A COMPARATIVE STUDY OF THE PROBLEMS AND PROSPECTS OF THE APPLICATION OF INVENTORY MODELS IN SELECTED COMPANIES

i

BY

MAITURARE, MOHAMMED NASIRUDEEN

BEING A PROJECT SUBMITTED TO THE POSTGRADUATE SCHOOL, AHMADU BELI.0 UNIVERSITY, IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF MASTERS OF BUSINESS ADMINISTRATION (M.B.A.) DEGREE.

DEPARTMENT OF BUSINESS ADMINISTRATION
FACULTY OF ADMINISTRATION
INSTITUTE OF ADMINITRATION
AHMADU BELLO UNIVERSITY

ZARIA.

NOVEMBER, 1988

DECLARATION

I hereby declare that this project is the result of my initiative, and has to the best of my knowledge never been previously presented in any submissions for a higher degree. All works consulted have been duly acknowledged in the footnotes and the end of chapter references.

KAITURARE, MOHAMMED NASIRUDEEN		21/11/88
NAME OF STUDENT	SIGNATURE	DATE
MALLAM ABDULLAHI TAFIDA		21/11/88
NAME OF SUPERVISOR	SIGNATURE	DATE

CERTIFICATION

This project titled "A Comparative Study of the Problems and Prospects of the Application of Inventory Models in Selected Companies" by Mohammed Nasiruddeen Maiturare, meets the regulations governing the award of the degree of Masters of Business Administration Ahmadu Bello University and is approved for its contribution to knowledge and literary presentation.

Internal Examiner

Date

External Examiner

Date

MBA Coordinator

Date

Head of Department

9/2/89

Date

Dean, Postgraduate School

10/7/89

Date

TABLE OF CONTENTS

PAGE

ACKNOWLEDGEMENT

I wish to express my appreciation and gratitude to the numerous people who, in one way or the other, have contributed towards making this project possible.

First of all I am especially grateful to my supervisor Mallam Abdullahi Tafida for his patience and full cooperation. My thanks also goes to the following people: Alhaji Kabiru Isah Dutse, The Chief Accountant and the Deputy Chief Miller, all of Northern Nigerian Flour Mills, Kano, Mr. Janakiraman of Rigidpak (Nigeria) Ltd.; Mr. Olajide and Mallam Abdullahi of Comrade Cycle (Nigeria) Ltd.; and all those staff of these corporations who had, in one way or the other, assisted me in this work.

My thanks also goes to the following people who have tangibly or intangibly contributed towards making this project possible. They are:- Hadiza Ibrahim Imam, Rufiat Imam, Abdullahi Abba, Bata Inuwa, Danfuloti Kado, Umar Magam, Salisu Batagarawa, Shuraihu Saidu, Safiya Adamu, Mallam Garba Gezawa, Mallam Ismaila Dikko, Kabiru Asma'i, Mallam Yahaya Alhassan for taking the pains to type the whole work and others whose names I have not mentioned.

DEDICATION

To my parents.

ABSTRACT

The Nigerian business sector, and, indeed the economy, as a whole is in crisis.

This project, therefore, represents a humble attempt to study the current state of the art of inventory control in our manufacturing companies by analysing the current inventory systems of the three companies selcted for the study, namely;-

(1) Northern Nigerian Flour Mills Ltd., Kano
(2) Comrade Cycle (Nig.) Ltd., Zaria and
(3) Rigidpak (Nig.) Ltd., Zaria.

The project is aimed at finding out what inventory control models, if any, are used in these companies in establishing inventory policies; and determining the appropriateness or otherwise of the models being used in the light of the given situations of each company. To this and such inventory management variables as stock levels re-order quantity, and general replenishment practices and procedures have been thoroughly analysed.

In the course of the study however, it was observed that none of the three companies gave any serious consideration to using inventory models for making inventory decisions. However, Rigidpak's policy of varrying enough safety stock represents the company's recognition of the usefulness of inventory models in production operations.

Suggestions and recommendations were made accordingly

CHAPTER ONE

GENERAL INTRODUCTION

1.1 General Introduction

"The manager who can make rational decisions in the face of uncertainty and unclear personal judgements is a person to be envied."[1]

Recent developments in the business environment has made it almost impossible for today's managers to rely on the syllergistic process of deductive reasoning - that we call intuition - in making decisions. For, since the advent of the industrial revolution, the world has seen a remarkable growth in the size and complexity of organisations. The artisan's small shops of an earlier era have evolved into the billion dollar corporations of today.

In like manner, the Nigerian business arena has witnessed tremendous growth in size, scope and complexity of operations since the 'white man' first set foot on the Nigerian soil. The small-time village textile weaver has been replaced by giant multi-million naira textile companies like the United Nigeria Textiles Limited (UNTL) and Arewa Textiles Limited, local grain flour hawkers are also being replaced by giant flour mills with daily production capacities of thousands of

1. H. Moskowitz & G.P. Wright: Operations Research Techniques for Management (Prentice-Hall, Inc. Englewood Cliffs, USA 1979) p. 8.

bags like the Nigerian Flour Mills Limited and the Northern Nigeria Flour Mills Limited; even the local indigenous blacksmiths and brass-workers are slowly giving way to much bigger and more sophisticated firms in that field like the Agricultural Division of John Holt Limited and Tower galvanised products limited. Many other examples abound.

An integral consequence of this revolutionary change is that as the complexity and specialisation in an organisation increase, it becomes more and more difficult to allocate it's available resources to it's various activities in a way which is most efficient for the Organisation as a whole. Moreso that what is best for one component of the organisation frequently is detrimental to another. And so they may end up working at cross purposes. For example, when inventories seem too large, the financial manager will complain about the investment tied up and the cost of carrying them. On the other hand when inventories are low, the production manager will complain about likely disruptions in the production process, while the marketing manager will complain about poor service to customers and it's attendant cost - the cost of being out of stock.

These kinds of problems and the need to resolve them provided the environment for the emergence of a body of quantitative models which are collectively called techniques of operations research.

They include:-

1) Inventory control models
2) Linear programming
3) PERT/CPM
4) Queueing theory
5) Dynamic programming
6) Game theory
7) Simulation
8) Regression analysis
9) Transportation models
10) Probability theory

These techniques have gained so much popularity and acceptance in recent times that some of it's most ardent proponents have dared to posit that: "anything that cannot be expressed in figures is not worth expressing at all".

Although this sweeping statement may sound a bit of an an exageration, especially to the non-quantitative minds, the importance of quantitative models in aiding complex, rational, modern managerial decision making process cannot be over-emphasized. Presently most managers have realised that it is easier to examine and analyse complex problems if the concepts, tools and technques of operations research are used to decompose the problem into simpler elements.

In a survey of operations research activities at the corporate level conducted by E. Turban[1], he found that nearly

---

1. E. Turban, "A Sample Survey of Operations Research activities at the corporate level". OPERATIONS RESEARCH, 20:708-721 1977.

fifty percent (50%) of the companies selected for the survey have special departments at their headquarters that is mainly engaged in operations research activities. While about twelve percent (12%) of them indicated that they intended to establish such a department in the near future. The survey also indicated how widely the techniques of operations research had been applied to current projects. (See appendix 1). As a result of the importance and practicability of these techniques, several new more sophisticated models have been developed to guide managers in their onerous task of making sound rational decisions for the maximum attainment of their organisations goals and objectives.

Operations research as a whole is based on the basic premise that it is easier to resolve complex decision problems if the factors that influence the decisions are made 'visible' and quantifiable. Once the concepts and techniques of operations research are used to decompose the problem into simpler elements, the elements can, then, be easily aggregated or synthesised. This will give insight into the problem and will provide direction on its resolution. Thus the operations research approach helps in the construction of a model that synthesises the segments of an organisation that are affected by the decision.

1.2 Development of Operations Research Techniques

Operations Research can be characterised as the application of scientific methods, techniques and tools to problems involving the operations of systems so as to provide those in control of the operations with optimum solutions to the problems.[3] Operations Research Society define "Operations Research as the application of the methods of science to complex problems arising in the direction and management of large systems of man, machine, materials and money in industry, business, government and defence. The distinctive approach is to develop a scientific model of the system, incorporating measurements of factors such as chance and risks, with which to predict and compare the outcome of alternative decisions, strategies or controls. The purpose is to help management determine its policy and activities scientifically.

Although it is difficult to mark the official beginning of operations research, it's roots can be traced back many decades, at the turn of the 20th century when early attempts were made to use a scientific approach in the management of organisations. However, the beginning of the activity called operations research, as it's being practiced today has been generally attributed to the military services early in World War II. To maximize the war effort, it was necessary to

---

3. G.W. Churchman, R.L. Ackoff, and E.L. Arnoff, Introduction to Operations Research, New York: John Wiley & Sons, 1957, pp. 8 – 9.

allocate scarce resources to the various military operations and to the activities within each operation in an effective manner.

After the war, the apparent success of operations research in the military attracted the attention of industry which was then seeking solutions to the problems caused by increasing complexity and specialisation tbn organisations. When it became apparent to a growing number of people, including business consultants who had served on or with the operations research teams during the war; that these were basically the same problems but in a different context than had been faced by the military, the use of formal tools of operations research began to creep into industry and business.

Since then the techniques of operations research have been so developed and adapted to industry and business that there is virtually no aspect of managerial decision making variables that cannot be reduced into mere figures and numbers by the mathematical wizards. The basic thinking, as mentioned earlier, being that it is easier to resolve complex decision problems if the factors that influence the decision are made visible and quantifiable. Hence quantitative models abound for practically all areas in business ranging from simple optimal transportation patterns, through efficient queueing systems in factory operations and plant maintenance, to the optimal level of inventory to stock at any given period of time; and other related decisions.

There is no doubt that the operations research approach is one of the most important recent developments in the management of organisations. Some of the benefits to be derived from using this approach have been mentioned above. However, the operations research approach is beneficial to the organisation in more ways than have been mentioned above, as observed by Moskowitz and Wright.[4]

1) It provides decision makers with a set of concept and tools that will enable them to make decisions in a logically consistent fashion, and with as much precision as possible. Stated simply, a quantitative approach results in better decisions.

2) It gives decision makers an improved insight into how they make their decisions, so that they can improve their own intuitive decision making process.

3) Formalisation and quantification of the problem facilitates communication and coordination. In this way, divergent preferences and information among individuals can be reconciled and decisions coordinated.

4) Formalisation of routine or repetitive decision problems (i.e. handling the daily operating activities and

4. Ibid, p. 7.

their monitoring for dangerous trends) frees managers to concentrate on more pressing matters except when unusual circumstances arise, requiring review of the course of every-day action. In this way managers achieve better control of their operations and can allocate their time more efficiently.

5) Quantitative techniques facilitates the development of better organisational planning, operating and control systems. An operations research study initiated to analyse a particular decision problem may ultimately become an integral part of the organisation decision system to be employed repetitively. Thus the cost of undertaking the first application may produce longer-run benefits and spin-off benefits not originally envisioned.

6) It serves as a matter of record, that is of historical and current informational value. Thus managers can trace the development of a system, new managers can quickly become familiar with the existing system, problems can be more easily traced and isolated, and revisions to the system are more easily made and made known to those involved.

The above general discussion on operations research applies equally to inventory control models as well as other techniques of operations research.

Manufacturing companies as well as most non-manufacturing enterprises, whether operating in developing or industrialised economies, large or small, capital-intensive or labour-intensive, operating in turbulent or stable environments, are constantly being faced with the perennial problem of how much inventory to stock at any particular time and when to place orders for replenishments. In short, inventory control is a universal phenomenon. Though the problem of inventory management could be even more crucial in Nigeria.

In Nigeria, like in most other developing nations a significant portion of the materials used for business purposes is being imported from abroad. The situation being further worsened by the devastating effect of (S) FEM on the naira, the recent upward review of custom duties and tariffs and the total ban on the importation of certain commodities like wheat which forms the bulk of the raw material of many industries. These factors along with other factors like increased competition, shorter product life cycles, increased product variety and a higher cost of capital have left companies with no other choice than to seek ways of cutting down costs and minimising wastages in order to survive profitability.

With the situation as it is now, companies are beginning to realise that inventory management and control represent an avenue with substantial potential for increasing profits, lowering costs and releasing scarce capital. With this development is the emergence of a cost reduction technique called Materials Requirement Planning (used to schedule production and controlling of inventories), and the Just-in-time technque (JIT).

The managing of inventories is not simply a question of keeping track of the materials. It is the responsibility of top management to formulate company policies for inventory management and control. These policies will be statements of target inventory investments for a certain planning horizon, aimed at reducing and minimizing the costs related to inventory after certain restrictions have been fulfilled.

Two types of cost which must be reduced here are the ordering cost and inventory carrying cost. It is usually a bit more difficult to control the first of the 2 costs mentioned above, but if a firm is able to reduce the inventory level without sacrificing other performance measures like production efficiency, it would have saved enough in terms of reduced costs. For instance, a good inventory control system will reduce the cost of stockrooms, warehouse and their operation and maintenance; cost of spoilage, damage and pilferage; cost of insurance for goods and warehouses; and above all the cost of capital invested in inventories.[5]

To achieve a good control of inventories the company

5. Management in Nigeria, April 1988, p. 19.

must address itself properly to the following questions:-

1) How much material is needed over time?

2) How much should be ordered each time?

3) When should it be ordered?

The savings to be made in this area is so substantial that any cost reduction programme, no matter how small, which helps to reduce the failure rate associated with rule-of-thumb procedures in dealing with practical inventory problems should be developed and implemented. It is in this spirit that I decided to make inventory control the subject of my M.B.A. Project, notwithstanding the obvious and oft-cited limitations attributed to measurement in carrying out a study of this nature.

1.3 Problem Statement

For many companies the root causes of undue production stoppages and high production costs could easily be traced to unscientific methods of arriving at general inventory policies and crucial inventory decisions. The situation being more acute in a developing country like Nigeria where the practical applications of operations research technques in industry and business enterprises is in its infancy. Moreover the bulk of the raw materials inventory and the finished goods inventory used by companies in developing countries have to be imported from the industrial nations of Europe, America and Asia. Thus given rise to higher cost of procurement and higher uncertainty in the availability of such important components as CKD parts, spare parts, packaging materials and other basic raw materials.

Since the objective of every business whether in a developed or developing country is to maximize the owners' wealth through long-run profitability, there is a great need for the application of scientific inventory models in our manufacturing companies.

1.4 Definition of Key Terms

INVENTORY:- The quantity of goods, commodities or other economic resources that are stored or idle at any given point in time.

ORDERING COSTS:- These incremental costs associated with inventory replenishment.

SET UP COSTS:- The incremental costs associated with producing the item(s) in-house. From the initiation to the termination of a production run.

CARRYING (HOLDING) COSTS:- These costs are associated with holding a given level of inventory on hand, and vary with the level and length of time inventory is held. They include the opportunity cost on capital tied up in inventory; storage costs, product determination or obsolescence, taxes, depreciation and insurance.

SHORTAGE (STOCKOUT) COSTS:- These are the penalty costs incurred as a result of running out of stock when the commodity is needed. They generally include costs resulting from loss of customers' goodwill and potential loss in profit due to loss in sales.

SALVAGE VALUE:- The value attached to an unsold item that is to be carried over to the next time period.

LEAD TIME:- This refers to the time between the placement and the receipt of an order.

SAFETY STOCK:- extra inventory held to save as a buffer against possible stockout situation.

RE-ORDER POINT: This is a condition that signals someone, usually a purchasing officer, that a purchase order should be placed to replenish the inventory of some item(s).

LOT-SIZE:- The size of the order that will be purchased to replenish inventory.

EOQ:- Economic Order Quantity refers to the most economic lot size the firm should order when replenishing inventory.

ORDER CYCLE:- This refers to the time period between two successive order placements.

depreciation and insurance.

SHORTAGE (STOCKOUT) COSTS:- These are the penalty costs incurred as a result of running out of stock when the commodity is needed. They generally include costs resulting from loss of customers' goodwill and potential loss in profit due to loss in sales.

SALVAGE VALUE:- The value attached to an unsold item that is to be carried over to the next time period.

LEAD TIME:- This refers to the time between the placement and the receipt of an order.

SAFETY STOCK:- extra inventory held to save as a buffer against possible stockout situation.

RE-ORDER POINT: This is a condition that signals someone, usually a purchasing officer, that a purchase order should be plased to replenish the inventory of some item(s).

LOT-SIZE:- The size of the order that will be purchased to replenish inventory.

EOQ:- Economic Order Quantity refers to the most economic lot size the firm should order when replenishing inventory.

ORDER CYCLE:- This refers to the time period between two successive order placements.

1.5 Statement of Objectives

Having earlier elucidated my reasons for choosing inventory as the subject matter of my project, I will now proceed to state the objectives of the study in accordance with the reasons mentioned. The objectives, therefore, are:-

i) To find out what inventory models, if any, are used presently in the companies I have selected, for making inventory decisions. Like are they using the DETERMINISTIC MODELS or the STOCKASTIC ones.

ii) To determine whether or not the particular models being employed are the most appropriate ones for the respective companies in the light of their given situations.

iii) To identify those factors that may render the application of the general models not feasible or even totally impossible.

iv) To attempt to develop 'special' models that will best suit the circumstances of each organisation. And to provide useful suggestions that will go a long way to improving their present inventory control practices in particular and those of the remaining companies operating in Nigeria in general.

1.6 Statement of Hypothesis

The optimum level of inventory to have in stock at any given point in time, the most economic quantity to order when replenishing the inventory, and the most appropriate time to place the order are all variables that could be scientifically determined given adequate information on the following components:-

a) The cost of ordering or manufacturing the item(s).

b) The costs of keeping the item(s) in storage.

c) The penalty costs to be incurred as a result of running out of stock when the item is needed.

d) The discount value associated with order quantities and even the time value of money.

e) The probability values associated with the forecast figures and states of nature.

f) The salvage value of left-over items, where applicable.

g) The daily/weekly/monthly/annual consumption rate.

h) The price of the inventory item(s).

i) Lead time.

Once these components have been 'accurately' determined and it is possible to do so, all that remains is to plug in the resulting values in their respective positions in the model(s) and out will come the most optimum inventory decision one can ever hope to arrive at in the circumstances. These models will be fully discussed in chapter two.

Where some of the components can only be determined in a highly subjective manner, a number of highly sophisticated stockastic inventory models have been developed to substitute the deterministic models. The results when these models are used are normally expected to be within a reasonable degree of accuracy.

1.7 Methodology

Essentially, data collected for this project was done through interviews and personal observations. A questionnaire-like format was designed and made available to the principal officers of each selected company. The officers concerned were left to study the format for a couple of days after which we had a detailed discussion on the items in the format. Except in the case of Rigidpack, data on costs was supplied by the principal officers in the accounts department. While data on the production process and inventory control technques was supplied from the production department through interviews with production managers, supervisors and personal observations in the factory. However, in the case of Rigidpack all the data was supplied by the marketing manager who happens to be an expert on production management. The answers to the question were recorded on tape for precision.

1.8 Limitations of the Study

As earlier stated certain obvious and oft-cited limitations are inevitable in carrying out a study of this nature. The major limitations to this study are:-

i) The greatest constraint I faced in carrying out this study was lack of cooperation from the other companies I intended to include in the study.

ii) Due to the sensitivity of the topic the organisations were not too inclined to release information on certain cost like unit cost of production elements, which they consider as classified.

iii) Lack of time and financial constraints have made it impossible for me to try out a greater number of companies for a fairer representation.

iv) Considering the scope and pervasiveness of inventory control three companies are hardly a good enough sample to present all the problems and information necessary to represent all other companies in the country.

v) Finally, companies just like individuals have certain unique features, and so it is very difficult to have even two companies that are identical in all respect. Therefore the result from one selected company might not exactly fit any other company even if they are engaged in similar business.

CHAPTER ONE REFERENCES

1. MOSKOWITZ, H. and WRIGHT, G.P.: Operations Research Techniques for Management, (Prentice-Hall, Inc., Englewood Cliffs, 1979), pp. 3 - 11.

2. BROWN, R.V.: "Do Managers Find Decision Theory Useful?" Havard Business Review, May - June 1970, pp. 81 - 88.

3. WAGNER, H.M.: Principles of Operations Research. Englewood Cliffs, N.J.: Prentice-Hall Inc., 1969.

4. WAGNER, H.M.: "The ABC's of O.R.: "Operations Research, Journal of, 19, 1971 pp. 1267-1276.

5. HILLER, F.A. and LIEBERMAN, G.J.: Introduction to Operations Research (Holden-Day, Inc., 1980), pp. 2 - 14.

6. TURBAN, E.: "A Sample Survey of Operations Research Activities at the Corporate Level". OPERATIONS RESEARCH, 20 pp. 708-721, 1972.

7. CHURCHMAN, C.W., ACKOFF, R.L., and ARNOFF, E.C.: Introduction to Operation Research, John Wiley & Sons, New York, 1957, pp. 8 - 9.

8. THIERAUF, R.J., and KLEKAMP, R.C.: Decision Making Through Operations Research (John Wiley and Sons, New York, 1975) pp. 3 - 8.

9. KALU, A.: "Cost Reduction, Productivity and Performance Improvement". Management in Nigeria, April 1988, pp. 17 - 20.

CHAPTER TWO

REVIEW OF RELATED LITERATURE ON INVENTORY MODELS

2.1 Introduction

Inventories exist in all business, playing a major role in the determination of a company's internal effectiveness; that is, how efficiently the manufacturing operations can be carried out as well as meeting production goals. Thus retail firms, wholesalers, and manufacturing companies generally have a stock of goods on hand. However the big question is how do such organisations decide upon their inventory policies, i.e. when and how much does it replenish? Thus the basic inventory decisions involve how many units to order and when to order. In a small firm the manager may keep track of his inventory and make these decisions. However, this may not be feasible even in small firms, and so many companies have relied on scientific inventory management techniques. And by so doing have saved themselves large sums of money. Scientific inventory management involves the following basic steps:-

i) Formulate a mathematical model describing the behaviour of the inventory system.

ii) Derive an optimal inventory policy with regard to this model.

iii) Crate a sound and efficient stores control procedures to maintain a record of the inventory and to signal when and how much to replenish.

Inventory can be broadly defined as the quantity of goods, commodities or other economic resources that are stored or idle at any given point in time. The economic resources vary in quantity over time in response to a 'demand' process which operates to reduce the inventory level, and a replenishment process which operates to increase it.[1] Normally demand is uncontrollable but the magnitude and timing of the replenishment are controllable.

Inventory may include raw material's waiting to be used in producing goods (raw material inventory), semi-finished stored goods or goods in process temporarily stored during the production process (work-in-process inventory), goods awaiting shipment from the factory to the wholesaler or retailer (finished goods inventory).

In addition to such physical goods as flour, bicycles, cartons, automobiles, cash, human resources, human body parts, and library space available for new books can also be viewed as inventoriable items. Patients waiting in a doctor's office can also be regarded as inventory. The rate at which the doctor sees and treats the patients is the demand process. As this is occuring, new patients arrive to replenish those that have been seen and treated. The how many and when decisions are determined by how the doctor schedules his appointments.[2] Such is the pervasiveness of the concept of inventory that it transpires in almost all human endeavours - economic, social and even political and legal set ups. However, we are only concerned with inventory management in business organisations.

2.2 THE FUNCTIONS OF INVENTORIES

Inventories perform a number of vital functions in the operations of manufacturing organisations which makes them critical to the operations of these production systems. Without inventories organisations could not hope to achieve smooth production flow, obtain reasonable utilisation of machines and reasonable material handling costs or expect to give reasonable service to customers.

The basic function of inventories whether they be raw materials, work-in-process, or finished goods is that of decoupling the operations involved in converting inputs into outputs. This allows the successive stages in the purchasing, manufacturing and distribution process to operate somewhat independently of one another, without complete reliance on the schedule of output of prior activities in the production process. Furthermore, the decoupling function allows both time and spatial separation between production and consumption of products the operating system. The decoupling function may be

2. Moskowitz, H. & G.P. Wright, Op. cit, p. 964.

performed in at least four ways.

First, process and pipeline inventories sometimes called transit inventories are necessary where significant amounts of time are required to transport goods from one location to another. In essence, the warehouse must, at a minimum, carry enough stock on hand to meet demand during the transit (lead) time. For example, an inventory representing a month's demand would be needed in store if one month were required to ship the goods from a supplier to a manufacturer's warehouse.

Second, lot-size or cycle inventories are inventories that the organisation orders in lot sizes because it is more economical to do so than in ordering on an as needed bases to meet demand. The rationale is that economies may be realised from larger lots versus smaller lots through quantity discounts or lower total set up costs.

Third, when demand for an item is known to be seasonal or variable, it may be more economical for a firm to absorb some of the fluctuation by permitting inventories rather than its level of production to oscillate. Thus inventories used for this purpose are designed to more economically meet seasonal demand than by varying production levels to meet such demand fluctuations. By establishing production, the costs of acquiring and training workers, retrenchment benefits, and overtime work to meet periods of peak demand, which are higher than the costs of carrying inventory, are greatly minimized.

Fourth, fluctuation inventories may be required if an adequate supply of items is to be available when needed and stockouts are to be minimised. In effect, safety stocks are necessary so that fluctuations above average demand can be met.

Lastly, inventories can also be used for other purposes apart from those mentioned above. For example, when inventories are displayed they serve as promotional investment. Raw-materials and finished-goods inventories are frequently accumulated to hedge against price rises, inflation and strikes. Inventories also serve to smooth out irregularities in supply.

If for nothing else, the simple fact that inventories serve these functions implies that they have value to management. However they should not be regarded as a substitute for management, moreso that the inventory question is not a one-sided. One, which is precisely why inventories are a problem in the operation of a productive system. If there were no optional level to shoot for, there would be no problem. Anyone could follow the simple rule: "make inventories as big as possible".[3] On the other hand inventories should not necessarily be minimized. Organisations who carry minimal inventory levels can incur extremely high production and distribution costs. What is needed, therefore, is a way to determine optimal inventory levels in a given situational context. This requires balancing a set

3. BUFFA, E.S.: Modern Production Management: Managing the operations functions (fifth edition) published by John Wiley & Sons, Inc., 1977 p. 327.

of costs that decreases with higher inventory levels.

In essence, inventories act to decouple organisational activities, thereby achieving lower cost operations. Inventories act to reduce procurement costs, and inventories act to provide good customer service and smooth production flow by providing one-time delivery and avoiding costly stock shortages. Inventories ordered in large quantities can result in lower freight charges and price discounts. On the other hand inventory require tying up capital that would otherwise be invested elsewhere. Hence there is an appropriate opportunity cost associated with their value. Inventory also requires costly storage space; and such costs as insurance, spoilage, obsolescence, pilferage, and taxes must be incured as a result of maintaining inventory. Thus, management seeks decision rules that will optimally balance these controversies costs for a given system. It is in response to this management quest for guidance in handling inventory decision situations that a number of technques (models) have been developed to serve as aid to management in achieving optimal inventory solutions.

2.3 Development of Inventory Control Models

Interestingly, inventory control - the subject matter of this study - happens to be the first area in business in which quantitative models were applied to aid managers in making better and more efficient inventory decisions. Beginning about

1915, attention was focussed on the development of mathematical approaches designed to aid decision makers in setting optimum inventory levels. The first model was developed in the same year by Harris. Since that time increasingly sophisticated analytical tools have been brought to bear on the problems of inventory management. Koontz et al, have this to say on the subject matter: "perhaps in the history of operations research more attention has been directed to inventory control than to any other practical area of operations operations".[4] More than anything else this pioneering role and the prominence given inventory control over all the other practical areas in business has clearly demonstrated how important the issue of inventory has been and still is in business organisations.

One reason for greater attention to inventory is that this asset, for many firms is the largest one appearing on the balance sheet. Secondly inventory problems of too great or too small quantities can cause difficulties to the organisation. As one executive vice-president succinctly puts it:

"When inventories seem too large, the president complains about the investment tied up, and the cost of carrying them. When inventories are low, the marketing vice-president complains about poor service to customers".[5]

---

4. *Koontz et al, Management*, eight edition, (McGraw-Hill International Book Co., Japan, 1984) p. 608.

Furthermore, if a manufacturer experiences a stock out of a critical item, production halts can result. Similarly if an item is not stocked when a customer thinks it should be the firm losses a customer not only on that item but perhaps on many other items in the future. It is largely as a result of these crucial issues and many others that the development of quantitative models for inventory control took precedence over all the other areas.

As earlier mentioned, the development of the first inventory model is credited to F.W. Harris. Raymond extended Harris' work in the early 1930's. Since then, particularly since World War II, the development of inventory theory and inventory models has proliferated to a point of high development. Today, there are numerous inventory models covering practically imaginable inventory situation.

2.4 Types of Inventory Models

Basically there are two main categories of inventory model techniques - the Deterministic models and the stockastic (probablistic) models. The Deterministic models are so called because they are based on the assumption that demand is a known quantity. The deterministic models are further sub-divided into six different sub-categories.[6]

6.

i) Classic EOQ model (shortages not permitted)
ii) EOQ model (shortages permitted)
iii) EOQ model with quantity discounts
iv) EOQ model for production runs: single product
v) EOQ model for production runs: multiple products
vi) EOQ model with resource constraints.

a) THE CLASSIC EOQ MODEL

The EOQ model is the best known and most fundamental inventory decision model. Although this model is too over-simplified to represent most real-world decision situation, it is, nevertheless, an excellent starting point from which to develop complex and more realistic inventory decision models. This model is potentially opplicable when the entire quantity ordered (or produced) can be considered to arrive in the inventory simultaneously and when the demand rate for the item (which is assumed with certainty) is constant. Typical situations to which the classic EOQ model may apply include; use of clerical supplies such as paper clips, pens and note-books; use of certain industrial supplies such as nuts and bolts and use of toilet supplies in buildings. There are many other situations to which the simple EOQ model could be applied.

As in the case with all models, the validity of EOQ model depends on a number of assumptions which are as follows:-

1) Inventory is replenished when the inventory is exactly equal to zero (no shortages).
2) Demand (usage) rate is known and constant.
3) Lead time, the interval between the time the order

is placed and the time it is received, is known and constant.

4) Carrying cost is linear throughout the entire inventory range and varies with average inventory.

5) Price of the product does not depend on the quantity purchased.

6) Ordering of the product is independent of ordering other products.

As earlier indicated, many of the above assumptions (requirements) are violated in most real-life situations. This, however, does not mean that the EOQ approach lack usefulness. Rather, the EOQ approach represents the first step in solving the inventory problem and it can be expanded to accommodate exceptions to the above assumptions which occur in practice. For example, the demand rate, is rarely known with certainty and is often subject to extreme fluctuations, and the lead-time may also vary widely. Also if the firm has a limited amount of capital the carrying cost may not be linear, but it may increase as the level of inventory increases. In such cases, the EOQ formula may be slightly modified with the appropriate mathematical manipulations to accommodate the unique situations as will be shown later.

When assumption 6 is violated, however, it is often desirable to abandon the EOQ approach and use a different type of inventory system. For example when several products are ordered from the same supplier, substantial economies may result from combining orders for the several products which indicates an inventory system different from the EOQ system. However, if the violations of the assumptions are not too extreme, the EOQ model may be quite insensitive in the sense that, its application may result in an order quantity and cost that is not far off from optimal.

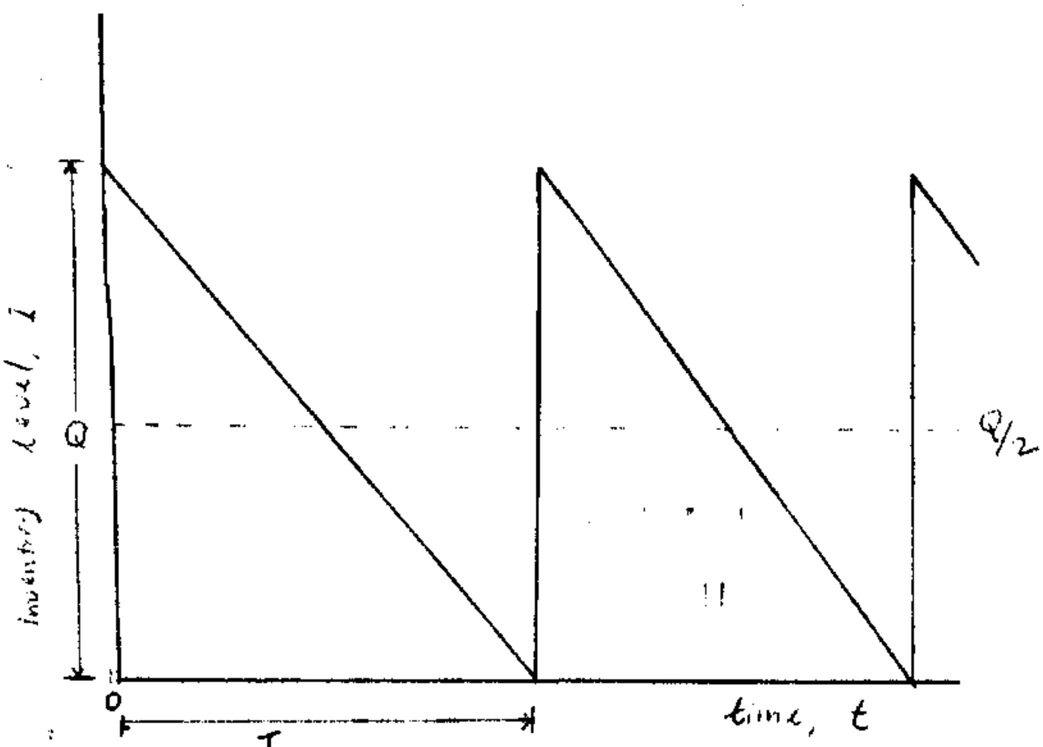


Figure 2.1

The above graph illustrates the variation of the inventory level over time for the classic EOQ model. The downward-sloping curve indicates that the inventory level is being reduced at a constant rate over time - assumption 1.

When the inventory level reaches the re-order point level, Q units of goods are ordered. The order is received at the time when the inventory level is reduced to zero during the lead time (L). This raises the inventory to Q and the cycle is repeated.

THE MODEL FORMULATION

The first step in constructing the inventory model is to define its variables and parametres. Let

Q = Order quantity

C_o = Cost of ordering or set up cost

C_c = Inventory carrying cost

D = Annual demand requirements

L_T = Lead time

N = number of orders or manufacturing runs per annum.

TIC = Total inventory associated cost.

Having defined the notations used in inventory models the next step is to express the total inventory costs in terms of the variables and parameters defined. The inventory associated costs can then be represented by a linear equation.

$$TIC = \frac{1}{2} Q C_c + C_o \frac{D}{Q}$$

(Inventory holding cost) + (Order costs).

In order to derive the EOQ model, the TIC is differentiated and set to zero.

$$\frac{d}{dQ}(TIC) = \frac{1}{2} C_c + C_o (- Q^{-2}) D$$

$$= \frac{1}{2} C_c - \frac{C_o}{Q^2} D$$

setting $\frac{d}{dQ}(TIC) = 0$, we obtain

$$1/2 C_c = C_o D/Q^2$$

$$C_c Q^2 = 2 C_o D$$

$$Q^2 = \frac{2 C_o D}{C_c}$$

$$Q^* = \sqrt{\frac{2 C_o D}{C_c}}$$

The classic EOQ model has thus been formulated. In the same way the cost of an optimal solution by this formula can be easily derived by substituting Q^* into the total incremental cost formula and solving for TIC.

$$TIC = \frac{1}{2} Q C_c + C_o \frac{D}{Q}$$

$$TIC^* = \frac{1}{2} Q^* C_o + C_o \frac{D}{Q^*}$$

$$= \frac{C_c \sqrt{\frac{2 C_o D}{C_c}}}{2} + \frac{C_o D}{\sqrt{\frac{2 C_o D}{2}}}$$

$$= \frac{C_c \sqrt{\frac{2 C_o D}{C_c}} \times \sqrt{\frac{2 C_o D}{C_c}} + 2 C_o D}{2 \sqrt{\frac{2 C_o D}{C_c}}}$$

$$= \frac{\cancel{C_c}\,\dfrac{2\,C_oD}{\cancel{C_c}} + 2\,C_oD}{2\sqrt{\dfrac{2C_oD}{C_c}}}$$

$$= \frac{2C_oD + 2C_oD}{2\sqrt{\dfrac{2C_oD}{C_c}}}$$

$$= \frac{2\cancel{2}\,C_oD}{\cancel{2}\sqrt{\dfrac{2C_oD}{C_c}}}$$

$$= \frac{2C_oD}{\sqrt{\dfrac{2C_oD}{C_c}}}$$

multiply both the numerator and denominator by

$$\sqrt{\frac{2C_oD}{C_c}} \quad \text{we obtain,}$$

$$TIC^* = \frac{2C_oD\sqrt{\dfrac{2C_oD}{C_c}}}{\sqrt{\dfrac{2C_oD}{C_c}}\sqrt{\dfrac{2C_oD}{C_c}}}$$

$$= \frac{2C_oD\sqrt{\dfrac{2C_oD}{C_c}}}{\dfrac{2C_oD}{C_c}}$$

$$= \frac{\sqrt{\dfrac{2C_oD}{C_c}}}{1/C_c}$$

$$= \sqrt{\frac{2C_oD}{C_c} \times C_c^2}$$

$$= \sqrt{\frac{2C_oD\ C_c^{\cancel{2}}}{\cancel{C}_c}}$$

$$\therefore TIC^* = \sqrt{2C_o\ C_c\ D}$$

The next parameter, in the inventory model formulation, to be determined is the optimum number of orders or manufacturing runs per year (N)

$$N^* = \frac{D}{Q^*}$$

Lastly, the time between orders - cycle time - can be determined by any of the following formulae:-

$$T^* = \frac{1}{N^*}$$

OR

$$T^* = \frac{Q^*}{D}$$

Finally, the re-order point (R) represents the level of inventory of inventory at which an order is placed for Q items. For the deterministic inventory system, the re-order point is easily determined as follows:-

$$R = L_T \quad \times \quad U_R$$

(Number of days) (Utilisation per day)

Observing the optimal re-order point (R^*) is equal to the demand during the lead time: the number of days in the lead-time multiplied by the demand per day. The obvious implication of this relationship is that the inventory system assumes that the lead time is less than the time required to deplete the total order quantity. Otherwise the re-order quantity will be higher than the lot size.

The classic economic order quantity is defined directly by the cost per order, the carrying cost per unit, and the demand. With these input parameters, the EOQ model provides the direct derivation of the optimal order quantity which minimizes the total incremental cost.

b) EOQ MODEL WITH SHORTAGES PERMITTED

One of the assumptions of the classic EOQ model that hardly holds in real-life inventory situations is assumption 1. The Classic model assumes that an order is received precisely at the time when the inventory level fell to zero. Hence the classic inventory decision model does not allow for shortages. Consequently shortage cost is ignored.

While it is true that in many inventory situations stock-outs should be avoided, there are cases where it is 'profitable' - economically justifiable - to plan for and allow stockouts. This is because the cycle length can be increased with a resultant saving in set up costs. However, this benefit may be offset by the cost that is incurred when shortages occur. Hence a detailed analysis is required before an optimal decision is reached. This model attempts to do just that. And in doing so the model first relaxes the assumption of no stock-outs and permit inventory shortages to occur. And adds a further assumption that all demands not satisfied as a result of an inventory shortage are back-ordered and eventually filled. Meanwhile all the assumptions of the classic EOQ model still apply, except of course, assumption 1, which does not permit shortages to occur.

When shortages are permitted, the optimum level of inventory to stock automatically becomes the function of both the inventory carrying costs and the cost of stockouts. Thus, when the cost of running out of stock is sufficiently small relative to the carrying cost, then the cost trade-off may indicate a decision to do both.

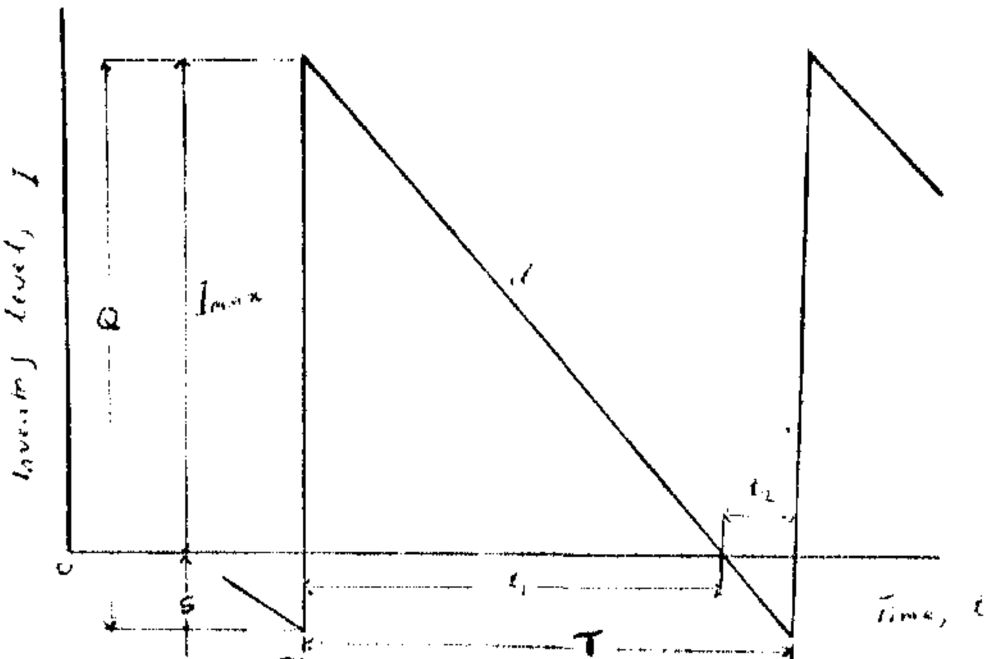


Figure 2.2

The above diagram depicts inventory level as a function of time when shortages are permitted. The pattern of inventory is still similar to the diagram in Figure 2.1, but drops below the zero inventory level, given rise to a situation of negative inventory. The term negative inventory represents commodities that are sold but back-ordered rather than delivered. Since back-orders (shortages) are filled when an order is received, the maximum inventory level does not reach the order quantity as it does in the classic EOQ model. Rather, shortages are filled immediately upon the receipt of an order and the inventory level returns to a level Imax = Q - S, the maximum inventory level. Since the maximum inventory level is less when stockouts are permitted than when they are not, likewise, the inventory carrying cost is reduced. An extreme case would be one in which all demands are back-ordered, resulting in zero inventory and hence zero holding costs. However, the reduction in holding costs must be balanced against the stockout costs associated with these back-orders.

THE MODEL FORMULATION

In addition to the symbols already defined in the formulation of the Classic EOQ model the EOQ model with shortages permitted uses the following terms:-

C_s = Cost of stockouts.

S = Number of shortages during the inventory cycle perid.

Imax = Maximum inventory level when back-orders are satisfied.

t_1 = time during which inventory is on hand.

t_2 = time during which a shortage exists.

T = the length of the inventory cycle.

When shortages are permitted, the total incremental cost expression must be modified in order to include the cost of being out of stock that will now be associated with the total cost of inventory. The annual overall cost function for the inventory model with shortages permitted is:-

TIC = ordering cost + holding cost + shortage cost.

Taknig the components are after the other, the ordering cost remains as it is in the classic model L_1 Simply multiplying the cost per order (C_o) with the number of orders placed per year gives the total annual ordering cost.

$$\text{Ordering cost/year} = C_o \frac{D}{Q}$$

In order to determine the new expression for the annual inventory carrying cost, two important variables have to be considered. One is the period during which there is positive inventory level and the new maximum inventory level. It is easy to see from the diagram in figure 2.2 that t_1 represents the period during which there is a positive inventory level while the maximum inventory level is

$$\text{Imax} = Q - S \quad \text{—— (1).}$$

The average level of inventory during which inventory is on hand is determined by the same principle as that used in the classic model. That is

$$\text{average inventory} = \frac{I_{max}}{2} = \frac{Q - S}{2} \quad \text{—— (2).}$$

The next step is to determine the holding cost during a given inventory cycle. (T from the diagram). Thus

$$\text{Carrying cost} = \frac{C_c I_{max}\, t_1}{2} = \frac{C_c\, Q - S\;\; t_1}{2} \quad \text{—— (3).}$$

Having determined the inventory carrying cost during one single inventory cycle, the next step is to determine the annual carrying cost. To do that we note that the usage rate, (d), can be expressed thus:

$$d = \frac{Q - S}{t_1} \qquad \text{—— (4).}$$

Looking at the diagram in figure 2.2 it is easy to see that, by similar triangles d can be expressed thus:-

$$d = \frac{Q}{T} \quad \text{—— (5).}$$

Setting equation (4) equal to equation (5) and solving for t_1, we obtain

$$\frac{Q - S}{t_1} = \frac{Q}{T}$$

$$T(Q - S) = t_1 Q$$

$$t_1 = \frac{T(Q - S)}{Q}$$

Substituting this expression for t_1 into equation (3) the expression for the carrying cost per cycle becomes:-

$$C_c \frac{Q - S}{2} t_1 = C_c \frac{Q - S}{2} \frac{T(Q - S)}{Q}$$

$$= C_c \frac{(Q - S)^2 T}{2Q} \quad \text{———} \; (6).$$

To get the appropriate expression for the annual carrying cost we multiply equation (6) by the number of orders in a year, (N).

$$\text{annual carrying cost} = C_c \frac{(Q - S)^2}{2Q} TN$$

where TN = 1 (year);

$$\text{annual carrying cost} \quad C_c \frac{(Q - S)^2}{2Q} \quad \text{———} \; (7).$$

So far the appropriate expressions for both the ordering costs and the carrying cost have been determined, the next step is to derive an appropriate expression for the shortage costs. From the diagram in figure 2.2 (S) represents the minimum levels of shortages. Hence the average level of shortages during the period in which there is a shortage, t_2, will be $S/_2$. The shortages cost in a given inventory cycle is thus

$$\text{Shortage cost/cycle} = C_s \frac{S}{2} t_2 \quad \text{———} \; (8).$$

To determine the annual shortage cost, the relationship between the demand rate and the number of shortages per order (S) is equated to the relationship between the demand rate and the order quantity (Q) to get an expression for the period in which there is shortage (t_2) in terms of T, S and Q. Again, it is clear from figure 2.2 that

$$d = \frac{S}{t_i}$$

$$\text{or} \quad d = \frac{Q}{T}$$

$$= \quad d = \frac{S}{t_2} = \frac{Q}{T}$$

$$= \quad t_2 Q = TS$$

$$t_2 = T\frac{S}{Q} \quad \text{———} \ (9).$$

Substituting equation (9) into equation (8) we obtain

$$\text{Shortage cost/cycle} = C_s \frac{S}{2} \times T \frac{S}{Q}$$

$$= C_s \frac{S^2}{2Q} T \quad \text{———} \ (10.$$

Now, since the annual shortage cost is N times equation (10), and since TN = 1 (year), then,

$$\text{annual shortage cost} = \frac{C_s S^2}{2Q}$$

Thus,

$$TIC = C_o \frac{D}{Q} + C_c \frac{(Q - S)^2}{2Q} + \frac{C_s S^2}{2Q}$$

$$= C_o \frac{D}{Q} + \frac{C_c \frac{Q}{2} + C_c Q^2 - 2Q^2 + S^2}{2Q} + C_o \frac{S^2}{2Q}$$

$$= C_o \frac{D}{Q} + C_c \frac{Q}{2} + \frac{C_c + C_s}{2Q} S^2 - C_c S \quad \text{———} \ (11)$$

Taking the partial derivative $\frac{d(TIC)}{dQ}$ and setting it equal to zero gives

$$\frac{dTIC}{dQ} = C_o \frac{D}{Q^2} + \frac{C_c}{2} - \frac{(C_c + C_s)^2}{2Q^2} = 0 \quad \text{———} (12)$$

Similarly taking the partial derivative $\frac{d(TIC)}{dS}$ and setting it equals to zero gives

$$TIC = C_o \frac{D}{Q} + C_c \frac{Q}{2} + \frac{C_c + C_s}{2Q} S^2 - C_c S$$

$$\frac{dTIC}{dS} = \frac{2(C_c + C_s)}{2Q} S - C_c = 0$$

$$\frac{C_c + C_s}{Q} S - Cc = 0$$

$$\frac{S(C_c + C_s)}{Q} = C_c$$

$$S^* = \frac{C_c\ Q}{C_c + C_s} \quad \text{———} (13).$$

Substituting equation (12) in equation (11) we obtain,

$$TIC = C_o \frac{D}{Q} + C_c \frac{Q}{2} + \frac{C_c + C_s}{2Q} Q^2 \left(\frac{C_c}{(C_c + C_s)}\right)^2 - \frac{C_c\ QC_c}{C_c + C_s}$$

$$\frac{dTIC}{dQ} = \frac{-C_oD}{Q^2} + \frac{C_c}{2} \quad \frac{C_c^2}{2(C_c + C_s)}$$

setting $\frac{dTIC}{dQ} = 0$, we obtain

$$\frac{C_o\ D}{Q^2} = \frac{C_c}{2} - \frac{C_c^2}{2(C_c + C_s)}$$

$$\frac{C_c\ (C_c + C_s) - C_c^2}{2(C_c + C_s)}$$

$$\frac{C_c^{\,2} + C_c\,C_s - C_c^{\,2}}{2(C_c + C_s)}$$

$$\frac{C_o D}{Q^2} = \frac{C_c\,C_s}{2(C_c + C_s)}$$

$$Q^2\,C_c\,C_s = 2(C_o D(C_c + C_s)$$

$$Q^2 = \frac{2C_c D(C_c + C_s)}{C_c\,C_s}$$

$$= \frac{2\,C_o D \times C_c + C_s}{C_c \qquad C_s}$$

$$\therefore\ Q^* = \sqrt{\frac{2\,C_o D}{C_c}}\ \sqrt{\frac{C_c + C_s}{C_s}}$$

similarly,

$$I^*max = \sqrt{\frac{2C_o D}{C_c}}\ \sqrt{\frac{C_s}{C_c + C_s}}$$

and

$$TIC^* = \sqrt{2C_c\,C_o D}\ \sqrt{\frac{C_c}{C_c + C_s}}$$

It is easy to notice that the difference between these formulae and those derived for the classic model is the inclusion of the second square root terms. It is also easy to observe that the effect of including shortage costs is to increase Q^*, since annual inventory holding costs are smaller due to the smaller average inventory, and TIC^* is smaller than for the classical EOQ model without shortages because both inventory holding costs and order costs are lower. It can further be observed that as the shortage cost C_s becomes large relative to the inventory carrying cost C_c, the quantities $(C_c + C_s)/C_s$ and $C_s/(C_c + C_s)$ in Q^* and TIC^* approach 1. When that happens the EOQ model with shortages permitted and the Classical EOQ model give similar results. As C_c becomes large relative to C_s, Q^* increases while I^*max decreases; hence, $S^* = Q^* - I^*max$, increases. This relationship explains why many high-valued items (which have a very high per-unit cost and hence high per-unit inventory cost) are handled on a back-order basis.

c) EOQ MODEL WITH QUANTITY DISCOUNTS

None of the EOQ models discussed above took into account the factor of quantity discounts. The models have assumed that the unit cost of an item was the same, independent of the quantity purchased. However, it is common business practice for suppliers to offer quantity discounts to purchasers to provide an incentive for purchasing large quantities by offering lower unit costs when commodities are purchased in large lots or quantities. Like all other inventory decisions, buying in large quantities has some favourable and some unfavourable features. The advantages of buying in large quantities include: lower unit cost, lower ordering costs, fewer stockouts, and lower transportation cost. On the other hand, buying in smaller quantities presents these disadvantages: higher inventory carrying costs, more capital required, greater chance of deterioration and depreciation of inventory, and older stock - obsolescence.

There are three basic approaches used in evaluating quantity discounts namely:-

1) The cost comparison approach
2) The price change approach and
3) The price break approach.

The Cost Comparison Approach

This approach, due to it's simplicity, is more widely used than any of the other two approaches. The quantity discount model, in this approach, is formulated in the same way as the Classic EOQ model, except that the cost of goods purchased (in addition to carrying and order costs) must be included as an incremental cost in the TIC expression. Thus giving TIC as:-

$$TIC = \text{order cost} + \text{holding cost} + \text{purchase cost}$$

$$= C_c \frac{D}{Q} + C_c \frac{Q}{2} + cD$$

where C = cost value of one unit at the appropriate price break level.

The present total annual inventory costs, using an optimum purchase basis or economic ordering quantity, is compared to the proposed total annual inventory cost conditions which qualify the buyer for the quantity discounts. A decision is then made in favour of the situation that results in lower total costs.

The Price Change Approach

The second approach for evaluating quantity discounts is to determine the point where the reduction in ordering cost and unit price is equal to the additional carrying cost which result from purchasing in larger amounts. In other words, the problem is one of finding a solution for the largest order quantity, expressed in naira, that it is economical to order at the price offered with the discount. The following terms are used in the development of this model:-

X = largest order quantity, in naira, that is economical to order.

Y = discount, expressed as a percentage of D.

D = old annual requirements in naira.

C_o = ordering cost per order.

Q = economic order quantity in dollars previous to discount price offer.

C_c = annual carrying cost, expressed as a percentage of average inventory.

The first step in developing a model for this approach is to determine the reduction in ordering cost. This is found by simply subtracting the new ordering cost from the ordering cost which prevailed before taking the quantity discount. The present ordering cost is the annual naira usage (D) divided by the economic ordering quantity in naira (Q) times the ordering cost per order (C_o) or $(^D/_Q)\ C_o$. The new ordering cost is the new annual usage in naira or $D(1-Y)$ divided by X, the naira size of new orders, multiplied by C_o, the ordering cost per order, or

$D(1-Y)\ ^{Co}/_{X}$. Thus the present ordering cost $(D\ (1-Y)/X)C_o$, is the resultant decrease in ordering cost. The reduction in total cost of units due to the lower unit price must be calculated to complete the left-side of the equation. This is the samething as multiplying the discount (Y) times the annual requirements in naira (D), i.e. YD. The resultant left-hand side of the equation for the reduction in ordering cost and unit price is:-

$$\frac{DC_o}{Q} - \frac{D(1-y)C_o}{X} + YD$$

The next step is to determine the other side of the equation which expresses the additional carrying cost that results from buying in larger amounts. The starting point is an expression for the carrying cost of the proposed plan. This is obtained by taking the largest order quantity to order at a reduced price (X) and dividing by 2; the resultant figure is multiplied by the carrying cost (C_c) or $(H_2)C_c$. The carrying cost, under the economic ordering quantity before the discount, is next formulated. EOQ in naira before discount (Q) divided by 2 times the carrying cost (C_c) is $(Q/2)C_c$. The additional carrying cost is thus:-

$$X/_2C_c - \frac{QC_c}{2}$$

The next step is to equate the savings in ordering cost and the reduction in total purchasing price with the additional carrying cost and solve for X:-

$$\frac{DC_o}{Q} - \frac{D(1 - y)}{X} + YD = X/2 C_c - Q/2\, C_c$$

multiplying both sides of the equation by X will convert the equation into the general algebric guadratic formula

$ax^2 + bx + c = 0$

$$X\frac{DC_o}{Q} - D(1 - y)C_o + XYD = \frac{X^2}{2} C_c - X\frac{Q}{2} C_c$$

re-arranging the equation it becomes

$$\frac{X^2}{2} C_c + \left(- \frac{QC_c}{2} - YD - \frac{DC_o}{Q}\right)X + D(1 - y)\, C_o$$

solving the guadratic equation by the formula

$$x = \frac{-b \pm\sqrt{b^2 - 4ac}}{2a} \qquad \text{gives}$$

$$X = \frac{\frac{Q}{2} C_c + YD + DC_o + \sqrt{\left[-\left(\frac{QC_c}{2} + YD + \frac{DC_o}{Q}\right)\right]^2 - 2C_c\, DC_o\,(1 - y)}}{C_c}.$$

Solving for X in this equation yields the largest order quantity economical to order in dollars at the lowest unit price.

The Price Break Approach

The third approach for evaluating quantity discounts is the price break approach. One of the shortcomings of the two previous approaches is that they were limited to the case where only one discount price is offered. The price break approach seeks to overcome this shortcoming by determining the economic order quantity with any number of successive discounts taking effect as the purchase quantity increases. The successive discounts are known as price breaks.

To illustrate the application of this approach, assume that a company is offered the following range of price breaks along with the price break quantity:-

Price Break Quantity	Unit Price (₦)
0 - 999	10.00
1,000 - 2,999	9.50
3,000 - 5,999	9.00
6,000 - 7,999	8.50
8,000 and above	

The procedure in applying this approach as to first calculate the EOQ for each price. Any of the resulting EOQS that exceeds the upper limit for it's given range is automatically rejected while those that fall below the upper limit of their given ranges are evaluated and the total costs compared. The EOQ with the lowest total cost is then choosen as the most economic ordering quantity.

d) ECQ MODEL FOR PRODUCTION RUNS: SINGLE PRODUCT

This model considers the case where goods are received for inventory at a constant rate over time as units are being consumed. This is in contrast to the preceeding models, where the entire quantity is assumed to be received instantaneously. This model is typically designed for production situations in which an order is placed, production begins, and a constant number of units are added to inventory each day until the production run has been completed. At the same time units are being demanded and consumed at a constant rate. It is assumed that the production rate is greater than the demand rate. A fundamental assumption of this model is that the production rate is greater than the demand rate. Otherwise, there will be no inventory build-up and the firm will experience frequent stockout situations.

THE MODEL FORMULATION

In formulating the EOQ model for production runs, two additional parameters are defined:-

p = production rate, which is assumed to be constant

d = usage or demand rate, also assumed to be constant.

The annual overall cost function for this inventory is the same as for the simple EOQ model,

TIC = ordering cost + holding cost.

The ordering cost is as before equal to $C_o\,{}^{D}/_{Q}$. The interpretation of the order cost in a production situation is more aptly referred to as production set-up cost. This cost, which includes man-hours, material, and lost production costs incurred while preparing the production system for operation is a fixed cost which occurs for every production run, regardless of the production quantity. The carrying cost is also equal to, as before, the annual unit holding cost times the average inventory. However, since the production of the total order quantity (Q) takes place over a period of time (defined by the production rate p), and the parts go into inventory, not in one large batch but in smaller quantities as production and consumption continues, an inventory pattern different from the ones already considered results. The maximum inventory level, and hence the average inventory level, will not only be a function of the lot size as in the Classic EOQ model but also a function of the production rate (p) and demand rate (d).

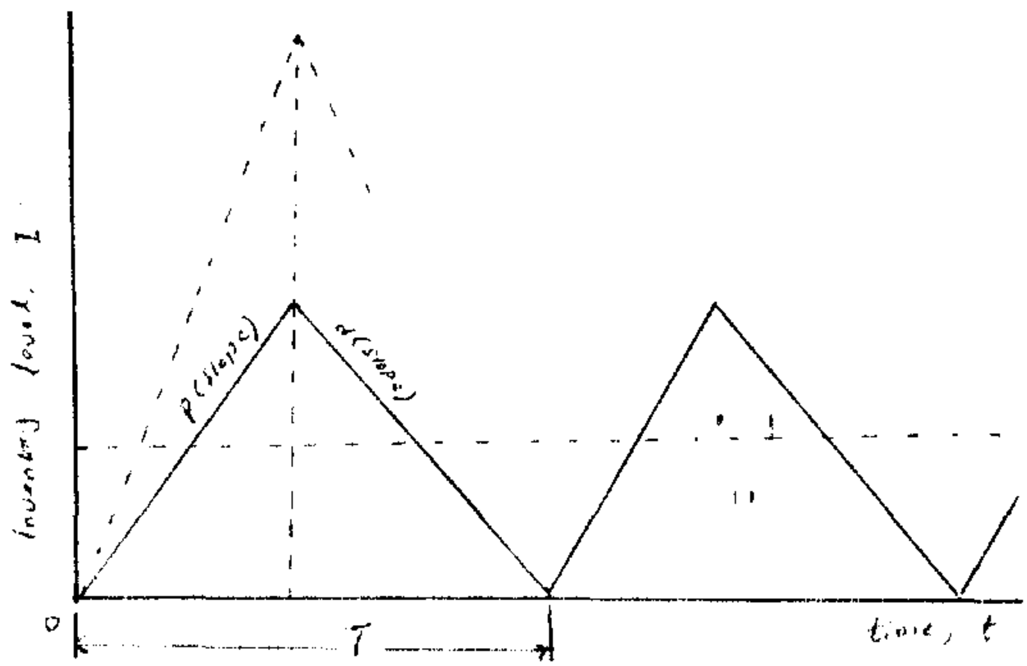


Figure 2.3

In this model, the maximum (and hence average) inventory level must be adjusted for the fact that goods are being received and consumed simultaneously. The average inventory level is thus determined as follows:-

$$t_p = \frac{Q}{P},$$

The maximum inventory level is

$$Imax = t_p\ (p - d)$$

$$\text{average inventory} = \frac{Imax}{2} = \frac{t_p\ (p - d)}{2}$$

$$= \frac{Q}{p}\left\{\frac{p - d}{2}\right\}$$

$$= q\ \frac{Q}{2}\ \left\{1 - \frac{d}{p}\right\}$$

The annual carrying cost is thus

$$C_c\ \frac{Q}{2}\ \left\{1 - \frac{d}{p}\right\}$$

$$\therefore\ TIC = C_o\ \frac{D}{Q} + C_c\ \frac{Q}{2}\ \left\{1 - \frac{d}{p}\right\}$$

$$\frac{dTIC}{dQ} = -\frac{C_oD}{Q^2} + \frac{C_c}{2}\left\{1 - \frac{d}{p}\right\}$$

setting $\frac{dTIC}{dQ} = 0,$

$$\frac{C_oD}{Q^2} = \frac{C_c}{2}\left\{1 - \frac{d}{p}\right\}$$

$$Q^2 = \sqrt{\frac{2C_oD}{C_c\left\{1 - \frac{d}{p}\right\}}}$$

$$\therefore \quad Q^* = \sqrt{\frac{2C_oD}{C_c\left(1 - \frac{d}{p}\right)}}$$

$$TIC^* = \sqrt{2C_o\ C_c\ D\left(1 - \frac{d}{p}\right)}$$

e) EOQ MODEL FOR PRODUCTION RUNS: MULTIPLE PRODUCT

Some manufacturing firms use the same equipment to produce a variety of products on a cyclical basis. These resources become a constraint and the independent determination of EOQ^s for each product by the formula derived for the single product is no longer feasible due to the interference among production runs for the various products. Instead, the production runs and EOQ^s must be determined jointly so that scheduling incompatibilities are avoided in other words, the model seeks to determine the number of units required for each production run in order to minimize costs for the firm.

THE MODEL FORMULATION

The basic approach to setting an economical cycle length and the economic order quantities (EOQ^s) for the multiple products is the same as in the case of one product, that is, to find the cycle length and economic lot size which will make the total set up (or change over costs) and inventory costs a minimum. The change over costs increase with more cycles in a given period while inventory costs tend to fall because of more frequent cycles. Thus the resulting formula is very similar to that for a one-product condition.

The annual overall cost function for the n products is the sum of the set-up costs plub inventory holding costs, that is

$$TIC = \sum_{i=1}^{n} \frac{D_i}{Q_i} C_{o_i} + \sum_{i=1}^{n} C_{c_i} Q_i \left(1 - {d_i}/{p_i}\right)$$

But $N = {D_i}/{Q_i}$, therefore

$$TIC = N \sum_{i=1}^{n} C_{Q_i} + \frac{1}{2N} \sum_{i=1}^{n} C_{c_i} D_i \left(1 - \frac{d_i}{p_i}\right)$$

The above formula expresses the total incremental cost function in terms of the decision variables N - the length of the production run - rather than the lot size Q. We can determine the minimum cost N by the use of the differential calculus, as we have done for the previous models. That is, we differentiate TIC with respect to N, set the result equal to zero and solve for N

$$TIC = N \sum_{i=1}^{n} C_{o_i} + \frac{1}{2N} \sum_{i=1}^{n} C_{c_i} D_i \left(1 - \frac{d_i}{p_i}\right)$$

$$\frac{dTIC}{dN} = \sum_{i=1}^{n} C_{o_i} - \frac{1}{2N^2} \sum_{i=1}^{n} C_{c_i} D_i \left(1 - \frac{d_i}{p_i}\right) = 0$$

making N the subject of the formula, we get

$$N^{*} = \frac{\sum C_{c_i} \; D_i \; (1 - {d_i}/{p_i}}{2 \; \sum_{i=1} C_{o_i}}$$

$$Q^{*} \quad \frac{D_i}{\sum_{i=1}^{n} C_{c_i} \; D_i \; (1 - {d_i}/{p_i})}$$

$$\text{since } Q^{*}_{i} = {D_i}/{N^{*}}$$

$$TIC^{*} = 2 \sum^{n} C_{o_i} \; \sum C_{c_i} \; D_i \; (1 - {d_i}/{p_i}$$

If for example a firm uses one machine to produce 4 products and $N^{*} = 12$, what this means is that each of the four products would be produced 12 times each year in lot sizes equal to one-twelfth of the annual demand requirements.

f) EOQ MODEL WITH CONSTRAINTS

It is not uncommon to encounter situations in which an EOQ model produces results that are infeasible. These situations frequently occur in the quantity discount model and also in the production-run model for multiple products using the same production facilities. Another situation in which the EOQ model can produce infeasible results is when inventory is constrained by such factors as storage space and/or the total amount of capital that may be invested in inventory.

Suppose, for example, storage space and/or capital constraints limit the order quantity to some maximum value say 1,200 units. Then, one would proceed by first determining the EOQ using the appropriate EOQ formula, completely ignoring the constraint. If the computed EOQ turns out to be feasible (e.g. Q^* = 1,000 units, which is less than 1,200), then the optimal order quantity remains 1,000 units. If on the other hand, the resulting EOQ is not feasible (e.g. Q^* = 1,500, which is greater than 1,200), then the optimal order quantity is 1,200 units, which is the maximum feasible order quantity.

The general formulae for this model are given as follows:-

$$TIC = \sum^{n} C_{o_i} D_i/Q_i + C_{o_i} Q_i/2 + W_i k_i Q_i$$

$$Q_i = \frac{C_{o_i} D_i}{C_{o_i} + 2k_i (\ + w_i)}$$

$$\text{and} \sum_{i=1}^{n} \frac{2D_i C_{o_i}}{C_{o_i} + 2k_i (\ w_i)} = k$$

where,

k_i = available storage space for item i;

w_i = the rental of the warehouse per cubic feet per year for each item.

k = the maximum available storage space.

 = the lagrangian multiplier.

STOCHASTIC INVENTORY MODELS

The deterministic inventory models assume that demand is constant and known with certain. The probablistic models, on the other hand, consider inventory situations in which the exact demand and lead time for an item is uncertain and therefore can only be described in terms of a probability distribution.

The basic assumptions of the stochastic inventory models are as follows:

1. Demand is uncertain
2. Lead time is uncertain
3. Lot sizes are being purchased rather than produced inventory
4. Back-orders are permitted (i.e. stockouts are penalised but not lost)
5. Unit price, ordering cost, unit inventory carrying cost, and unit stock-out cost are constant.

In situations where demand is known with certainty, or can be assumed to be, the determination of the optimal order quantity becomes straight forward as it was demonstrated by the deterministic models. However, when the item demand and lead time are uncertain, the determination of the economic order quantity, Q^*, and re-order point, R, becomes considerably more complex. Because of the uncertainties involved, a probability distribution of demand during lead time (DDLT) must be determined. These uncertainties cause an interaction between order quantity, Q, and re-order point, R, which precludes their independent determination.

The formulae are as follows:-

$$TEC = \frac{C_o\, E(D)}{Q} + C_c \left(\frac{Q}{2} + R - E(DDLT)\right) + C_s\, E(S)\, \frac{E(D)}{Q}$$

$$Q^* = \frac{2E(D)\left(C_o + C_s\, E(S)\right)}{C_c}$$

$p(s)^*$

$$P^*(S) = \frac{C_c\, Q}{C_c\, E(D)}$$

where

TEC = expected total annual increment inventory cost.

E(D) = expected (average) demand.

E(DDLT) = expected demand during lead time.

E(S) = expected stockouts during lead time.

R = re-order point.

$P(S)^*$ = probability of a stockout for a given Re-order point.

The two equations for Q^* and $P(S)^*$ cannot be solved independently. Rather, they interact in a slow way, and thus must be solved by a back-and-forth trial-and error procedure. That is assume an R^* and solve for Q^*. Now solve again for R^* using the Q^*. With new R^*, solve again for Q^*, and so further, until the solutions "settle down" - giving consistent results.

2.5 RECENT DEVELOPMENT IN THE FIELD OF INVENTORY CONTROL

The types of inventory models listed and discussed above are by no means exhaustive of the pool of inventory models that have been developed to date. However, they are the ones most commonly used by firms, which is precisely why I decided to dwell on them. This is not to say, however, that the recent inventory models are less relevant to these firms. Rather, it is the complexities attached to their application that often precludes their being used by the firms.

The formulation and development of the models above is based upon differential calculus but in the past decade most research into inventory management models have used dynamic programming and optimal control methodologies to allow for changing cost structures and demands and also permit simultaneous analysis of production patterns.

The analysis of inventory systems have also been extended to include products that cannot be stored indefinitely. Products like foodstuffs, drugs, and volatile liquids all undergo some degree of perishability. For these products that are subject to either perishability or decay, inventory models have been developed for determining optimal and sub-optimal stocking policies. Perishability refers to the case where an item may be retained in stock for a fixed period of time with no loss in utility. However, if it has not been used to meet a demand before the expiration date it must be discarded. Exponential decay corresponds to situation where a fixed fraction of stock on hand expires each period or where the utility for each item decreases exponentially over time. Inventory models have been developed for the deteriorating process using such parameters that include specification of a maximum product life time, a constant decay rate for the product and a fixed point in time where the product is not demanded regardless of it's age.[7]

Another area to which recent inventory analysis is being applied is Hotel over-booking problems, which arises as a consequence of the option normally given to prospective quests to cancel their reservations - with no penalty - at any time prior to their arrival date. As a means of (partially) overcoming this problem, hotel managements practice over-booking expecting that due to (probabilistic) cancellations the number of actual "show ups" at a given date will be as close as possible to the hotel's nominal capacity. The new models developed for this situation are designed to find the optimal over-booking policy such that some measures of effectiveness, say, expected profit will be minised.[8]

Other models included in the recent inventory models developments are:-

---

7. Management Science, Volume 25, No. 1 January 1979, U.S.A. p. 90.

1) Multiple-item inventory model with a job completion criteria.

2) Economic lot size deterioration in multi-stage assembly system.

3) Infinite stage dynamic inventory models.

4) Inventory models for By-product production systems.

5) Non-stationary infinite horizon inventory models.

6) Dynamic lot size models with time-varying production capacity constraint.

The list goes on and on. However for the purpose of this project all the relevant models have been adequately discussed.

CHAPTER TWO REFERENCES

1. MOSKOWITZ, H. and WRIGHT, G.P.: Operations Research Techniques for Management (Prentice-Hall, Inc., Englewood Cliffs, N.J., 1977) pp. 563 - 655.

2. HILLER, F.S., and LIEBERMAN, G.J.: Introduction to Operations Research (Holden-Day Inc., San Francisco, 1980) pp. 492 - 914.

3. THIERAUF, R.J. and KLEKAMP, R.C.: Decision Making Through Operations Research, 2nd edition (John Wiley & Sons, Inc., New York, 1975), pp. 343 - 376.

4. RICHARD A. JOHNSON et al: Production and Operations Management: A Systems Concept (Houghton Mifflin Company Boston, 1974) pp. 358 - 381.

5. SMITH, D.E.: Quantitative Business Analysis; (John Wiley & Sons, New York, 1977) pp. 459 - 516.

6. ZIMMERMANN, H. and SOVEREIGN, M.G.: Quantitative Models for Production Management (Prentice-Hall, Inc., Englewood Cliffs, New Jersey, 1974) pp. 431 - 404.

7. STARR, M.K., and D.W. MILLER: Inventory Control: Theory and Practice (Prentice-Hall, Inc., Englewood Cliffs, N.J. 1962).

8. HADLEY, G., and T.M. WHITIN: Analysis of Inventory Systems (Prentice-Hall, Englewood Cliffs, 1963).

9. FETTER, R.B. and W.C. DALLECK: Decision Models for Inventory Management (Richard D. Irwin, Inc., 1961).

10. LEVIN, R.I. and KIRKPATRICK, C.A.: Quantitative Approaches to Management (McGraw-Hill, Inc., 1965) pp. 114 - 141.

11. MANAGEMENT SCIENCE, Volume 24, No. 11, July 1978, U.S.A. pp. 1150 - 1153.

12. Ibid, Volume 25, No. 1, January 1979, U.S.A. pp. 90 - 94.

13. Ibid, Volume 24, No. 15, November 1978, U.S.A., pp. 1668 - 1670.

14. Ibid, Volume 28 No. 10, October 1982, U.S.A., pp. 1174 - 1185.

15. JOURNAL OF OPERATIONS RESEARCH SOCIETY, Volume 30, No. 1, January 1979, pp. 43 - 53.

CHAPTER THREE

DATA COLLECTION

3.1 Introduction

When I first thought of writing a project on Inventory Control, I had had in mind a well researched and comprehensive package that will serve as a useful guide to both manufacturing companies and service firms in Nigeria in selecting and designing inventory systems that will enhance efficiency and effectiveness in their operations. Little did I know that my zeal and enthusiasm on the subject matter will not be shared by most of the organisations to whom the effort is directed.

To be able to design a sound inventory model for any organisation a detailed analysis of the inventory system and complete information on all the inventory components are necessary prerequisites. However, of the many companies I slated for this project, only the three I have now ended up with were able to offer any reasonable assistance. This difficulty in collecting data, is the greatest hinderance to research work in Nigeria. For no meaningful research can be conducted without pertinent information being made available.

As I have earlier mentioned in the methodology, data from the three companies in this study were gathered in the following ways:-

1) The relevant officers providing answers to the question in my questionnaire - like format.

2) Verbal discussions with the principal officers.

3) Answers to the questions recorded on tape.

4) Personal observations in the factories.

The data from each company presented below:-

3.2 Data From Northern Nigerian Flour Mills Limited Kano

3.2.1. Company Background

The Northern Nigeria Flour Mills Limited, Kano was incorporated on the 31st of March 1972, with an initial capital of N13 million. The major shareholders of the company are

i) Flour Mills of Nigeria Limited
ii) Kano State Investment and Properties Limited.

The rest shares are distributed among individuals like Alhaji A. Dantata and Alhaji A.M. Gashash.

At the time of its inception in 1972, it had over 300 junior staff and about 20 expatriate officers. Today the company has in its employment about 150 junior staff, 52 senior staff among whom are 5 expatriates.

3.2.2 Production Process At Northern Nigerian Flour Flour Mills

The Corn is received from lorries into the intake conveyor.

It is then converyed by (chain) elevator passing through the intake scale to the silos, which has a capacity of about 500. From here the corn is taken through the cleaning scale to the seperator (with the help of floor balancer) which removes rubbish, dust, and pops. Then it moves to the dry stone where stones are removed.

The corn then moves to the dumping conveyor where water is mised in the temper bins, it then moves to another temper bin where the same process is repeated to make the corn fully ready for crushing.

From the temper bin, the maize goes to milling scale to measure the exact quantity of corn left for crushing. From here it goes to the infelloder - first machine to break the corn into pieces - then to the degerminator machine to modify it to course pieces. From there it moves by conveyor and pass through vibrator to the siffer division one where the product is seperated into various products (curse, flour cannel and bran).

The curse goes to the puritier—curse bin.

The bran to bran bin.

The flour cannel goes to the rollers for grinding into finer floor then back to the second siffer which will again separate the product into curse bran and pure floor. The floor then goes into the floor bin. Then it is ready for packaging into sacks of 10kgs and 50kgs.

3.3 Data Presentation

The major raw materials of Northern Nigerian Flour Mills Limited are wheat, vitamin enrichments (energo), maize, sorghum, millet and water. The vitamin enrichments cirstitive less than 1% of the proportion of the final product. While wheat and maize are the two most important products used for the firm's operations.

The company has a weekly requirement of about 10,000 tons of wheat which it orders at the cost of ₦100 per ton. Wheat used to be imported at the cost of ₦480/ton. However, with the recent ban on the importation of wheat the company now buys its wheat locally at the cost of ₦3,200/ton to the yard. The off-loading charges at the yard is about ₦10/ton. The annual holding cost of wheat in terms of insurance, storage space and opportunity cost of capital tied up in the inventory is about 18% of the average inventory value. The combined capacity of the (wheat) silos is 10,000 metric tons. The wheat mills have the capacity to process 70,000 tons of wheat per week. It used to take about 3 months between the time an order is placed and the time it is received. Now it takes about a month.

Maize had always been purchased locally, at the cost of

₦2,000/ton on the average. The handling cost at the yard is also about ₦10/ton, while the cost of keeping the maize in stock is about 14% of the average inventory value. The maize mills have the capacity to process 50,000 tons per week on a 24-hour 3-shift basis. However the current weekly production rate is 1,400 tons/week.

The company also uses quite a large quantity of diesel oil for its operations. For whenever production is about to begin the company switches off the NEPA mains and use their own plants. The production section needs about 300,000 litres monthly. There are two tanks with a capacity of 300,000 litres each. The company's policy is to place an order for 300,000 litres at the end of each month which normally comes in lots of 30,000 litres. While maintaining a constant safety stock of 300,000 litres monthly, to guard against eventualities.

The cost of being out of stock for any of the materials is estimated at ₦2,000 per ton per year. The cost of carrying the inventory is estimated to be 16% while ordering cost is estimated to be ₦100 per order.

3.3 DATA FROM COMRADE CYCLE

3.3.1 Company Background

Brief History of Comrade Cycle

Comrade Cycle is a bicycle assembling company located in

Zaria, Kaduna State. The company started in 1979, as a one man outfit engaged in the distribution of bicycles and spare parts, under the name of Baka-Cycles. Baka-cycles was owned and operated by Alhaji Ibrahim A. Mohammed, the current Chairman of Comrade Cycle (Nigeria) Limited.

Sometime around the middle of the 1980's Baka-cycles decided to expand its operations by venturing into bicycles assembling instead of being just a distributor of bicycles. Baka-cycles then got in touch with Comrade Cycle of London on the issue. On its part Comrade Cycle of London introduced Alhaji Ibrahim A. Mohammed to United Greefields Limited (UCL) of Shephards bush London. The result was a partnership agreement between UCL and Alhaji Ibrahim to set up a bicycle assembling factory in Zaria, to go by the name Comrade Cycle (Nigeria) Limited. In 1986, the factory was commissioned by the Minister of Mines and Industries, Alhaji Bunu Sheriff Musa, thus marking the metamorphosis of Baka-cycles from bicycle distribution to bicycles assembling.

The company's ownership is shared among three parties as follows:-

1) Alhaji Ibrahim A. Mohammed (50%)
2) United Greenfields Limited (UCL) 30%.
3) Northern Nigerian Investment Limited (NNIL) 20%.

3.3.3 The Production Process at Comrade Cycle

The first stage in the production process is DEGREASING. All components go into the degreasing machine first for 15 minutes. While in the machine certain chemical known as Friklone is used to render the components grease-less. After degreasing the next task is frame forming.

The first stage in the frame forming process is head tube punching after which spot welding is done to hold the head and the tube together. Next is the top tube matching and the bottom tube matching to form the triangle-shaped structure. Next is the seat tube sloping which enables the seat to be firmly attached to the frame, by making it possible to fit the lug into the slot.

After forming the triangular structure the next stage is to fix the chain stay blade to the bottom bracket after which the chain stay bridge is brazed to the chain stay blade. Next the back-stay bridge is braced to back slade and finally the back stay is fixed to the chain stay blade. And a bicycle frame is completed.

After the frame is formed the next process is assembling and frame alignment. The frame is punched at all joints so as to be firmly held together. The brazing of the frame, heating with a nozle, is done to further hold the joints together. After the brazing is the seat-tube remmer which is done to enable the seat pillar to go in very well. The next process is attaching the brake work and holding it in place at the bottom bracket and at the bottom lug. Short-blashing for 4 minutes to remove all particles from the assembled frame is next. The next task is smoothening the frame at the finishing stage.

The next process after 'finishing' is the spraying. The first coat is applied to the frame (fork) for 35 minutes, by passing it through the even at 175°c, to prevent rushing. The second painting is done according to the dealers specification. The next process is lining and attaching stickers of brand marks. After which all the accessories are passed on to the final assemblers. The company presently exports its products to Ghana and Mali.

3.3.4 Data Presentation

The number of parts that go into making a bicycle are numerous. There are dozens of such parts. Fortunately, the parts are not purchases separately. The company purchases about 48% of the materials locally and import the rest 52 from overseas.

The locally sourced raw materials include:-

(1) Tyres, (2) tubes, (3) pipes and (4) paint.

The imported items include:-

(1) Pedals, (2) the frame, (3) gear cases, (4) chain covers, (5) spokes, (6) rims, (7) handle bars, (8) forks, (9) back chains, (10) free wheels (hobs), (11) centre rods, (12) saddles and (13) brakes.

The company pays 35% duty on the imported items plus 5% handling charges at the port. The freight charges from Lagos to Zaria is ₦2,000 per 30-ton trailer.

The company pays an annual premium of ₦7,500 on its stock. It takes about nine months between the time an order is placed and the time it is received at the factory. The company produces about 100 bicycles a day on a one-shift six working days arrangement.

The cost of being out of stock in terms of less profit and loss of goodwill is estimated at ₦100 per unit per yeat.

3.4 DATA FROM RIGIDPAK

3.4.1 Introduction

Rigidpak is a manufacturing company engaged in the manufacture of cartons, located in Zaria. The company started operations in September 1980. The company's major shareholders are:-

1) Tower Group of Companies
2) Comfroft Limited of London, and
3) New Nigeria Investment Limited (NNIL).

3.4.2 Data Presentation

The company's major raw materials are:-

1) Craft paper (2) Printing Ink
3) Stiching wire (4) Bundling planks, and
5) Chemicals for making glue.

The craft paper forms 90% of the cost of material. The craft paper is being made by Nigerian Paper Mill Limited Jebba. The craft paper being made by the Nigerian Paper Mills is not as good as the imported one. There are two types of craft paper (1) The liner and (2) The floating paper. Nigerian Paper Mills makes the liner much better than the floating paper. Hence the company's policy is to import most of their floating paper. The company buys about 60% of its liner requirement from Nigerian Paper Mills and import the rest 40% from Norway, Sweden and North America.

The ordering cost in terms of issuing the purchase order, follow-up receiving the goods, quality control and placing them into, inventory is estimated at ₦25,000 for the imported paper and about ₦20,000 from Jebba.

The company mostly operate on overdraft facilities thus paying an interest of 18% per annum. Both the Nigerian Paper Mills Jebba and the foreign suppliers insist on payment first When importing the company has to pay the money to the bank and then did for the foreign exchange. From the time the foreign exchange is granted and the company opens a letter of credit (L/C) and then place an order with the suppliers abroad and the material is received at the company, it takes four months. When the company orders its paper from Jebba it normally takes two months to arrive. Neither the foreign suppliers nor Nigerian Paper Mills give any trade discounts at the moment.

The company's installed capacity is 450 tons per month. However current production rate is 160 tons per month. As a matter of policy the company keeps a minimum of 4 months inventory as a safety stock. The company's order size is 20 tons.

The penalty costs incurred as a result of running out of stock when the commodity in needed is terms of loss of customer goodwill and potential loss in profit due to loss in sales is estimated at ₦300 per ton per year.

The company's policy is to produce strictly based on order. Hence the company hardly keeps any finished goods inventory. This is because all jobs are made according to customer specification.

CHAPTER FOUR

DATA ANALYSIS

Having presented the data from the three companies considered in this study, an analysis will now be made for each company based on the given data; comparing the result with what current obtains in these companies. The tools to be used for the analysis are those inventory models derived and discussed in chapter two of this project. As I have already mentioned in the previous chapters most of the officers who supplied me with information contained in the preceeding chapter were somewhat 'afraid' of giving me the exact answers to my questions. Because of that the values for some of the parameters may not be the exact figure incurred by the companies.

This, howevers, will not affect the validity of the results from the models in any significant way. Nonetheless, sensitivity analysis will be carried out on the results to determine the extent to which over-statement or under-statement of certain cost figures can alter the decision so reached from the models.

4.1 APPLICATION OF INVENTORY MODELS TO DATA FROM NORTHERN NIGERIA FLOUR MILLS LIMITED, KANO

The company has two kinds of inventory, raw material inventory and finished goods inventory, arising from purchasing and production activities respectively. The analysis, therefore, will be done separately for the raw materials and for the finished goods.

RAW MATERIAL INVENTORY

WHEAT

D = 520,000 tons per annum

C_c = ₦3,000 per order

C_c = 18% of average inventory value

= ₦540/ton/year.

C_s = ₦2,000/ton/year.

Price/ton = ₦3,000.

The relevant model to apply here is the EOQ model shortages permitted.

$$Q^* = \frac{2C_o\ D}{C_c} \times \frac{C_c + C_s}{C_s}$$

$$= \frac{2 \times ₦3,000 \times 520,000}{₦540} \quad \frac{₦540 + ₦2,000}{₦2,000}$$

= 2,404 x 1.27

= 3,055 kons.

Thus, the most optimum quantity for NNFM to order whenever the company is replenishing its inventory is 3,055 tons. Next we can compute the optimum optimum level of safety stock (S) contained in this figure from the relationship

$$I^*_{max} = \frac{2C_oD}{C_c} \quad \frac{C_s}{C_c + C_s}$$

$$= \frac{2 \times \text{₦}3,000 \times 520,000}{\text{₦}540} \quad \frac{\text{₦}2,000}{\text{₦}540 + \text{₦}2,000}$$

$$= 2,404 \times 0.887$$

$$= 2132 \text{ tons}$$

$$\therefore \; S^* = 3,055 - 2132$$

$$= 923 \text{ tons.}$$

Next is the calculation of the incremental cost associated with the optimum ordering quantity

$$TIC^* = 2C_o \; C_cD \quad \frac{C_s}{C_c + C_s}$$

$$= 2 \times \text{₦}3,000 \times \text{₦}540 \times 520,000 \quad \frac{\text{₦}2,000}{\text{₦}540 \times \text{₦}2,000}$$

$$= \text{₦}1,297,998 \times 0.887$$

$$= \text{₦}1,151,324.$$

VALIDATION OF HYPOTHESIS

Having used one of the inventory models to arrive at an ordering quantity, we can now attempt to validate the claim that the quantity so computed is, indeed, the most economical. There are a variety of statistical techniques for testing hypothesis. However, for the purpose of this project a simple procedure will be employed. The procedure involves taking any two arbitrary quantities one below the figure of 3,055 and the other above it, and substituting these figures in the TIC equation if both quantities result in higher inventory costs than what the EOQ of 3,055 tons gives, then the hypothesis is validated. If, on the other hand, any of the quantities results in a lower TIC, then the hypothesis is wrong.

Assume on ordering quantity of 2,500 tons. This means that 555 tons (3,055 - 2,500) will have to be back-ordered. The total incremental cost for this is

$$TIC_1 = \frac{₦3,000 \times 520,000}{2,500} + \frac{₦540\ (2,500 - 555)^2}{2 \times 2,500} \times \frac{₦2,000\ (555)^2}{2 \times 2,500}$$

$$= ₦624,000 + ₦409,567 + ₦123,210$$

$$= ₦1,155,777.$$

Next assume an ordering quantity of 4,000 tons in which the case there will be no back-orders since 4,000 is greater than $Q^* = 3,055$. The total cost for this situation is

$$TIC_2 = ₦3,000 \times \frac{520,000}{4,000} \times ₦540 \times \frac{4,000}{2}$$

$$= ₦390,000 + ₦1,080,000$$

$$= ₦1,470,000.$$

Since both TIC_1 and TIC_2 are higher than the TIC^*, the hypothesis is, thus, validated. Having ascertained that 3,055 tons is the most economic quantity to order, we can now proceed to calculate the optimal number of orders per year (N^*), and the time between orders (T).

$$N^* = \frac{D}{Q^*}$$

$$= \frac{520,000}{3,055}$$

$$= 170$$

$$T^* = \frac{1}{N^*}$$

$$= \frac{1}{170}$$

$$= .006.$$

Since the company works all days of the week

$$T^* = .006 \times 360$$

$$= 2.16 \text{ days.}$$

This means the company should place an order every 2.16 days or approximately every 3 days.

MAIZE

D = 72,800 tons

C_o = ₦300 per order

C_c = 14% of average inventory

= ₦280/ton/year

C_s = ₦2,000/ton/year

price/ton = ₦2,000.

$$Q^* = \frac{2 \times ₦300 \times 72,800}{₦280} \quad \frac{₦280 \times ₦2,000}{₦2,000}$$

$$= 395 \times 1.14$$

$$= 450 \text{ tons.}$$

$$TIC^* = 2 \times ₦300 \times 72{,}800 \qquad \frac{₦2{,}000}{₦280 + ₦2{,}000}$$

$$= ₦110{,}591 \times 0.9366$$

$$= ₦103{,}580$$

$$I^*max = 2 \times ₦300 \times 72{,}800 \qquad \frac{₦2{,}000}{₦280 + ₦2{,}000}$$

$$= 395 \times 0.9366$$

$$= 370 \text{ tons}$$

$$S^* = Q^* - I^*max$$

$$= 450 - 370$$

$$= 80 \text{ tons.}$$

HYPOTHESIS VALIDATION

First assume an ordering quantity of 400 tons which means that 50 tons would have to be back-ordered. The total incremental cost is

$$TIC_1 = ₦300 \times \frac{72{,}800}{400} \times ₦280 \frac{(400 - 50)^2}{2 \times 400} \times \frac{₦2{,}000\ (50)^2}{2 \times 400}$$

$$= ₦54{,}600 + ₦42{,}875 + ₦6{,}250$$

$$= ₦103{,}727.$$

Next assume an ordering quantity of 500 tons in which case there will be no back-orders since 500 is greater than $Q^* = 450$.

$$TIC_2 = ₦300 \times \frac{72{,}800}{500} \times ₦280 \times \frac{500}{2}$$

$$= ₦43{,}680 + ₦70{,}000$$

$$= ₦113{,}680.$$

Both TIC_1 and TIC_2 are higher than TIC^*. Hence the model result is validated.

$$N^* = \frac{72,800}{450}$$

$$= 162$$

$$T^* = \frac{1}{162}$$

$$= .006.$$

The company works all days of the week. Hence,

$$T^* = .006 \times 360$$

$$= 2.16 \text{ days.}$$

FINISHED GOODS INVENTORY

WHEAT FLOUR

D = 520,000 tons per annum

C_o = set up cost = ₦4,000/run

C_c = ₦620/ton/year

d = 10,000 tons/week

p = 70,000 tons/week.

$$Q^* = \frac{2C_oD}{C_c(1 - d/p)}$$

$$= \frac{2 \times 4,000 \times 520,000}{620 \left(1 - \frac{10,000}{70,000}\right)}$$

= 2,798 tons/runs.

$$TIC^{*} = 2 \times 4{,}000 \times 520{,}000 \times ₦620 \times \frac{10{,}000}{70{,}000}$$

$$= ₦1{,}486{,}857$$

$$N^{*} = \frac{520{,}000}{2{,}798}$$

$$= 186$$

$$T^{*} \quad {}^{1}/_{186} = .005$$

$$T^{*} = .005 \times 360 = 1.8 \text{ days.}$$

<u>MAIZE FLOUR</u>

$$D = 72{,}800$$

$$C_{o} = ₦3{,}000/\text{run}$$

$$C_{c} = 620/\text{ton}/\text{year}$$

$$d = 1{,}000/\text{week}$$

$$p = 1{,}400/\text{week.}$$

$$Q^{*} = \frac{2 \times 72{,}800 \times ₦3{,}000}{₦620 \left(1 - \frac{1{,}000}{1{,}400}\right)}$$

$$= 1570 \text{ tons.}$$

$$TIC^{*} = 2 \times ₦3{,}000 \times ₦620 \times 72{,}800 \times \frac{1000}{1{,}400}$$

$$= ₦439{,}818$$

$$N^{*} = \frac{72{,}800}{1{,}570} = 46.4$$

$$T^{*} = {}^{1}/_{46.4} = .022$$

$$= .022 \times 360 = 7.92 \text{ days.}$$

Taking any other quantity apart from the Q^*s will result in higher inventory costs as has already been proved above.

APPLICATION OF INVENTORY MODELS TO DATA FROM COMRADE CYCLE

$D = 31,200$ frames

$C_o = ₦2,000$/order

$C_c = 7,5\%$ of ₦400

$= ₦30$/unit/year

$C_s = ₦100$/unit/year

Unit price = ₦400 per bicycle.

$$Q^* = \frac{2 \times ₦2,000 \times 31,200}{₦30} \quad \frac{₦30 \times ₦100}{₦100}$$

$$= ₦2,040 \times 1.3$$

$$= 2,652 \text{ units.}$$

$$TIC^* = 2 \times 2,000 \times 31,200 \times ₦30 \quad \frac{₦100}{₦30 + ₦100}$$

$$= ₦61,188 \times 0.877$$

$$= ₦53,665$$

$$I^*max = 2 \times ₦2,000 \times 31,2000 \quad \frac{₦100}{₦30 + ₦300}$$

$$= 2,040 \times 0.877$$

$$= 1,789 \text{ units.}$$

$$S^* = Q^* - I^*max$$

$= 2,652 - 1,789$

$= 863$ units.

VALIDATION OF HYPOTHESIS

Assume Q = 1,800 units

$$TIC_1 = ₦2,000 \times \frac{31,200}{1,800} + \frac{₦30\ (1,800 - 852)^2}{2 \times 1,800} + \frac{₦100\ (852)^2}{2 \times ₦1,800}$$

$$= ₦34,667 + ₦7,487 + ₦20,164$$

$$= ₦62,318$$

next assume Q = 3,000

$$TIC_2 = ₦2,000 \times \frac{31,200}{3,000} + \frac{3,000}{2} ₦30$$

$$= ₦20,800 + ₦45,000$$

$$= ₦65,800$$

Both TIC_1 and TIC_2 are higher than TIC^*. Hence the model result is validated.

$$N^* = \frac{31,200}{2,652} = 11.765$$

$$T^* = \frac{1}{11.865} = 0.085$$

The company works 6 days a week, Hence,

$$T^* = 0.085 \times 312 = 26.52 \text{ days.}$$

FINISHED GOODS INVENTORY - BICYCLES

D = 31,200 bicycles

C_o = ₦2,500/run

C_c = ₦10/unit/year

d = 100 bicycles per day

p = 200 bicycles per day (2-shifts).

Price/unit = ₦500.

$$Q^* = \frac{2 \times 31,200 \times ₦2,500}{₦10 \left(1 - \frac{100}{200}\right)}$$

= 5,586

$$TIC^* = 2 \times 31,200 \times ₦2,500 \times ₦10 \times \frac{100}{200}$$

= ₦27,928

$$TIC = C_o \times \frac{D}{Q} + C_c \frac{Q}{2} \left(1 - \frac{d}{p}\right)$$

VALIDATION OF HYPOTHESIS

Assume a Q = 6,000

$$TIC_1 = ₦2,500 \times \frac{31,200}{6,000} + ₦10 \times \frac{6,000}{2} \left\{1 - \frac{100}{200}\right\}$$

= ₦13,000 + ₦15,000

= ₦28,000

Assume a = 5,000

$$TIC_2 = ₦2,500 \times \frac{31,200}{5,000} + ₦10 \times \frac{5,000}{2} (.5)$$

= ₦15,600 + ₦12.500

= ₦28,100.

Both TIC_1 and TIC_2 are higher than TIC^*, thus the model had again produced the optimum result.

$$N^* = \frac{31,200}{5,586} = 5.585$$

$$T^* = 1/5.585 = 0.179.$$

The company works 6 days of the week. Thus'

$$T^* = 0.179 \times 312 = 55.86 \text{ days.}$$

APPLICATION OF INVENTORY MODELS TO DATA FROM RIGIDPAK

IMPORTED CRAFT PAPER

$D = 1920 \times .4 = 768$ tons

C_o = ₦25,000 per order

C_c = 18% of average inventory value.

= ₦180/ton/year

C_s = ₦300/ton/year.

$$Q^* = \frac{2 \times 768 \times ₦25,000}{₦180} \quad \frac{₦180 + ₦300}{₦300}$$

$$= 462 \times 1.18$$

$$= 545 \text{ tons.}$$

$$TIC^* = 2 \times 768 \times ₦180 \times ₦25,000 \quad \frac{₦300}{₦180 + ₦3000}$$

$$= ₦83,138 \times .79$$

$$= ₦65,679$$

$$I^{*}max = \frac{2 \times 768 \times ₦25,000}{₦180} \quad \frac{₦300}{₦180 + ₦300}$$

$$= 462 \times .79$$

$$= 365 \text{ units.}$$

$$S^{*} = 545 - 365$$

$$= 180 \text{ tons.}$$

VALIDATION OF HYPOTHESIS

First Assume $Q = 500$

$$TIC^{*}_{1} = ₦25,000 \times \frac{768}{500} \times \frac{₦180\ (500 - 45)^2}{2 \times 500} + \frac{₦300\ (45)^2}{2 \times 500}$$

$$= ₦38,400 + 37,265 + ₦607$$

$$= ₦76,272.$$

Next assume $Q = 600$.

$$TIC_2 = ₦25,000 \times \frac{768}{600} \times \frac{600}{2} \times ₦180$$

$$= ₦32,000 + ₦54,000$$

$$= ₦86,000.$$

Both TIC_1 and TIC_2 are higher than TIC^{*}. Therefore the model result is the optimal.

$$N^{*} = \frac{768}{545} = 1.41$$

$$T^{*} = {}^{1}/1.41 = 1.71,\ .71 \times 312 = 221 \text{ days.}$$

LOCALLY MADE CRAFT PAPER

$$D = 1920 \times .6 = 1152 \text{ tons}$$

$$C_o = ₦20,000 \text{ per order}$$

$$C_c = 18\% \text{ of average inventory value.}$$

$$= ₦180/\text{ton/year.}$$

$$C_s = ₦300/\text{ton/year.}$$

$$Q^* = \frac{2 \times 1152 \times ₦20{,}000}{₦180} \quad \frac{₦180 + ₦300}{₦300}$$

$$= 506 \times 1.18$$

$$= 597 \text{ tons.}$$

$$TIC^* = 2 \times 1152 \times ₦20{,}000 \times ₦180 \quad \frac{₦300}{₦180 + ₦300}$$

$$= ₦91{,}074 \times .79$$

$$= ₦71{,}948.$$

VALIDATION OF HYPOTHESIS

Asume $Q = 550$

$$TIC_1 = ₦20{,}000 \times 1152 \times ₦180 \frac{(650 - 47)}{2 \times 550} + \frac{₦300\ (47)^2}{2 \times 550}$$

$$= ₦41{,}891 + ₦41{,}401 + ₦602$$

$$= ₦83{,}894$$

next assume $Q = 620$

$$TIC_2 = ₦20{,}000 \times 1152 + \frac{₦180}{620} \times \frac{620}{2}$$

$$= ₦37{,}161 + ₦55{,}800$$

$$= ₦92{,}961.$$

Both TIC_1 and TIC_2 are higher than TIC^*. Hence 597 is the optimum order quantity.

$$N^* = \frac{1152}{597}$$

$$= 1.93$$

$$T^* = \frac{1}{1.93}$$

$$= .518.$$

The company operates 6 days a week. Thus,

$$T^* = .518 \times 312$$

$$= 162 \text{ days}.$$

This means the company should place a new order every 162 days.

SENSITIVITY ANALYSIS

The EOQ models derived in chapter have just been applied to the data from the three companies in this study. The question now is how accurate are estimates of the cost used in the models. This is one of the difficulties in applying mathematical models in decision making. Usually, extreme precision is often impossible to obtain because of measurement problems and the need to assign values to intangible items such as investment opportunities, lost sales, goodwill, and so on. These measurement problems, however, are no excuse for depending on intuitive judgement in decision making. For it is possible to determine precisely the extra cost resulting from errors in cost estimation.

If it can be proved that a particular model is fairly insensitive (robust) to cost estimation errors, then it can still be used as a decision making aid, and it will normally produce better solutions than intuitive judgement. The extra cost resulting from an error in estimating one of the values in the EOQ formulae can be calculated as follows:-

$$\text{Percentage of extra cost} = \left(\frac{k+1}{2\sqrt{k}}\right) - 1$$

where,

$$k = \frac{\text{estimated value}}{\text{true value}}$$

Suppose that the carrying cost in the wheat problem had been incorrectly estimated at ₦777, the magnitude of the error can be calculated, thus:

$$k = \frac{777}{540} = 1.44$$

$$\text{\% of extra cost} = \left(\frac{1.44+1}{2\sqrt{1.44}}\right) - 1$$

$$= 0.016$$

The effect of making a very large error of 44% in estimating carrying cost results in only 1.6% increase in total inventory associated costs. Thus

TIC = ₦1,151,324 (1.016)

= ₦1,169,745.

Generally total cost is more sensitive to under-estimation of parameter values than to over-estimation, but within a rather large range the total cost is relatively inesnsitivy to errors in either direction. Although some combinations such as over-estimating C_o and under-estimating C_c accentuate the error, other combinations such as over-estimating both C_o and C_c cancel the error out.[1] In any case applying the models to problem of inventory decision will result in more efficient decision than simply relying on intuition.

COMPARISON OF THE THREE RESEARCH CASES

In the analysis of data from NNFM Ltd only inventory decisions in respect of wheat and maize and their end products were considered for analysis. This is not to say, however, that the other raw materials like vitamins enrichments and millet are not important. Rather it is only for these two products - wheat and maize - that sufficient data were provided to enable any meaningful analysis. In any case these two products and their finished products constitute over 90% of the total inventory value. Hence the analysis of these two products suffice.

For wheat the order quantity which minimizes the TIC is calculated to be 3,055 tons, while for maize it is 450 tons. Deviations from these quantities, whether negative or positive, results in a higher cost. Similarly, for wheat flour and maize flour the optimum quantity to produce in one production run is calculated to 2,798 tons and 1,570 tons respectively.

The company does not use any scientific techniques in formulating its inventory policies. Rather, foreign partners just keep sending stock as long as the market is moving. For its own local purchase, however the company maintains a stock replacement account of ₦2,471,776.00. Now that wheat importation is banned the company has to purchase its wheat requirement locally. Whatever the case is, the company can always determine the optimum order quantity since most of the inventory relevant costs can be ascertained by simply going through the records.

For a company like Comrade Cycle having dozens of inventory items it is not feasible to compute the optimum inventory cost associated with each item. To solve this problem I have decided to use the frame on the 'pivot' inventory item in that it is the pivot to which all other accessories are attahced. Using the frame on a base for all other parts can be found by simply the number of each part required on a bicycle by the EOQ frames.

For example, the optimum number of pedals to order is found by simply multiplying the EOQ units by 2 (i.e. 2 x 2,652 = 5,304 pedals). The optimum order for other accessories like gear cases, quantity rims, spokes, and so on, is found in the same way.

The optimum number of bicycles to produce per production run has been determined as 5,586 units. Deviations from this quantity were shown to have produced higher inventory costs. The determination of the optimum quantities to order or produce is relatively straightforward in this company. All the pertinent information necessary for inventory model application could be obtained by simply going through a few records. Since the company has been operating for almost six year now a reasonable probablistic estimates could be made from past trends. Unfortunately, however, the company had never even attempted to use any mathematical models in aiding its decision making. As at the time I visited the company the production flow was not going smoothly because of lack of gear cases. And I was told that the situation had been like that for two weeks hence. These types of problems could be greatly minimized by making use of scientific techniques in formulating inventory policies.

The composition of inventoriable items in Rigidpak is similar to what obtains at the NNFM. A single inventory item - craft paper represents about 90% of the cost of material. Hence determining the economic order quantity for this item is sufficient enough for effective inventory control. The optimum order quantity for all other items could be found by determining how much of each of the other items goes into the processing of say one ton of craft paper. This is not a difficult task in that the records at the production department would make the task much easier.

In the analysis the economic ordering quantities were determined separately for the imported craft paper and for the one locally made at Jebba in the proportion that the company patronize each source. At the moment the company does not employ any of the popular inventory techniques in making inventory decisions. However, the company has a policy of keeping a minimum of three months supply in order to guide against stock-out during lead time. Generally the company likes to keep as much inventory as funds would allow. This is because the company believes that the frequent price rises in the market is much more than the interest it pays on its overdraft facilities.

One thing is obvious from the three researches cases in this project: none of the companies use any scientific inventory techniques in formulating its inventory policies. However, Rigidpak's policy of carrying no less than three months safety stock to guide against delays during lead time is more refined than the other companies' policies of just ordering on as-needed basis. Another common feature of the three cases is that they all exhibit inventory situations that are quite amenable to scientific inventory models applications.

Managers in all the three companies, with whom I had discussions, are very much aware of the existence of scientific techniques of managing inventories and the power of its analysis. But they have very little faith and confidence in its applicability in the real-life, complex unstructured and ill-structured problems of the Nigerian economy that they have to deal with.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1 Introduction

The economic trend in Nigeria and, indeed, most other developing economies, did not encourage productivity rises and cost reductions. The market structure is highly imperfect and goods and services are relatively scarce. There is very little competition in the manufactured-consumption goods sector. Even in the export goods sector, the inefficiency of production is protected through subsidies, exemption of duties and liberal credit at low rates of interest. Thus the manufacturing sector had very little incentive to increase productivity and reduce costs in a mark-up, pricing system as ours. Under this condition a private industrialist is not interested in using the scientific methodology of operations research in general in his problem solving process. Unlike what obtains in developed countries where demand and supply equilibrium in a competitive economy discriminate against inefficient establishments. Thus, there is a logical and economic compulsion to use the aids, tools and methods of science for the improvement of productivity and reduction of costs.[1]

However, of recent the trends in the Nigerian economy has

1. "Operations Research applications in Industry and Problems of Industrialization of a developing economy with special reference to India" by R. BANDYOPADHYAY JOURNAL OF OPERATIONS RESEARCH, September 1980, p. 775.

drastically change that only firms that seek and vigorously pursue ways of increasing productivity and cost reduction techniques can hope to sruvive the gloom. That the Nigerian business sector, and indeed the economy as a whole, is in crisis is a fact which every business organisation is accutely aware of. Rampant inflation, factory shut-downs and lay-offs, shrinkage of capital investment of profit margins, and the general economic chaos of the last five years are all symptoms of this crisis. Alongside the economic cricis, there is also a crisis of legitimation - an unwillingness among the labour force to accept passively the conditions of their labour, giving rise to strikes, threats of strikes and frequent strain in labour-management relations. The Nigerian business firms, therefore, have no other choice than to seek ways of increasing productivity and minimizing cost. In this endeavour, effective inventory control administration can act as an effective instrument.

5.2 CONCLUSIONS FROM THE STUDY

Having gone through all the necessary stages in conducting a research of this nature, it is now ripe to draw conclusions from the research findings and make appropriate recommendations. The conclusions are, essentially, a highlight of the problems associated with the application of inventory control models in our industries. The recommendations, on the other hand are intended to reinforce the prospects for the application of these models. Based on the findings of this study, the following conclusions are reached:-

1) Most managers are aware of the existence of inventory control models and the power of their analysis, but that they have very little faith and confidence in their applicability in the real life, complex unstructured and ill-structured problems of the Nigerian economy with which they have to deal with. As one senior manager at RICHPAK put it:

"Because of the inflationary nature of the economy, the company prefers to keep as much inventory as possible. If we have the funds, sky is the limit!"

2) Senior executives in the organisations consider such operations research techniques as inventory models to be very sophisticated techniques which can only be used in highly industrialised countries or by headquarters of multinational corporations operating in the country.

3) None of the three companies consider it necessary to engage the services of an operations research expert in handling their production and scheduling operations.

5.3 RECOMMENDATIONS

The objectives which this research set out to achieve were clearly stated under the heading of statement of objectives in chapter one. Therefore, the suggestions and recommendations profered here are made with those objectives in mind.

1) Operations research, the family to which inventory models belong, can be broadly defined as the application of quantitative techniques and a model-building approach to management problems. As such, it is more akin to be technology than to a science. The application of inventory models, therefore, should be appropriate to the context to which it is being applied like any other technology. This means that it should be done in ways which are comprehensible and acceptable to decision makers and the other interest groups involved. The inventory decision has already been shown to affect different interest groups in an organisation.

2) The present state of affairs whereby companies do not care to employ operations research experts to head their production and procurement divisions should have to change. Companies should show more interest in seeking young operations research experts and provide them with complex challenging inventory problems on which they could try out their bright, new chromium plated mathematical tools. However, where the organisation does not feel safe in passing high level information into the homes of strangers or outsiders as in the

case of consultants, the company should then search, among its employees, for reliable people who had been with the organisation for quite some time, who display talents that will make a good research and send them for training in operations research.

3) Successful application of inventory models require a sound data base. Therefore companies should endeavour to keep accurate records of all inventory related transactions and other related activities.

The three companies in this study and indeed other manufacturing companies in the country, are industrial companies. Industrial companies are purposeful organisations; and in a purposeful organisation something is made to happen when:

(a) The organisation sees the need to do it and

(b) The organisation has (or can require) the means to do it.

This is where the role of an operations research society is very important. Hence I am strongly recommending that all operations research experts in the country, whether they are in the academic institutions or other institutions should come together to establish an operations research society. For I am not aware that such a society exists, if on the other hand there is one currently in existence then its activities should be broaden to include programmes that will enlighten business firms on the benefits to be derived from making use of operations research techniques.

4) Operations research experts who find themselves working for business corporations should as much as possible avoid the use of sophisticated techniques with poor data. Rather the experts should concentrate their efforts in developing appropriate methodology for problem formulation, model construction and solutions where existing techniques cannot be applied, instead of 'twisting' problems to fit the available bag of techniques.

APPENDIX I

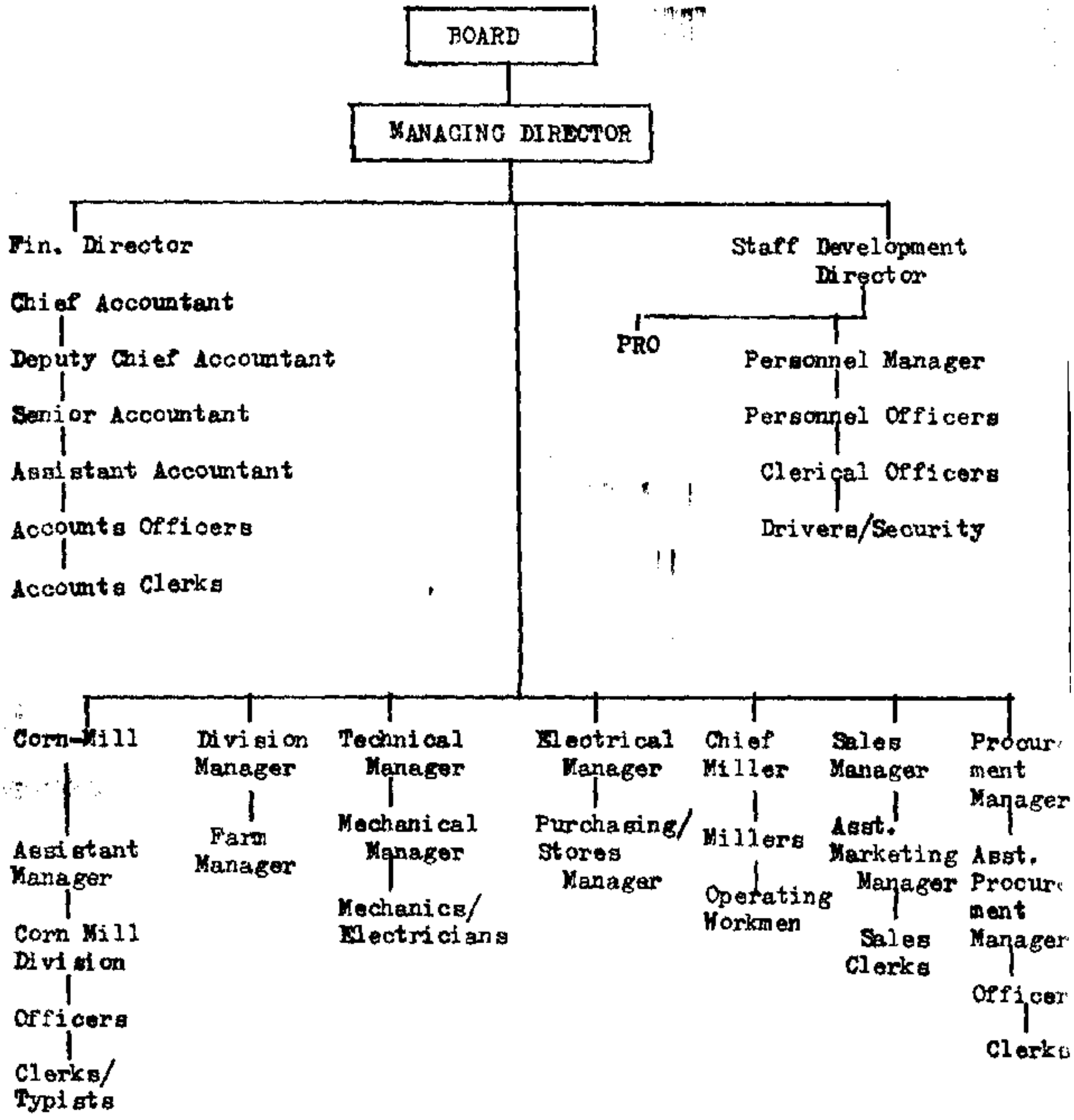
USE OF OPERATIONS RESEARCH IN CURRENT ACTIVITIES (TURBAN SURVEY)

TECHNIQUES	NO. OF PROJECTS	FREQUENCY OF USE (%)
Statistical analysis	63	29
Simulation	54	25
Linear programming	41	19
Inventory theory	13	6
PERT/CPM	13	6
Dynamic programming	9	4
Non-linear programming	7	3
Queueing	2	1
Heuristic programming	2	1
Miscellaneous	13	6

APPENDIX II

NORTHERN NIGERIA FLOUR MILLS LTD., KANO

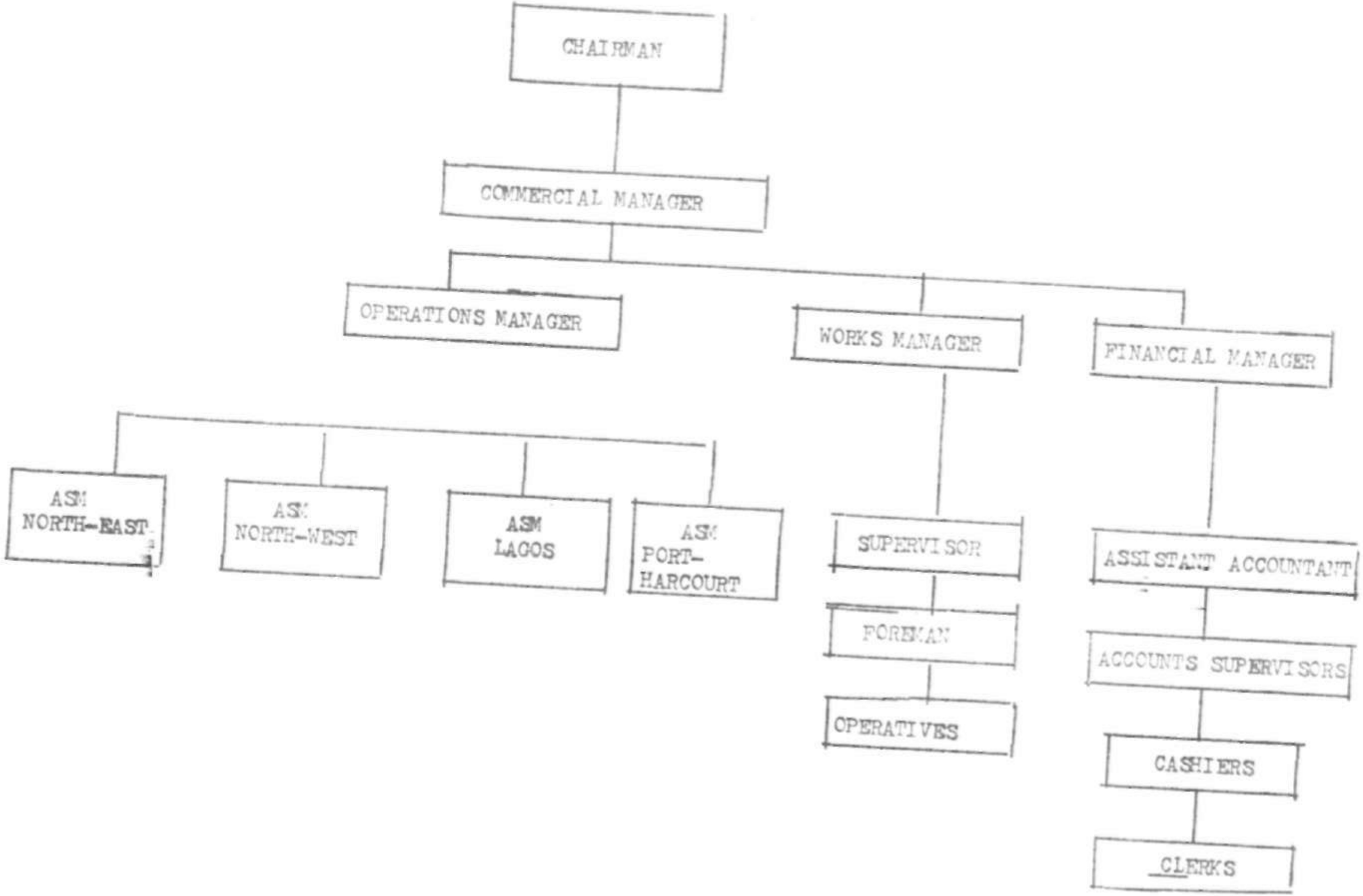
ORGANISATIONAL CHART



APPENDIX III

COMRADE CYCLE (NIG.) LTD., ZARIA

ORGANISATIONAL CHART



APPENDIX IV

RIGIDPAK (NIG.) LTD., ZARIA
ORGANISATIONAL CHART