there is proper allocation of task to the production facilities.

It was also observed that proper production planning and scheduling system can result in the reduction of cycle time and increase the turnover.

Significantly, the study revealed that a good production planning and scheduling system ensures quality in terms of production processes, products and packaging. Thus it provides adherence to quality standards thereby ensuring overall quality output. With scheduling, companies would have adequate time to package the finished goods for prompt delivery.

5.2 Conclusion

The company was able to minimize production cost by avoiding or cutting down the introduction of overtime production work schedule of the work plan of the workers by 3.07%.

During the production process for instance, the initial inventory only was 668 cartons together with 6180 cartons of goods produced during regular production in September were used to face demand of 4480 cartons in September. Although, a machine can break down for some length of time or very skilful key personnel could be indisposing at any given time. Even the prices of the row materials can shoot-up at any point in time, in that inventories will cushion the cost for the company to sensitise its customers of the new cost. So to some large extent, a certain level of inventory is necessary. Production scheduling by the company can also ensure that the right supplies are available at the right time.

Again, production planning and scheduling can bring about proper management of inventory. Thus proper production scheduling and control will assist the company to resort to just-in-time systems and thereby reducing the overall inventory. But too little inventory means an insufficient quantity of produce to meet the demand of consumers, in which case customers may defect to other firms.

5. 3 Recommendation

There are changes occurring in the world economic relations with repercussions that transcend national boundaries. The GGBL is well known in Ghana for its contribution to various projects and programmes in Ghana. It has earned some awards in recognition of these contributions. Beginning from the workplace which is the best thing to do, the GGBL has an awareness creation HIV/AIDS program and offers voluntary counselling and testing for employees. Further work on how motivation of employees affects production cost. This suggest that the company should not necessarily maintain a large working or labour force for its production activities as the level of demand must always be the same as the level of supply, for it has been shown that for a balance production the demand should be equal to the supply.

Overtime production scheduling should not be carried throughout the year unless it is to meet specific orders. Otherwise the company would have to stick to the regular production time to meet all orders. Since companies would have to pay higher wages to workers engaged in overtime production, ensuring optimum utilization of human capacity during regular production and of course with efficient machines, company would end up saving money and resources.

I therefore recommend that companies apply planning and scheduling computer software in their production processes in order to achieve optimal production and inventory cost.

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APPENDIX A

DEPARTMENT OF MATHEMATICS
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Our Ref No: Math 18/DA/V.2

Date: 28/08/2012

Brewery Limited Production unit
Kumasi

Dear Sir,

COLLECTION OF DATA

The bearer of this letter, Mr. Adom Derkye, is a second year Mphil. Industrial Mathematics Student in the Department of Mathematics, Kwame Nkrumah University of Science and Technology, (KNUST), and has been assigned a study.

The thesis topic which has been approved by the supervisor is: **"Production Planning and Scheduling".**

I would be grateful if you could assist him gather the needed data for a successful completion of his Mphil Thesis.

The Department guarantees the confidentiality of all information, which would be provided to the student.

Thank you for your kind cooperation.

Yours sincerely,

Dr. E. Osei Frimpong
SUPERVISOR

APPENDIX B

GUINNESS GHANA BREWERIES LIMITED
P.O.BOX 1536, KUMASI, GHANA
TELEPHONE:(233) 3220 83333 FAX:(233) 3220 83521

P.O.BOX 3610, ACCRA, GHANA
TELEPHONE:(233) 302 42 8000 FAX: (233) 302 42 8102

GUINNESS GHANA
BREWERIES LIMITED

September 1, 2012

Dr. E. Osei Frimpong
Supervisor / Lecturer
Department of Mathematics
Kwame Nkrumah University of Science and Technology (KNUST)
Kumasi

Dear Dr. Frimpong,

RE: COLLECTION OF DATA

Guinness Ghana Breweries Limited (GGBL), Ghana's leading total beverage company presents its compliments to you and your school.

We acknowledge receipt of your letter dated August 28, 2012 with reference **Math 18/DA/V.2** requesting to collect information for the bearer on an Mphil. thesis with topic "**Production Planning and Schedule**".

GGBL is one of the first companies to be listed on the Ghana Stock Exchange (GSE). We remain the only beverage company still listed on the GSE. As a listed company, information about GGBL is already available in the public domain.

We wish you well in your endeavor.

Yours faithfully,

Nana Yaa Ofori-Atta
Corporate Relations Director

CC: Mr. Adom Derkye, Student, Department of Mathematics, KNUST, Kumasi

APPENDIX C

GGBL PRICE LIST EFFECTIVE *JULY 09 2012*

GUINNESS GHANA BREWERIES LIMITED

DESCRIPTION	BAILEYS 1L	BAILEYS 75cl	BAILEYS 50cl	BAILEYS 5cl	BAILEYS 20cl	Baileys 75cl 6x01 Glass Pk	J.W RED LABEL 1L	J.W RED LABEL 75cl	J.W RED LABEL 5cl	J.W BLACK LABEL 1L	J.W BLACK LABEL 75cl	J.W BLACK LABEL 5cl	J.W Green LABEL 75cl	J.W Blue LABEL 75cl	J.W GOLD LABEL 75cl	J.W RED LABEL 20cl	Gordon's Dry Gin 1L	Gordon's Dry Gin 75cl	Gordon's Dry Gin 5cl	Gordon's Dry Gin 20cl	White Horse 1L	White Horse 75cl
PRICE LIST PER CASE																						
To Key Distributors	338.10	255.30	172.96	128.60	200.28	187.45	333.50	255.30	441.60	708.40	533.60	736.00	874.00	1,746.00	1,334.00	400.58	250.70	184.00	294.39	232.62	285.20	[illegible]
To Retailers	375.67	283.67	192.18	143.11	222.65	208.28	370.56	283.67	490.67	787.11	592.89	817.78	971.11	1,942.22	1,482.22	445.10	278.56	204.44	327.10	258.46	316.89	235.11
PRICE LIST PER BOTTLE																						
To Key Distributors	28.18	21.28	14.41	1.61	8.35	31.24	27.79	21.28	2.30	59.03	44.47	3.83	72.83	291.33	111.17	8.35	20.89	15.33	1.53	4.85	23.77	[illegible]
To Retailers	31.31	23.64	16.01	1.79	9.27	34.71	30.88	23.64	2.56	65.59	49.41	4.26	80.93	323.70	123.52	9.27	23.21	17.04	1.70	5.38	26.41	[illegible]
Recommended Retail Price per bottle	36.75	27.75	18.80	2.10	12.00	40.75	36.25	27.75	3.00	77.00	58.00	5.00	95.00	380.00	145.00	12.00	27.25	20.00	2.00	7.00	31.00	23.00

DESCRIPTION	Smirnoff Red 1L	Smirnoff Red 5cl	Smirnoff Blue 1L	Smirnoff Citrus Twist 1L	Smirnoff Orange Twist 1L	Smirnoff Rasberry Twist 1L	Smirnoff Apple Twist 1L	Smirnoff Black 1L	Smirnoff 20cl	[illegible] Jam Rum 1L 12X01	Captain Morgan Spiced 1L	J&B Rare 1L	J&B Rare 75cl	J&B Rare 5cl	J&B Rare 20cl	Vat 69 1L	Tanqueray Gin 75cl	Pimm's No. 1 Cup 75cl	Jose Cuervo ES Gold 1L	Jose Cuervo ES Silver 1L	Bell's Original 1L
PRICE LIST PER CASE																					
To Key Distributors	172.50	170.20	184.00	200.10	200.10	200.10	200.10	255.30	232.60	234.60	209.30	349.60	273.70	230.00	100.15	165.60	225.40	147.20	377.20	170.20	248.40
To Retailers	191.67	189.11	204.44	222.33	222.33	222.33	222.33	283.67	258.46	260.67	232.56	388.44	304.11	255.56	111.27	164.00	250.44	163.56	419.11	189.11	276.00
PRICE LIST PER BOTTLE																					
To Key Distributors	14.38	1.42	15.33	16.68	16.68	16.68	16.68	21.28	4.85	19.55	17.44	29.13	22.81	1.92	8.35	13.80	18.78	12.27	31.43	28.37	20.70
To Retailers	15.97	1.58	17.04	18.53	18.53	18.53	18.53	23.64	5.38	21.72	19.38	32.37	25.34	2.13	9.27	15.33	20.87	13.63	34.93	31.52	23.00
Recommended Retail Price per bottle	18.75	1.85	20.00	21.75	21.75	21.75	21.75	27.75	7.00	25.50	22.75	38.00	29.75	2.60	12.00	18.00	24.50	16.00	41.00	37.00	27.00

SPIRITS JULY 09 2012

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