APPLICATION OF LINEAR PROGRAMMING TO PRODUCTION SCHEDULING IN FUNTUA TEXTILE COMPANY LIMITED

BY

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D E C L A R A T I O N

THIS IS TO DECLARE THAT THIS PROJECT IS MY ORIGINAL WORK MADE POSSIBLE THROUGH THE ASSISTANCE OF MY SUPERVISOR, MAL. ABDULLAHI TAFIDA. ALL SOURCES OF INFORMATION ARE ACKNOWLEDGED ACCORDINGLY.

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C E R T I F I C A T I O N

THIS PROJECT TITLED, "APPLICATION OF LINEAR PROGRAMMING TO PRODUCTION SCHEDULING IN FUNTUA TEXTILE COMPANY" BY DANFULOTI KADO MEETS THE REGULATIONS GOVERNING THE AWARD OF THE DEGREE OF MASTER OF BUSINESS ADMINISTRATION (MBA) OF AHMADU BELLO UNIVERSITY, ZARIA AND IS APPROVED FOR ITS CONTRIBUTION TO KNOWLEDGE AND LITERARY PRESENTATION.

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D E D I C A T I O N

This work is dedicated to the following:

1. My father Late Alhaji Kadon Danyaro
2. My mother Khadija Abdulkadir
3. Shema'u Ibrahim
4. The entire members of my family.

A C K N O W L E D G E M E N T

IN THE NAME OF ALLAH

Success cannot be achieved absolutely singlehandedly by any individual. Although most of this work is done by me, the people that influenced its success are many; their contributions to the completion of the work so important that I cannot close my eyes and claim accomplishment without acknowledging the contributions of a few of them.

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As I recognised above that most of the work is done by me I also wish to assert taking respensibility of any sort partaining to this work.

D. K. GUGA

A B S T R A C T

This work was primarily undertaken to find out the applicability of linear programming technique to production scheduling in Nigerian manufacturing industry.

The work is divided into five chapters. Chapter one dealt with introducing the subject of complexity in decision making due to the geometrical development in organisational activities. It also introduced the discipline 'Operations Research' and of its tools - linear programming. The Chapter further highlighted the objectives,, of methodology of research and some percieved limitations of the study.

The second chapter dealt with an intensive review of related literature on its application to production scheduling and at the end came up with a hypothesis that guided and gave direction to the study.

Chapter three was dedicated to presentation of the data collected and the choice of an appropriate linear programming model to analyse the data .

The last two chapters dealt with the analysis of the data, discussion of the results thereto and suggestions thereupon.

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CHAPTER ONE

INTRODUCTION

1.1 GENERAL

As man advance in knowledge so also the advancement of scientific decision models that make the work of a decision maker easier in coping with the dynamic decision environment. With increased understanding, all areas of human endeavour evolved with varying rapidity along a continous line from the extreme of pure art to that of pure science and the decision situation continued to be easily understood, explained and predicted. Through the dimensions of time, experiences and tests tended to generate guidelines to hypothesis which eventually became modelled into workable principles - theories laws and truths. With this transition, the hitherto "loosely structured qualitative decision models tend to evolve into more highly structured qualitative decision models".[1]

The area of business and economics has been affected by this advance in knowledge and the subsequent movement of problem solving from being more of an art to more of science. Better decisions were made through quantitative models that have been developed to suit a particular problem. One of the primary concern of people however, has always

been and will continue to be that of allocating scarce resources. Since resources - men, machines, funds, time, land, etc - are in limited supply, the problem of allocating them arises whenever there is more than one activity requiring their usage for the attainment of an objective. The quantitative model that man have developed and perfected in solving the problems of resource allocation is the one known as linear programing which is one out of many models for tackling problems scientifically. These quantilative models that help decision makers to resolve problem areas constitute a major part of the discipline broadly called'Management Science' or Operations Research.

Manufacturing firms like any other enterprise are faced with the issue and or problem of decision making. Issues such as what product line(s) should be maintained, what product items should be carried in the product line(s), what price should be charged for the products, how should the basic raw materials be sourced, what number of workers should be selected to do the various jobs, what level of inventory should be carried, what mode of financing should be embarked upon, are some of the areas of decision in a particular manufacturing company.

With the successes of applying scientific approach in resolving some of the above issues in industrial processes, this study wishes to discover the use of these scientific tools and the extent of their application in the manufacturing industry in Nigeria singling out Funtua Textile Company as a point of divergence for proper inferences. To achieve this, the Company's activity selected is production scheduling and the scientific tool of measurement, Linear programming.

1.2 OPERATIONS RESEARCH

The most important job of a manager is making decision. Decision making is basically choosing a course of action from among other alternatives that will optimize resource application in line with organisational objectives. These decisions are more often than not being made to meet the demands of future circumstances. Business exists primarily to satisfy the various needs of its customers and therefore deciding on how to meet these demands, making optimal use of the available human and material resources becomes an indispensable and challenging function of managers.

Operations research is a scientific approach among many that facilitates the work of a manager.

This is because deciding on future events is beseted by a multitude of problems manifested in the degree of certainty with which the future can be understood and predicted. For instance, a manager who is concerned with satisfying demands through optimal utilisation of the facilities at his disposal has to contend with the random nature of demand variation and management of workforce and inventory. It would have been easier to manage productive system if demands were constant.

Demand fluctuation notwithstanding, however, relative stability in the utilisation of available resources and satisfaction of customers' needs in the face of stiff competition are necessary prerequisite of sound business performance. This entails employment stability which in turn serves as an assurance for job security to a worker and therefore increase his commitment and identification with the company. This also allows management to plan and determine production cost with more precision and accuracy.

Any organisation, whatever its line of business activity has the onerous task of satisfying its customers' needs and expectation if it hopes to survive and grow. This task is accomplished through

management ability to predict with reasonable degree of accuracy the future demands and changes thereof of its customers and its capacity to plan effectively to produce what is capable of satisfying those demands. However the ability of a company's management to effectively predict the future is subject to some factual realities that make it necessary for a company to strive hard to remain in business.

In whatever business an organisation is engaged in, it is strongly likely that it will face competition in both the acquisition of the resources it uses and the set of customers it serves. In addition, a company has to be aware of the costs associated with the factors of production. Efficient utilisation of resources such as labour, machinery and capital is necessary due to the high costs involved in obtaining them and need for the company to operate at low production cost, realisation of invested funds at the minimum possible time and making reasonable profit as an indicator of company's ability to favourably compete and continue to remain in a particular line of business. This is only possible if there is good assessment of opportunities and constraints, self analysis of strength and weakness and economical application of available resources.

The above problems and many more others could successfully be tackled by the use of operations research. The technique of operations research has provided managers with various mathematical theories and models for guidance in decision regarding those areas where the key variables could easily be quantified.

"Operations research may be described as a scientific approach to decision making that involves the operations of organisational systems".[2] This means that for a successful application of the technique, the activities of an organisation must where possible be reduced to quantifiable variables that could easily be treated using any of the various techniques of operations research that may well suit the circumstance at hand. Among the various techniques of operations some include: probability theory, queueing theory, simulation techniques, inventory models, mathematical programming, network programming, goal programming, etc. Depending upon the problem and decision circumstances prevalent at a particular time, a choice is made among the various tools of 'operations research' with a view to providing optimum solution to whatever problem is at hand. An effective manager therefore has to have a good working knowledge of the various models and possess the

ability to apply them to decision situation rightly.

Areas of inventory control, assignment of personnel, assignment of jobs to machines, blending of materials, feed and production mix problems, distribution and transportation and investment portfolios etc. are good examples where operations research has successfully been applied with rewarding results. The problem of how to utilise limited resources to the best advantage is tackled by a set of techniques developed and known as Mathematical programming of which linear programming is among the simplest and widely used.

1.3 LINEAR PROGRAMMING

The problem of how to utilise limited resources to the best advantage is not a new one. The set of techniques developed to tackle such problem is known as mathematical programming. Linear programming, the simplest and most widely used of these techniques, is a method for deciding how to meet some desired objective, such as minimising cost or maximising profit, subject to contraints on the amounts of commodities required or resources available.

Linearity is considered to mean proportionality. Invariably this means that if 1kg of a commodity cost ₦1.50, 10kg will cost ₦150.00; or if a steel rolling

mill can produce 200 tons in 1 hour, it can produce 1000 tons in 5 hours.

Linear programming, among others such as Search Decision Rule, Material Requirement Planning, Linear Decision Rule, is used in solving a myriad of problems of which among others is production schedule. Linear programming as earlier stated deals with the problem of allocating "limited resources among competing activities in the least possible way"[3]. This kind of problem can arise whenever there exists a situation when a manager has to select the level of some events that compete for scarce resources necessary to performe certain activities. For example, allocation of production facilities to products, allocation of national resources to domestic needs, portfolio selection, shipping pattern, agricultural planning, etc. tipify the successful use of linear programming technique. Many manufacturing companies have successfully applied linear programming techniques and others in their various production schedules.

1.4 STATEMENT OF THE PROBLEM

Operations Research techniques has had and will indeed continue to have wide application in the operations of organisations the world over especially in the developed countries. However in developing countries the use of these techniques as studies[4]

nave shown left more to be desired. In developing countries like Nigeria, where most of the machinery is oimported one would nave thougnt that optimal utilisation and maintainance tnrougn tne application of scientific approach particularly linear programming which is proved to ue simple[4], should ue one of tne pre-occupations of production managers.

Again as contrasted with developed countries, in tne developing nations like Nigeria there is lack of managerial and technical expertise which often resulted in tne engagement of foreign personnel to nandle macnines and to train locals in tne nandling of machines and their maintenance. This is however more often than not harpharzardly done resulting in low efficient application of the sophisticated machinery and the cost associated with the hiring of foreign personnel. As Anthony Lawal concluded in a study on the extent of application of operations research techniques in the Northern States of Nigeria, tnat "only few operations researcn techniques are fairly widely used and that overall, tne utilisation of these techniques is unsatisfactory"[5].

It therefore uecomes parliament to conduct more researches with a view to identifying tne causes for the low application of these techniques - which are universally proved to ue of superior outcome - in Nigeria, to apply some of tne techniques in order

to find out the problems and prospects and possibly to develop, test and suggest a model particularly in the area of production scheduling in the manufacturing industry in the country.

1.5 SOME FACTORS CONSIDERED IN THE CHOICE OF THE COMPANY FOR THE STUDY

1. Co-operation and easy accessibility to necessary required information.
2. Time and financial resources and the nature of production schedule. Due to the constraints of time and financial resources and the nature of the study, Funtua Textile Company Limited is chosen. It is however hoped that some general inferences will be drawn and generalised to reflect the nature of textile subsector of the industry in particular and the manufacturing sector in general.
3. Type of production process of raw material processed and the size and production capacity of the company. Although the company is relatively small, its operation warrants it to be considered to satisfy the objectives of the study.
4. The company's length of production experience. As an assumed pre-requisite, the company is deemed to have satisfied the requirement of being capable to provide adequate data for the study.

1.6 OBJECTIVES OF THE STUDY

1. Identification of the problems or setbacks associated with successful application of linear programming techniques to production scheduling.

2. To explore the applicability of other techniques or production scheduling not in use in the company but with records of successful universal application with a view to finding out whether they can be used in Nigerian manufacturing firms and the possible prospects and problems that are likely to hinder their successful usage.

3. To determine what factors are considered in the choice of a particular model in the company under study.

4. To determine what factors ought to be considered in the choice of a particular model of linear programming in production scheduling for the textile manufacturing industry in Nigeria. It is also the objective of the study to identify variations in the factors considered from one company to another.

5. To develop a model which could be used for production scheduling in the company under study in particular and for the manufacturing sector in general.

6. To suggest possible conditions that could provide an atmosphere for the successful application of the model to be developed in (5) above.

1.7 RESEARCH METHODOLOGY

1. A survey will be conducted in the company selected to determine the current nature of arts of production scheduling through personal interviews, records checking and observations.

2. Types of production processes, type of raw material processed, size and management of the company will then be studied through analysis of performance records.

3. A study of the existing technique of production scheduling highlighting their constraints and prospects will be conducted and a choice of suitable model to be tested will be made therefrom.

4. Application of the model selected by the use of collected data for a specific period of operation will be tried with a view to testing its validity and reliability and a final test on its significance or lack of it to production scheduling.

5. The result of the study as tested in (4) above will be compared in juxtaposition with the existing system of the company's production scheduling in order to provide the yardstick for the rejection or acceptance of the model chosen in (3) above.

6. Suggestion and recommendation will then be put forward based on the problems and prospects the method of research employed is able to identify.

1.8 LIMITATION OF THE STUDY

From the outset some facts that are likely to hamper the full realisation of the objectives of the study must be made clear: In a country like Nigeria where the culture of readership is not well developed and imbibed by individuals and organisations, there is strong tendency that information collected through direct interviews will contain errors of misrepresentation especially in a study of this nature where the information sought concerns the internal activities and operational strategies of an organisation as it might be rightly or wrongly thought that divulging such information will be inimical to the survival of the company; secondly, the implied assumption that one company could serve to provide an umbrella under which the study is to be carried out and its objectives realised in highly inadequate in view of the fact that the study wishes to provide a workable model that should apply not only to textile manufacturing subsector but also to the Nigerian manufacturing industry as a whole.

The above facts are further compounded by the following limitations:

1. Errors due to wrong recording of events on the part of the employees entrusted with such duty.

2. Time and Financial resources.

3. One company is not adequate to supply enough data that could be used to make a general analogy.

4. One model could not be sufficient for the company.

5. The assumption that past circumstances that provided the historical data to be studied will persist in future is highly suspected.

1.9 DEFINITION OF SOME KEY TERMS

SYSTEM - This is termed as a collection of interdependent objects or components, functions or activities that are grouped together to interact and make up a single object or function to perform a desired job.

MODEL - It is a tool that represent the experiences and characteristics about the essence of real system, object or situation that could be used to understand, predict and control the system. A model is usually used to test and evaluate systems and relationships between different variables without the need to act on the actual or real system itself.

PRODUCTION SCHEDULING - This is the sequencing or programming of plant activities with the aim of having finished product emerging from an assembly of machines within the plant at a specified period of time as so programmed.

OBJECTIVE FUNCTION - Is a function that relate the decision variables with their economic contribution or firm's financial comittment that need to be maximised or minimised as the case may be. That is, if the objective of the company dictated by the situation prevalent, is to reduce cost, the objective then is to minimise the objective function while the reverse will be the case when profit maximisation is the objective.

VARIABLES - These are the various items or factors which are limited or unlimited in supply with others being constant, but all are very crucial to the organisation's activity. These variables form the constraints that have to be reckoned with in any planning exercise of a company, they can either be machines and their capacity, raw materials available, market demand for the products and social, economic legal and other environmental factors which are capable of influencing organisational decisions and consequently the objective function.

CONSTRAINTS - Means those variables that are limited in supply or constant. Simply put, they are uncontrollable variables that influence the decision variables, often represented as inequalities.

DECISION VARIABLES - These are the variables - in the case of this study, the products of the company - which are influenced by the constraints

as to what number could be produced at optimum point through the use of Linear programming technique.

SIMPLEX ITERATION - The method used in solving the linear programming problem with as many number of variables as possible that uses matrix algebra in arriving at a solution.

PRIMAL PROBLEM - This is the initial statement of linear programming problem after having determined the objective function and the set of constraints.

DUAL PROBLEM - Is the mirrowimage of the primal representation of the problem arrived at by simply transposing the primal system of matrix. This sub-sumes that in any linear programming problem there are two sets of solution giving the same decision dimension.

SLACK - This is the time that a factor of production, for example machine, remains idle. Stack is very important in analysing the economic worth of a factor of product or in another sence the opportunity cost for not utilising the factor to full capacity.

SENSITIVITY ANALYSIS - This analysis covers the aspect that deals with the economies of slack variable. In essence, the behaviour or impact of adding new variables to the existing system of simplex matrix is vital and hence a better conclusion be reached through sensitivity analysis.

FOOTNOTES TO CHAPTER ONE

1. BILLY, M. T. AND PAUL, P.
   Introduction to Management Science: Quantilative Approaches to Managerial Decisions.

2. HILLIER AND LIEBERMAN:
   Introduction to Operations Research, Holden-day, 1980.

3. ABDULLAHI, S.B.
   Linear Optimisation Techniques as a Tool for Better Production Schedules: A comparative case study of three companies in Kaduna State of Nigeria. Unpublished MBA dissertation, ABU, ZARIA, 1984.

4. HILLIER AND LIEBERMAN
   Op cit.

5. LAWAL, A.
   Study on the extent of Application of Operations Research Techniques in the Manufacturing Sector in Northern States of Nigeria. Unpublished MBA dissertation, ABU, ZARIA, 1983.

CHAPTER TWO

REVIEW OF RELATED LITERATURE

2.1 INTRODUCTION

Linear programming technique has been proved to be applied with substantial success to solve problems of allocating resources to many areas of human endeavour including the subject of this study - production scheduling - and will continue to be one of the most widely used operations research tools particularly at the present time of technological advancement (the age of computer). Theories on Linear programming appear in as many operations research textbooks and Linear programming books and other related areas as there are authors to write about this important phenomenon in as much as one get the feeling that there is nothing left to write about. However, a review of the existing material is vital to this study.

Production scheduling is the art of assigning men, machines and raw materials in the best possible way in line with the targeted or forecasted level of activity per period of production. Many factors are considered in this assignment of the resources of production; the available machines, men to man the machines and the raw materials that go into the

production to name a few. Often, in cases of intermittent product where a company faces the problem of inventory and lay-off and set up costs, the problem of resourse allocation becomes compounded. Since it is an accepted fact that all these resources are in short supply because of obvious reasons (either the money to pay for them is not sufficient or actually they are scarce because of their multifarious uses thereby making their acquisition difficult when the little is available), it becomes impafative that the little that is at hand be utilised judiciously. Linear programming is one out of many techniques that helps executives decide on how to allocate these precious resourses to the best use.

However, to review the literature on linear programming and indeed its application to production scheduling it has been deemed necessary to start by looking at what mathematical models or techniques of which it falls within are about. To do this naturally will require an indeptn review of the discipline know popularly as "operations research".

2.2 OPERATIONS RESEARCH

Operation Research and indeed its various components is not a new phenomenain the field of decision making. Whatever the business (activity) or an organisation, be it military, government, private

or public the importance of deciding on courses of action in attaining targeted results cannot be over-emphasised. As the need for scientific approach to decision making became vital right from the times of industrial revolution when small businesses of the earlier era metamophosed into gaints billion naira corporations of today.

This scientific technique as defined by Hillier and Lieberman to mean "... a scientific approach to decision making that involves the operations of organisational system", involves the research on operations. Thus it can be said to be applicable to problems that concern how to conduct and coordinate the operations or activities within an organisation.

2.3 DEVELOPMENT OF OPERATIONS RESEARCH

The evolution of operation research dates back to the period of world war II when it became necessary to plan effectively and allocate the resources efficiently. Not that there was no need to allocate resources of an organisation in the pre-war times or that the idea of operations research was not even in the minds of scientists at that time, but operations research as known today to be a discipline of its own and studied in schools came to limelight in the period of world war II.

The roots of operations research may extend back even before the First Industrial Revolution, but the need which operations research serves began to develop during the Second Industrial Revolution (ACKOFF and SASIENI, 1968). The coming of machines tools and the development of national transportation and communication systems gave industrial activities great impetus and made industries what they became today. This revolution brought in its wake complexities in the handling of the activities of organisations by their individual owners. ACKOFF & SASIENI 1968 reported:

"... As companies expanded, it became less possible for one man to manage them; therefore the owners divided his job into parts, which he assigned to others. For example, managers of production, finance, personnel, marketing and research and development began to appear. With further industrial growth even these functions were subdivided; for example, production was sometimes divided into procurement or purchasing, maintenance, traffic, quality control, and production scheduling. As population grew and spread, new markets were formed and new sources of raw materials were discorvered. Consequently, industrial operations ....multiple production

> facilities and sales officers became common place and each required its own management. Thus the functional and geographical segmentation of management that we know today was a natural consequence of the industrial growth brought about by the first industrial revolution".

To carry out the executive function it is necessary to establish objectives for, and measures of, the performance of subunits reporting to it. For example, company executives normally establish the following objectives for the main functions of business.

Production: To maximise the amount of goods (or services) produced and to minimise the unit cost of production.

Marketing: To maximise the amount of goods (or services) sold and to minimise the unit cost of sales.

Finance: To minimise the capital required to maintain any level of business.

Personnel: To maintain morale and high productivity among the employees.

The work of an executive is the integration of these functional objectives in order to achieve the overall corporate goals of the organisation. Obviously, there are bound to be conflicts in the execution of the activities at functional levels in the attainment of these various objectives which makes the work of the chief executive considerably difficult. An executive, therefore, must be experienced and possess good judgement in order to be effective. Good judgement, however must be supported by scientific analysis of events that culminated into the expansion of organisational activities and their resultant complexities. This difficulties associated with the management of the hitherto small firm not only gave rise to management consultancy but also to the emergence of the phenomenon known presently as Operations Research.

It is significant to note that Operations Research development might not have been possible only because of the evolution of large industrial organisation had military organisations not experienced parallel expansion at the time it did. For almost the same reasons necessary for industrial evolution, the military organisations activities increased in scope. Specialisation and division in managerial skills increased with the development of new tech-

nologies which necessitated the differentiation of managerial function within the military establishment into four: administration, intelligence, operations and training, and supply and logistics. (ACKOFF AND SASIENI, 1968).

One could conclude that, serious development of the operations research techniques started during the world war II when reliance on intuition started to ware. Some of the investigations carried out by the British in the early days of the war were the determination of the optimum convoy size to minimise losses from submarine attacks, the determination of the correct colour of aircraft to minimise detection by submarines, the determination of the best ways to deploy radar units to maximise potential coverage against possible enemy attacks.

With the successes recorded during the war through the application of operations research techniques, the attention of industries were attracted. Industries then were engulfed with a multitude of problems varying from increased demand in certain products and the obvious shortages of certain materials immediately after the war, problems of increased complexities and specialisation in organisational activities and solutions or guides to faci-

litate solutions to these problems were desperately sought. The result of complex decision problems prompted business organisations to use the formal tools of operations research. An example of such formal tools is the simplex method for solving linear programming problems, which was developed in 1947 by the American Mathematician George Dantzig. Many of the standard tools of operations research such as Linear programming, dynamic programming, simulation, inventory theory, queueing theory, etc were fairly developed before the end of the 1950s.

Most of the formal approaches to decision making in industry were typically applied to special types or rather clear-cut, routine, operating problems, such as those of production control and resource allocation until 1960. Since that time, however, formal approaches have been applied increasingly to the less-well-structured planning problems as well. Partly as a result of this a more general technology has emerged for impossing logical structure on the reasoning that underlies any specific decision. This technology based on the concepts of decision theory, has been called "decision analysis". While decision theory appears to have originated from Bernolli, its application to decision problems was developed later, (MOSKOWITZ and GORDON, 1979).

2.4 NATURE OF OPERATIONS RESEARCH

Like many other fields, operation research was defined in various ways which are more or less general in nature. However it should be noted that "the approach of operations research isthat of scientific method".

ACKOFF and SASIENI, 1986, defined Operations Research in regard to its historical evolution as being;

> "1 - the application of scientific method
> 2 - by interdisciplinary teams
> 3 - to problems involving the control of organised (man-machine) systems so as to provide solution which best serve the purpose of the organisation as a whole".

This defination encompasses the basic characteristics of operations research that it is system orientation, the use of interdisciplinary teams and the application of scientific method to proolems of control.

Hillier and Lieberman (1980) defined Operations Research as "a scientific approach to decision making that involves the operations of organisational systems".

Operations Research as the name implies involves research on operations. Thus it can be said to be applicable to problems that concern how to conduct and integrate the operations of organisational systems. Essentially operation research is concerned with the scientific application/allocation of limited resources in order to meet, in the best way possible, the organisational objectives, and also attempts to solve the conflicts of interest among the components of an organisation in a way that is best for the organisation entirely.

Frederick Winslow Taylor known in management circle as the father of scientific management looked at scientific approach to management (operations research) as an attempt to find the best or optimal solution to problem. Rather than being content with merely improving the status quo, the goal is to identify the best possible cause(s) of action.

Perhaps a more wider definition of the phenomenon is best represented in the summary of Hillier and Lieberman (1980). Thus:

> "In summary, operations research is concerned with optimal decision making in, and modelling of, deterministic and probabilistic systems that originate from real life.

> These applications, which occur in government, business, engineering, economic, and the natural and social sciences, are largely characterized by the need to allocate limited resources ...."

They also believed that the contribution from operations research approach stems primarily from;

> "1 - The structuring of real life situation into a mathematical model, abstracting the essential elements so that a solution relevant to the decision makers' objectives can be sought. This involves looking at the problem in the context of the entire system.
>
> 2 - Exploring the structure of such solutions and developing systematic procedures for obtaining them.
>
> 3 - Developing a solution, including the mathematical theory, if necessary, that yields an optimal value of the sustem measure of desirability (or possibly comparing alternative courses of action by evaluating their measure of desirability).

Operations research, therefore, serves to provide more adequate instruments for making decision in the face of changing environmental conditions and

glaring contrasts and proves more suitable than other methods hitherto been used in tackling managerial problems, as the proponents of scientific approach to management aptly put it that "anything which cannot be quantified is not worth considering at all". One of such unscientific approach is the systematic approach to problem solving known also as the intuitive approach which boarders on the use of intuition, judgement and experience to select from among the available alternatives.

Among the earlier definitions of Operations Research is the one given by Morce and Kimbell which states; "Operations research is a scientific method of providing executive departments with a quantilative basis for decisions regarding the operations under their control"[1]. This definition however does not describe operations research adequately as other disciplines can also serve to provide departments with qualitative basis for decisions for example managerial finance.

Another early definition of operation research is the one given by Miller and Starr that "operations research is applied decision theory. Operations research uses any scientific, mathematical, or logical

1. P. M. Morse and G.E. Kimball, Methods of Operations Research, New York; John Wiley & Sons, 1951.

means to attempt to cope with the problems that confront the executive when he tries to achieve a thorough-going rationality in dealing with his decision problems"[2]. A recent definition given by Harvey M. Wagner stated: "For concenience, and with reasonable accuracy you can simply define operations research as a scientific approach to problem-solving for executive management"[3]. These definitions appear too general and suffer from the deficiency of not including the characteristics of operations research.

Operations research is defined in one of the best known textbook on operations research as; "Operations research in the most general sence can be characterised as the application of scientific methods, techniques, and tools to problems inolving the operations of systems so as to provide those in control of the operations with optimum solutions to the problems"[4]. Tnis definition is also general and does not include the essential characteirstics of operations research as it claims to do sucn as the use of inter disciplinary approach which is not indicated.

2. D.W. Miller and M.K. Starr, Executive Decisions and Operations Research, Englewood Cliffs, N.J.: Printice Hall, 1960.
3. H. M.Wagner, Principles of Operations Research, with Applications to Managerial Decisions, Englewood Cliffs, N.J.: Prentice Hall, 1969.
4. G.W.Churchman, R.L.Ackoff, and E.L.Arnoff, Introduction to Operations Research, New York: John Wiley & Sons, 1957.

As said earlier operations research is defined in many ways almost as many as there are authors on tne discipline. Tne Operations Research Society of America also gave its definition of the subject in 1971 as: "Operations research is an experimental and applied science devoted to observing, understanding, and predicting the behaviour of purposeful man-machine systems; and operations-research workers are actively engaged in applying this knowledge to practical problems in business, government, and society"[5]. Tnis definition is adequate so also is the one given by Thierauf and Klekamp (1975) as: "Operations Research utilizes the planned approach (updated scientific method) and an interdisciplinary team in order to represent complex functional relationships as mathematical models for the purpose of providing a quantitative basis for decision making and uncovering new problems for quantitative analysis".[6]

The foregoing definitions of operations research seem to possess common ideas; the use of the scientific method; study of complex relationships; and provision of a basis for decision making. Tnese ideas relate to the essential characterisitcs of operations research.

5. "Appendix I, Tne Nature of Operations Researcn", Operations Research, September, 1971.
6. Robert J. Tnierauf and Robert C. Klekamp, Decision making through Operations Resarch, Second edition, New York, John Wiley & sons, 1975.

2.4.1 Characteristics of Operations Research

Ackoff and Sasieni (1963)[7] gave three characteristics of operations research. These are:

a) its system (or executive) orientation
b) the use of interdisciplinary teams and
c) the application of scientific method to problems of control.

Thierauf and Klekamp (1975)[8] added a fourth characterisitc as essential in any operations research model. These are:

1 - Examine functional relationships from a systems overview.

2 - Utilize the interdisciplinary or mixed-team approach.

3 - Adopt the planned approach (updated scientific method)

4 - Uncover new problems for study.

Further, Moskowitz and Wright[9] gave six qualities as essentials for understanding the unique nature of operations research phenomenon which are:

1 - Focus

2 - Areas of Application

3 - Methodical Approach

7. R.L. Ackoff & M.W.Sasieni, Fundamentals of Operations Research, New York, John Wiley & Sons, 1963.
8. Robert J.Thierauf & Robert C.Klekamp, Decision Making through Operations Research, 2nd edition, New York, John Wiley & Sons, 1975 (op cit).
9. H.Moskowitz & G.P.Wright,Operations Research Techniques for Management, Prentice-Hall, Englewood Cliffs, N.J.:. 1979.

4 - Objective

5 - Interdisciplinary Team Approach

6 - Digital computer.

For operations research to be adequately described some of these characteristics have to be explained.

When these elements are present in any real life situation, it will become easier to handle the problem arising from the state using operation research techniques. However not all or these last set of characteristics must be in existence before the application of operations research can become possible. For instance even if there is no computer, problem of resource allocation with as fewer variables as three can be handled manually using the graphical method of linear programming.

2.5 MODEL BUILDING

Modelling according to Moskowitz and Gordon (1979) is the essence of an operations research approach. Constructing a model facilitates in putting the complexities and uncertainties of a decision-making problem into a logical structure that is amenable to formal analysis. It is therefore very important for an operations researcher or

decision maker to grasp the art of model building. Such mathematical model specifies the decision alternatives and their anticipated consequencies for all possible events that may occur, indicates the relevant data for analyzing the alternatives, and leads to meaningful and informative managerial conclusions. A model therefore is a well structured mechanism for reaching a well-structured preception of reality.

Further Moskowitz and Gordon (1979)[10] defines a model as: "an abstraction or an idealized representation of a real-life system", and give its objective as: "the objective of the model is to provide a means for analyzing the behaviour of the system for the purpose of improving its performance. Or if the system is not as yet in existence, to define the ideal structure of this future system indicating the functional relationships among its elements". However the reliability of the solution obtained from the model will depend on the validity of the model chosen in representing the real system.

There are basically three forms of models which are categorized by their types, dimensionality,

10. H. Moskowitz and G.P. Wright, Operations Research Techniques for Management, Prentice-Hall, Englewood Cliffs, N.J., 1979.

function, purpose, subject or degree of abstraction. These basic types include: iconic (physical), analogue (diagrammatic), and symbolic (mathematical).

The Iconic models are physical representations of the real system in an idealized form or on a different scale either up or down. For example a toy ship is an iconic model for a real one.

The Analogue models are essentially to do with the substitution of one property for another for the purpose of expediancy in manipulating the model. Demand curves, frequency distribution curves, and flow charts are examples of analogue models.

The symbolic or mathematical models use a set of mathematical symbols and functions to represent the decision variables. A type of symbolic model most commonly in operations research is an equation or inequality which is easily transformed into equation. And it is concise, precise and easily understood.

2.5.1 Nature And Structure Of Mathematical Models

Moskowitz and Gordon (1979) describe Mathematical models as having three basic sets of characteristics. These are:

1) decision variables and parameters,

2) constraints, and 3) objective functions.

2.5.1.1 Decisions variables and parameters; the variables unknown which the model is required to determine. While the parameters are the know values that relate the decision variables to the constraints and the objective function. These parameters can either be deterministic or stochastic.

2.5.1.2 Constraints: To take care of limitations, such as economic and technological, of the system, the model must include constraints that restricts the decision variables to a range of feasible values.

2.5.1.3 Objective function: The dimension defines the measure of effectiveness of the system as a mathematical function of the decision variables. An optimal solution to the model is obtained when the values of the decision variables yield a best value of the objective function, subject to the constraints.

A symbolic or mathematical model take the form:

U = f(Xi, Yj)

Where U = is the utility or value of the system performance

X_i = are the variables that can be controlled

Y_j = are the uncontrollable (constant) variables but do affect U

f = the relationship between U and X_i and Y_j.

2.6 IMPORTANCE OF OPERATIONS RESEARCH

Operations research techniques have been proved to be more suitable than other methods used in tackling managerial problems. Such method as the intuitive approach which boarders on the use of intuition, judgement and experience to select from the alternative decision variable is an inferior approach compared to operations research as A.O. Elbing (1970) stated:

1 - Learning from experiecne is generally at random.

2 - There is no guarantee that an individual learns from experience.

3 - What is learned from experience is generally circumscribed by the limits of experience.

4 - Changed conditions may mean that the past is not good indicator of the future.

A more chosen approach to operations research is the Normative approach which shows how a consistent decision maker should act to be successful. Decisions procedures are followed that will optimise such items as output, income, revenue, cost or utility. M.Alexis and C.Z Wilson (1976), pointed out a rational individual makes a choice on the basis of:

1. a known set of relevant alternatives with corresponding outcomes
2. an established rule or set of relations that produces a preferred ordering of alternatives,

3. the maximisation of somethings such as money, goods, or some form of utility.

The major features of this type of decision structure are:-

1. the strategies of the decision maker,
2. the state of nature,
3. the outcomes or payoffs.

Like the intuitive approach, this one ralies on inductive inferrecnes or reasoning, but frames the induction in terms of a scientific approach to problem solving.

Due to complexity of the process involved in decision making and the inadequacy of the other approaches in tackling managerial problems of changing business environment, operations research boarders 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. It is also easier to examine and analyse a complex problem if the concepts, tools, and techniques of operations research are used to decompose the problem into simplex elements.[11]

11. Herbert Moskowitz and Gordon P. Wright, Operations Research Techniques for Management (1979) Prentice-Hall.

Managers must and do make decisions constantly through intuitive approach, operations research or whatever rational model or technique is followed, but the fact remains that even if a decision is made within an orderly and methematical framework, it does not mean that it will necessarily has to be judged to have been a good decision. As Herbert and Gordon put it in their book "Operations Research Techniques for Management" that, "uncertainty about the future consequences plays a key role here, and thus an unsatisfactory outcome can result even for the best decision that could have been made.

Herbert and Gordon enumerated the following as benefits in applying operations research techniques to decision making:

1 - It provides decision makers with a set of concepts and tools that will enable them to make decisions in a logically consistent fashion, and with as much precision as possible. Stated simply, a formal 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 - Formalization and quantification of the problem facilitate communication and coordination. In this way, divergent preferences and information among individuals can be reconciled and decisions coordinated.

4 - Formalization of routine or repetitive decision problems frees managers to concentrate on more pressing matters, except when unusual circumstance arises, requiring review of the course of everyday. In this way managers achieve better control of their operations and can allocate their time more efficiently.

5 - Formalization 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 respectively. Thus, the cost of undertaking the first application may produce long-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.

However, as advocated by R.J. Thierauf, R.C. Klekamp and D.W. Geedug (1977), in order for the decision maker to adapt a "professional management" approach, it is necessary for him or her to encompass the best features of the intuitive and the normative approaches along with creativity which they called "planned approach". The need for such meshing - a new approach to decision - was set forth by Ralph C. Davis in hisdiscussion of the professionally trained executive:

> "A man who has nothing but background is a theorist. A man who has nothing but practical experience is a business mechanic. A professionally trained executive is one in whom there is an effective integration of these two general types of experiences, combined with adequate intelligence regarding the types of problems with which he must deal"

This approach - the planned approach - involves some steps which are an extension of the scientific

approach and the creativity, intuition, judgement, and experience of the decision maker. These steps are:

1 - Observation
2 - Definition of the real problem
3 - Development of alternative solutions
4 - Selection of optimum solution using experimentation.

By and large, the use of operations research techniques has become of tremendous significance that neglecting their enormous power in facilitating decision will leave the careless executive and the organisation he heads far behind in this present state of development where competition is always on the increase. However, notwithstanding the importance of operations research to management, it has to be applied with caution. Experts on the field should be given necessary encouragement by way of supplying unprejudiced information to them to be able to make the predictive power of the techniques more meanigful and applicable to the particular organisation which has the problem for diagnosis and prescription.

2.7 LINEAR PROGRAMMING TECHNIQUE

The current state of the art of linear programming is attributed to the American Mathematician,

Dr. George Dantzig who introduced his "Simplex method" as a systematic procedure for solving linear programming problems. But the beginning of the concept can be traced back to the input-output analysis developed by the economist W.W. Leontief. Hitchock, nowever was the first to interprete a transportation type of problem in 1941, which was later studied by Koopmans in 1942.

Linear programming assumes various discription. It can be defined as a mathematical technique for determining the best allocation of firm's limited resources. Thierauf and Klekamp described it thus: "An economist may define it as a method for allocating limited resources in a manner that satisfies the law of supply and demand for the firm's product. Yet a mathematician may define it as a method for solving problems in which an objective function must be maximised or minimised when certain constraints are considered. To business management, however it might be looked upon as a tool for solving problems that are in conformity with the firm's clearly defined objectives".

The main features of the techniques that make its application effective are:

1 - Well-defined objective function. For example, maximisation of benefits or minimisation of costs.

2 - Alternative causes of action, that is, making a selection between various combinations.

3 - Objective function and constraints must be expressed mathematically, that is, firm's objectives must be expressed in equations and inequalities and the equations/inequalities must describe the problem in linear form.

4 - Variables must be integrated, that is, be possible to formulate mathematical relationships among the variables describing the problem.

5 - Resources must be in limited supply, i.e., the resources must be finite and economically quantifiable.

However, sometimes, there are economies to be derived from increasing the scale of an operation such that the assumption of linearity, does not hold. Notwithstanding, anyway, within limits this proportionality usually exists, at least approximately, and hence the principles of linear programming have been found to be of wide application. Some of the advantages of using linear programming technique are:

1 - Improving the quality of decision by providing more objective and less subjective means of decision making process.

2 - Facilitating one best course of action from many alternative courses.

3 - The identification of production bottleneck, an advantage frequently overlooked.

4 - The optimum use of productive factors by indicating to manager the best way to select and distribute these factors.

2.7.1 Nature of Linear programming

Linear optimisation models deal with the problem of allocating limited resources among competing activities in the best possible (i.e. optimal) way. This problem of allocation can arise whenever one must select the level of certain activities. The variety of solutions to which this discription applies is diverse indeed, ranging from the allocation of production facilities to products to the allocation of national resources to domestic needs, from portfolio selection to the selection of shipping pattern, from agricultural planning to the design of radiation therapy and so on. However, the one common ingredient in each of these situations is the necessity for allocating resources to activities.

Linear programming uses a mathematical model to describe the problem of concern. The adjective 'Linear' means that all the mathematical functions in this model are required to be linear function. The word 'programming' does not refer here to computer programming; rather, it is essentially a synonym for planning. Thus linear programming involves the planning of activities to obtain an 'optimal' result, that is, a result that reaches the specified goal best among all feasible alternatives.

2.7.2 Assumptions of Linear Programming

I - Proportionality - is an assumption about individual activities considered independently of each other. In the linear programming model the quantities of flow of various items into and out of the activity are always proportional to the activity level. If we wish to double the activity level, we simply double all the corresponding flows for the unit activity level.

II - Additivity - this assumes that there are no interactions between any of the activities. Therefore the additivity assumption requires that, given any activity level (X_1, X_2, ...X_n), the total usage of each resource and the resulting total measure of effectiveness equal the sum of the corresponding quantities

generated by each activity conducted by itself. To be precise, for each item it is required that the total amount specified by the system as a whole equals the sum of the amounts flowing into the various activities minus the sum of the amounts flowing out. Thus, each item, in our abstract system, is characterized by a material balance equation, the various terms of which represent the flows into or out of the various activities.

III - Divisibility - this assumes that activity units can be divided into any fractional levels, so that noninteger values for the decisions variables are permissible.

IV - Certainty - the certainty assumption is that all the parameters of the model (the aij, bi and cj values) are known constraints. In real problem, this assumption is seldom satisfied precisely. Linear programming modles usually are formulated in order to select some future course of action. Therefor the parameters used would be based on a prediction of future conditions, which inevitably introduces some degree of uncertainty.

V - Linear Objective Function - this assumption makes it possible to have one solution (optimal) for the various items contributing to the much desired payoff. The contribution of each activity to the total payoff is the amount of the precious item that flows into or out of each activity. Thus, if the objective is to maximize profits, activities that require money contribute negatively and those that produce money contribute possitively to total profits.

VI - Non-negativity - this simply means that negative quantities of activities are not possible.

2.7.3 Building The model

The mathematical model of a system is the collection of mathematical relationships which characterise the feasible programs of the system. By feasible programms is meant those programs which can be carried out under the systems limitations. Even though the process of constructing a model is often difficult because of the richness, variety and ambiguity of the real world, it is possible to accomplish the task when certain steps are followed. These steps however

are based on the already mentioned assumptions underlying the linear programming model.

The following steps are due to G.Dantzig (1963):

Step 1: Define the Activity Set:
Decompose the entire system under study into all of its elementary functions, the activities, and choose a unit for each activity in terms of which its quantity, or level, can be measured.

Step 2: Define the item Set; Determine the classes of objects, the items, which are consumed or produced by the activities, and choose a unit for measuring each item. Select one item such that the net quantity of it produced by the system as a whole measures the"cost" (or such that its negative measures the "profit") of the entire system.

Step 3: Determine the Input - Output Coefficients - Determine the quantity of each item consumed or produced by the operation of each activity at its unit level. These numbers, the imput-output coefficients, are the factors of proportionality between activity levels and item flows.

Step 4: Determine the exogenous flows. Determine the net imputs or outputs of the items between the system, taken as a whole, and the outside.

Step 5: Determine the material Balance Equation: Assign unknown non-negative activity levels $X_1, X_2 \ldots X_n$, to all the activities; then, for each item, write the "material balance equation" which asserts that the algebraic sum of the flows of that item into each activity (given as the product of the activity level by the appropriate imput-output coefficient) is equal to the exogenous flow of the item.

The out-come of the model-building is thus the collection of mathematical relationships characterizing all the feasible programs of the system. And this collection is the "Linear programming model".

As stated earlier linear programming solution seeks to optimise the objective of a firm in allocating limited resources. It therefore means that one can add another assumption or rather state the fact that resources are in limited supply.

A standard form of the linear programming model is thus:

Maximise/minimise (optimise)

$$Z = C_1 X_1 + C_2 X_2 + \ldots\ldots + C_n X_n$$

the objective function, subject to

$$\left.\begin{array}{l} X_1 \geqslant 0 \\ X_2 \geqslant 0 \\ \vdots \\ X_n \geqslant 0 \end{array}\right\} \text{non-negativity constraints}$$

and

$$\begin{array}{l} a_{11} X_1 + a_{12} X_2 + \ldots\ldots\ldots a_{1n} X_n \leqslant b_1 \\ a_{21} X_1 + a_{22} X_2 + \ldots\ldots\ldots a_{2n} X \leqslant b_2 \\ \vdots \\ a_{m1} X_1 + a_{m2} X_2 + \ldots\ldots\ldots a_{mn} X_n \leqslant b_m \end{array}$$

Any problem which can be formulated as above with $a_{11} \ldots a_{mn}$, $b_1 \ldots b_m$ and $C_1 \ldots c_n$ sets of constants and $X_1 \ldots X_2$ a set of variables, is a linear programming problem which may be solved by either graphical or simplex method depending upon the number of variables involved.

For example, if the problem is that of production mix the above symbols in the linear programming model can be defined as follows:

n = number of products produced

m = number of machines required for their production

X_1 = number of units of product 1 produced

X_2 = number of units of product 2 produced

. .

X_n = number of units of product n produced

C_1 = profit per unit on product 1

c_2 = profit per unit on product 2

. .

C_n = profit per unit on product m

b_1 = number of hours available on machine 1

b_2 = number of hours available on machine 2

.

b_m = number of hours available on machine m

a_{11} = number of hours required on machine 1 by one unit of product 1

a_{12} = number of hours on machine 1 by one unit of product 2

a_{21} = number of hours required on machine 2 by one unit of product 1

a_{22} = number of hours required on machine 2 by one unit of product 2.

.
.
.
.
.
.

amn = number of hours required on machine m by one unit of product n.

Once the information in a given situation is mathematically represented into a system of inequalities which can be transformed to equalities by adding slack variables, the system is then solved using the elementary method for solving equations or delineated on a graph or in case of variables more than three by the use of simplex method. The set of solution is then evaluated using the objective function in order to arrive at the optimum level of activity which serves as the basis for decision.

2.7.4 The Simplex Method

The graphical method is tantamount to solving a system of linear equation simultaneously and testing out each set of solution using the objective function until the one was found which gave the greatest

profit or least cost. This is a possible method with a small scale problem but real-life problems are too complicated for this method; there would be just too many simultaneous equations to handle. An improvement would be to find a method which located the required vertex (corner point in the graphical representation with the optimum solution) as quickly as possible. This method is known as the 'simplex method'.

Hypothetically if we are to optimise the following:

$$\text{Constraints:} \quad X_1 + \tfrac{2}{3} X_2 \leq 250$$

$$X_1 + \tfrac{3}{4} X_2 \leq 150$$

$$X_1 \leq 125$$

$$X_2 \leq 140$$

Objective function $30X_1 + 40X_2 = Z$

to be maximized.

This state is transformed by adding slack variables thus:

$$\text{Constraints:} \quad X_1 + \tfrac{2}{3} X_2 + S_1 = 250$$

$$X_1 + \tfrac{3}{4} X_2 + S_2 = 150$$

$$X_1 + S_3 = 125$$

$$X_2 + S_4 = 140$$

Objective function $30X_1 + 40X_2 = Z$

The steps involved in this method as given by L.W.T. Stafford (1983) are:

Step 1:	Choose a variable	X_i chosen
Step 2:	Divide right-hand sides of each equation except the objective function by coefficients of chosen variable	R.H.S. ÷ 1 give 250 150 125 140
Step 3:	Choose equation with smallest r.h.s. constant after division	Equation 3: 125÷ 1 = 125
Step 4:	Bring coefficient of chosen variable in selected equation to unity by suitable division of whole equation.	No action: coeefient already unity
Step 5:	Clear chosen variables out of other constraints equations by suitable subtractions, as with ordinary simultaneous equations.	Subtract equation 3 from equations 1 and 2
Step 6:	Clear chosen variable from objective function	Multiply equation 3 by 15 and subtract from objective function

Step 7:	Check and interpret result. After interpretation	
Step 8:	Are there any positive coefficients on the left-hand side of the	If there is none, the optimum solution is reached. But there are, the optimum solution is not reached and therefore steps 1-7 must be repeated until there is no positive coefficient on the left-hand side of the objective function.

After the required iterations were made the original set of equations became:

$$\frac{9}{11}S_1 - \frac{20}{11}S_2 + S_3 = 59\frac{9}{11}$$

$$X_2 + \frac{12}{11}S_1 - \frac{12}{11}S_2 = 109\frac{1}{11}$$

$$X_1 - \frac{9}{11}S_1 - \frac{20}{11}S_2 = 60\frac{2}{11}$$

$$- \frac{12}{11}S_1 + \frac{12}{11}S_2 + S_4 = 30\frac{10}{11}$$

$$-\frac{210}{11}S_1 - \frac{120}{11}S_2 = Z - 6409\frac{1}{11}$$

Interpretations

$$S_3 = 59\frac{2}{11}$$

$$S_4 = 30\frac{10}{11}$$

$$S_1 = 0$$

$S_2 = 0$

$X_1 = 68\frac{2}{11}$

$X_2 = 109\frac{1}{11}$

Profit = ₦6409$\frac{1}{11}$

2.7.4.1 The Simplex Algorithm

The coefficients in the equations functions can be represented in vector form thus using the above example:

$$A = \begin{bmatrix} 1 & 5/3 \\ 1 & 3/4 \\ 1 & 0 \\ 0 & 1 \end{bmatrix}$$

and the variables

$$X = \begin{bmatrix} X_1 \\ X_2 \end{bmatrix}$$

so that $AX = \begin{bmatrix} X1 & 5/3X2 \\ X_1 & 3/4X2 \\ X1 & 0 \\ 0X_1 & X2 \end{bmatrix}$

and the constants on the right hand side as

$$b = \begin{bmatrix} 250 \\ 150 \\ 125 \\ 140 \end{bmatrix}$$

Therefore the system of the set of constraints becomes

$$AX \leq b$$

The simplex algorithm dealing with the matrix of the coefficient of the variables is thus

A	I	b
-c	o	o

Where the symbols I and O stand for the unit matrix and the zero vector.

The original set of equations using the simplex algorithm becomes

A		I				b
X_1	X_2	S_1	S_2	S_3	S_4	
1	5/3	1	0	0	0	250
1	3/4	0	1	0	0	150
1	0	0	0	1	0	125
0	1	0	0	0	1	140
-30	-40	0	0	0	0	0

The steps involved in solving the linear programming problem will now be easily understood.

Tableau 1

1	5/3	1	0	0	0	250
1	3/4	0	1	0	0	150
1	0	0	0	1	0	125
0	1	0	0	0	1	140
-30	-40	0	0	0	0	0

Tableau 2

0	5/3	1	0	-1	0	125
0	3/4	0	1	-1	0	25
1	0	0	0	1	0	125
0	1	0	0	0	1	140
0	40	0	0	30		3,150

Taoleau 3

0	0	1	-20/9	11/9	0	694/9
0	1	0	3/4	-4/3	0	331/3
1	0	0	0	1	0	125
0	0	-0	-4/3	4/3	1	1062/3
0	0	0	160/3	-70/3	0	50831/3

Tableau 4

0	0	9/11	-20/11	1	0	569/11
0	1	12/11	-12/11	0	0	1091/11
1	0	-9/11	-20/11	0	0	682/11
0	0	-12/11	12/11	0	1	30 10/11
0	0	$\frac{210}{11}$	$\frac{120}{11}$	0	0	6409 $\frac{1}{11}$

Which gives the optimum profit of #6409 $\frac{1}{11}$.

A simplex method has two sets of solutions which give the same signal or similar conclusion for decision making. The above set of equations are known as the 'Primal' which has an opposite or mirrow image known as the dual.

2.7.4.2 Duality

D. E Smith (1977)[12] concluded that, Duality is an important characteristic of linear programming problems. All linear programming problems come in pairs. These two problems the 'primal' and the 'dual'

12. D. E. Smith, Quantitative Business Anlysis, John Wiley & sons, New York, 1977.

have a direct component-by-component transference, that is, the rows of one are the columns of the other.

This means that a standard allocation of resources problem can be formulated in two ways. The decision variables can represent the ways to use the resources. They will be restricted by resource availability constraints. The problem will be to find the best values for the decision variables, subject to the constraints, to maximise an objective. The decision environment can be structured from a different perspective. The decision variables can represent the opportunity losses associated with using the resources. These decision variables will be restricted to resource usage cost constraints. The problem will be to find the best values for the decision variables, subject to the constraints, to minimize opportunity usage costs. The two formulations arrived at an identical allocation of the resources via conceptually different routes. Their final simplex tableaus will both contain identical information. A decision maker can formulate and solve a linear programming problem either way.

The dual problem is gotten from the primal by transforming the primal which can be done by transposing the primal matrix coefficients. Thus:

A decision maker can obtain the information needed to make proper resource allocation decisions. All relevant information is summerised in the final simplex tableau or a minor modification of the final tableau. If this wealth of information is put at a manager's fingertips can instantly obtain the information vital to responsible resource decisions.

2.7.4.4 Applications of Linear Programming

Linear programming technique has had wide application since the development of the beautiful method of simplex method which is capable of tackling problems with considerable number of constraints. Thierauf and Klekamp (1975) give the following areas of business and industrial applications that are solvable by linear programming technique.

1 - Advertising media Evaluation, Analyses the effectiveness of advertising space and time based on the available advertising media.

2 - Blast furnance operation. Aids production management in scheduling blast furnances for more accurately and efficiently than possible with other analytical methods.

3 - Blending of raw materials: Helps in blending the various ingredients of a particular mix in order to meet specified requirements and assist

manufacturing management by proportioning raw materials subject to quality restrictions.

4 - Inventory scheduling. Allows for the management of raw materials and semi-finished goods to minimize the firm's capital investment while maximising efficient production flow.

5 - Manpower management planning: Allows personnel management to analyze personnel policy combinations in terms of their appropriateness for maintaining a steady-state flow of people into, through, and out of the firm.

6 - Physical distribution: Determines the most economic and efficient manner of locating manufacturing plants and distribution centers for physical distribution management.

7 - Production Scheduling: Determines for manufacturing management the most profitable combination of products to manufacture for facilities possessing a wide range of production capabilities and the most efficient method for machine loading.

8 - Raw material allocation: Optimizes for buyers potential raw material sources for production and minimizes production costs.

9 - Site location: Helps the management in deciding which location is best for new plants, warehouses,

and branch offices and where to eliminate existing facilities.

10 - Time standards determination: Assists time study personnel in determining standard times for those type of jobs in which the discrete work elements are essentially the same but vary in number.

11 - Vendor quotation analysis: Aids buyers in analyzing vendor quotations in cases where a number of products are quoted by many vendors.

In addition, as studies have shown linear programming is applied to petroleum industry. But the application to Nigerian industries in not well encouraging as A.S.Bashir,[13] (1984) concluded that:

"1 - That operations research techniques, though proved to be profitable and effective, are not presently employed in our industries in Kaduna State. Some of the reasons felt responsible are lack of well trained operations research personnel or managers with the necessary background and due to under development (easy accessibility of computer at low costs).

2 - That while no single model was built in this research for general application in any type of

13 - A.S, Bashir, Linear Optimisation Techniques As a tool for better production schedules: A Comparative case study of three companies in Kaduna State of Nigeria: Unpublished MBA project, 1984

industry, it was strongly felt that if distributive and simplex models can be linked such a model may be possible.

3 - That four factors, namely; materials being processed, size of the company and company's management combine to determine the best system of scheduling for any company.

He futher suggested that for successful application of operations research techniques the following factors should be taken into account:

1- That in selecting a system of production scheduling, the company should consider its products, process, size and management.

2- The establishment and encouragement of the use of operations research techniques in our companies in Kaduna State and Nigeria as a whole. Training of both management and supervisory personnel in operations research techniques should be intensified through seminar, short courses and other formal educational system such as university and colleges of managements.

3- That operations research should be introduced as a subject in all fields of applied sciences such as all branches of Engineering, Medicines, Agriculture, etc in all Universities and Polytechnics where these courses are offered in Nigeria.

4- There is need to promote and encourage use of computer in our companies and intensify training of students in computer programming in institutions. Government should step in and establish computer services for companies and institutions needing them at reasonable prices.

E.V. Idachaba,[14] in her study: production scheduling and control: A comparison of intermittent production system and continous production systems concluded that, the application of operations research techniques "is lacking" in the two companies the study was conducted. Which made it difficult for the companies to be able to exploit some of the advantages that can be derived from the use of such research techniques. The study went further to caution that the importance of these techniques should not be overlooked "because a good production control and scheduling system has a possitive relationship with an efficient and economic utilisation of resources.

2.8 GENERATION OF HYPOTHESIS

Having reviewed the relevant available literature on the subject of linear programming technique to production scheduling it becomes apparent that the tool is of significance to management planning and

14- V.E. Idachaba, Production Scheduling & Control: A Comparison of Intermittent and Continuous Production System: Unpublished MBA project, 1987.

decision making. But a lot need to be done in order to make the technique workable in the Ningerian context.

A. S. Bashir has this to say after conducting a comparative study on some companies in Nigeria:

1- There is need to try distributive model in a company that process one type of raw material into two or more products as in the case of Kaduna Refinery.

2- To conduct research to study production schedule in a company that process two or more raw materials into a single product and try the application of the two types of linear programming (distributive and simplex) models in the system. For example in a shore company in which rubber, metal and leather are used to produce shoes.

3- Combine results of 1 and 2 above with that of this research so as to find the possibility of building a general model of production scheduling in any industry.

Other studies[15] conducted in Nigeria have also shown the importance of linear programming technique in the area of production scheduling to be of vital importance due to its simplicity in application and understanding but also showed the uneuthusiasism by manufacturing firms to employ it with vigor as is done in developed countries. This is either because

15- E. V. Idachaba, op cit.

the facilities are not there or the personnel with sound background in operations research are not available and management being reluctant to do much to curtail the problem.

As highlighted above, the application of linear programming has had wide usage particularly in developed countries but in general, the application of operations Research techniques as studies have shown are far from being satisfactory in the manufacturing industry and indeed in other private and public organisations in Nigeria. This study therefore wishes to take off on the assumption that linear programming technique is an indispensable tool in production scheduling to manufacturing firms in Nigeria and hopes to prove, subject to the impending constraints, the validity or lack of it of this premise or hypothesis.

2.9 REFERENCES TO CHAPTER TWO

P.M. Morse and G.E. Kimball, Methods of Operations Research, New York: John Wiley & Sons, 1951.

C.W. Churchman, R.L. Ackoff, and E.L.Arnoff, Introduction to Operations Research, New York John Wiley & sons, 1957.

D. W. Miller and M.K. Starr, Executive Decisions and Operations Research, Englewood Cliffs, N.J.: Printice Hall, 1960.

H.M. Wagner, Principles of Operations Research, with Application to Managerial Decisions, Englewood Cliffs, N.J.: Printice Hall, 1969

R.L. Ackoff and P.Rivett, A Manager's Guide to Operations Research, New York: John Wiley & Sons, 1963.

R.L. Ackoff and M.W.Sasieni, Fundamentals of Operations Research, New York: John Wiley & sons, 1968.

P.G. Carlson, Quantitative Methods for Managers, New York: Harper & Row, Publishers, 1967.

C.W. Churchman, The Systems Approach, New York: Dell Publishing Company, 1968.

P.E. Green and R.E. Frank, A Manager's Guide to Guide to Marketing Research, New York: John Wiley & Sons, 1967.

C.M. Paik, Quantitative Methods for Managerial Decisions, New York: McGraw-Hill Book Company, 1973.

S.B. Richmond, Operations Research for Management Decisions, New York: The Ronald Press Company, 1968.

G.M.F. di Roccaferrera, Operations Research Models for Business and Industry, Cincinnati, O.: South-Western Publishing Company, 1964.

G.B. Dantzig, Linear Programming and Extension, Priceton University Press, 1963.

D.Robert, P.A. Samuelson and R.M.Solow, Linear Programming and Economic Analysis. New York: The Mcmillan company, 1961.

E.S. Buffa, Modern Production Management, fifth edition (1977)

J. E. Freud and F. J. Williams, Elementafy Business Statistics: The Modern Approach, Prentice-Hall, Englewood Cliffs, New Jersey, 1964.

Bierman, H, Jr., C.P. Bonini and W.H. Hausman, Quantitative Analysis for Business Decisions Homewood, III: Richard D. Irwin, 1973.

Boulding, K.E. and W.A. Spivey, Linear Programming and the Theory of the Firm. New York: Macmillan, Co., 1960.

A. Charnes, and W.W. Cooper. Management Models and Industrial Application of Linear Programming, 2 Vols. New York: John Wiley & sons, 1961.

R.L. Childress, Mathematics for Managerial Decisions., Englewood Cliffs, N.J.: Prentice-Hall, 1974.

S.I. Gass, Linear Programming: Methods and Applications New York: McGraw-Hill Book Co., 1969.

R. P. Garver and G.L. Thompson; Programming and Probability Models in Operations Research. Belmont, Calif: Wadsworth Publishing Co., 1973.

G. Hadley, Linear Programming. Reading, Mass: Addison - Wesley Pubbishing Co., 1962.

C. Kim, Introduction to Linear Programming. New York: Holt, Rinehart and Winston, 1971.

R. I. Levin and C.A. Kirkpatrick, Quantitative Approaches to Management. New York MacGraw-Hill book co., 1975

N.P. Loomba, Linear Programming, An Introduction Analysis. New York: McGraw-Hill Book Co., 1964.

N. P. Loomba and E. Turban, Applied Programming for Management. New York: Holt, Rinehart and Winston, 1974.

W.A. Spivey and R.M. Thrall. Linear Optimisation New York: Holt, Rinehart and Winston, 1970.

J.EE. Strum, Introduction to Linear Programming

J. E. Strum, Introduction to Linear Programming, San Francisco: Holden-Day, 1972.

R.J. Thierauf and R.C. Klekamp, Decision Making Through Operations Research. New York: Hojn John:Wiley & Sons, 1975.

-- Management Principles and Practices. A Contingency and Questionnaire Approach, New York: HJohn Wiley &mSons, 1977.

H. Moskowitz and G.P. Wright, Operations Research Techniques for Management. Prentic-Hall, Inc. Englewood Cliffs, N.J., 1979.

F.S. Hillier and G.J. Lieberman, Introduction to Operations Research, Holden-Day, 1980.

F.W. Taylow, Principles of Scientific Management, New York: Harper and Bros., 1910.

A. Kaufmann, Methods, and Models of Operations Research, Prentice-Hall, Englewood Cliffs, N.J., 1963.

J.G. McCloskey and F. N. Trefethen; Operations Research Research for Management, Vol I, The Johns Hopkins Press, Baltimore, 1954.

S.B. Abdullahi, Linear Optimisation Techniques as a tool for Better Production Schedules: A Comparative Case Study of three companies in Kaduna State of Nigeria. Unpublished MBA Project, ABU, Zaria, 1984.

A. Lawal, Study on the extent of Application of Operations Research Techniques in the Manufacturing Sector in Northern States of Nigeria, Unpublished MBA Project ABU Zaria, 1983.

E.V. Idachaba, Production Scheduling and Control: A Comparison of Intermittent Production System and Continuous Production System, Unpublished MBA Project, ABU, Zaria, 1987.

CHAPTER THREE

DATA COLLECTION, PRESENTATION AND MODEL SELECTION

3.1 INTRODUCTION

This chapter is dedicated to explaining how the data that will be used in the subsequent chapters is collected emphasising on the mode followed and highlighting the difficulties encountered which germinated into actual limilations of the study.

The mode of presenting the data is by breaking it into various divisions of the company from which it became available. Based on the nature of the data a selection will be made from the various models of linear programming and other scientific form of analysis which will be adequate for its management. However, a brief history of the company will be given to serve as an eyeopener.

3.2 THE COMPANY

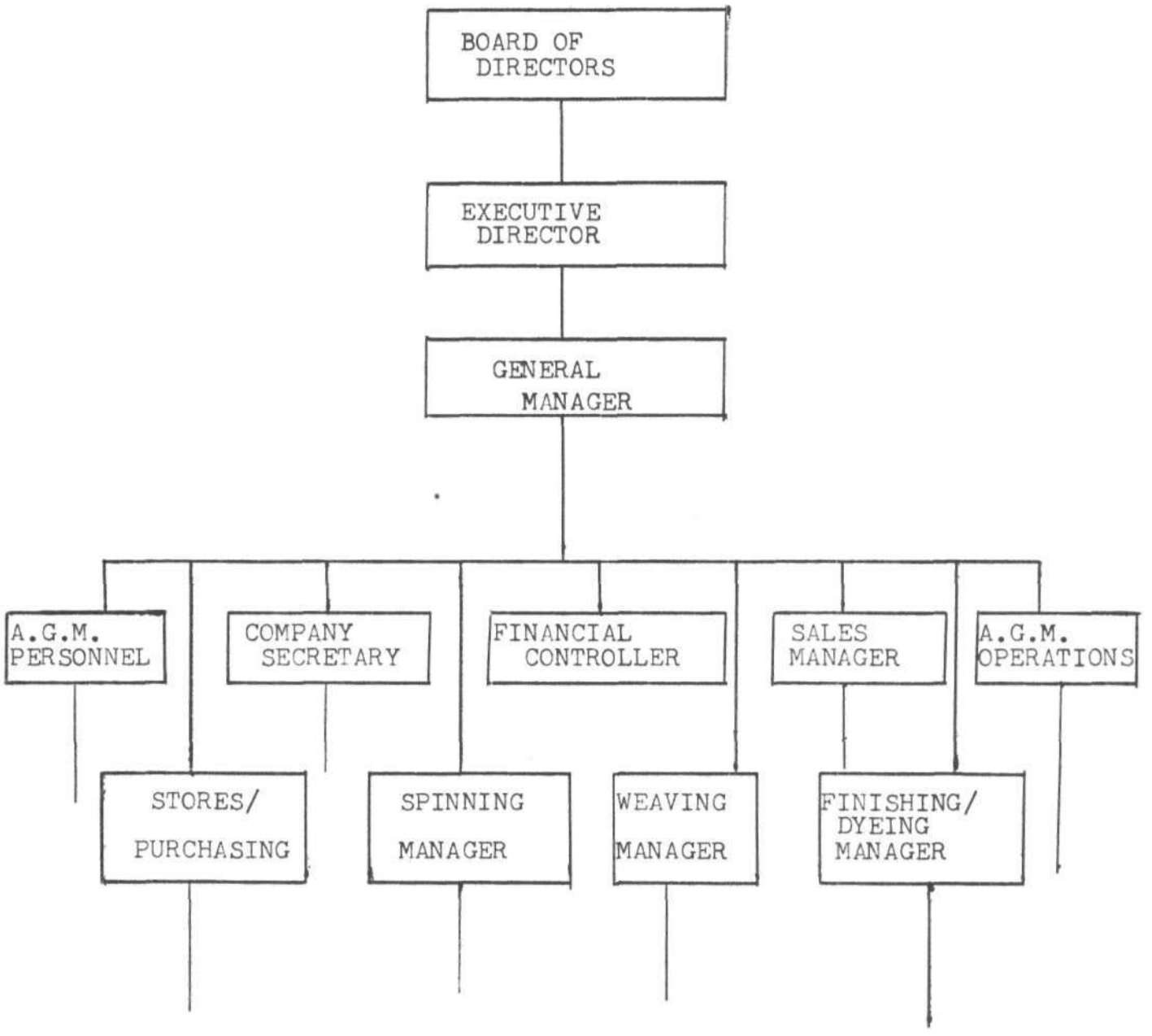
The company is a subsidiary of United Nigerian Textile Limited Kaduna, established in 1983 and commenced production in May of the same year. The scope of the comapny as per production activities is somewhat narrowed by virtue of its being a subsidiary of another. The arrangement being that, the company produces items that the parent company does not. However, it enjoys the advantages of being a subsidiary: it benefits from the good-will and sound reputation of the parent company as well as having technical and

managerial assistance it would otherwise not have in its operations.

Presently, the company has a staff strength of 991 workers out of which 16 are expartrates occuping mostly managerial and supervisory positions, while t the rest are locals drawn from the immediate environment and are largely unskilled workers. The comapny which is both capital and labour intensive does not have problems with regard to availability of labour.

The company is divided into four main departments with a departmental head who is directly responsible to the general manager. These divisions are personnel, finance, production and marketing. These departmental managers have in turn several officers both senior and junior under them. In addition to these line executives is the company secretary h who oversees and organised meetings of the board of directors as well as handling corporate legal issues.

ORGANISATIONAL STRUCTURE



3.3 DATA FROM FINANCE DEPARTMENT

The data presented from the finance department is that which have direct bearing to the purpose of this study and presented in tablular form.

3.3.1

	PRODUCTS MANUFACTURED	INSTALLED CAPACITY		
		1985	1986	1987
1.	YARN-SPINNING (SPINDLES)	15360	15360	15360
2.	GREY CLOTH-WEAVING (LOOMS)	384	384	384
3.	DYED BEDSHEET/TC CLOTH	-	-	-

3.3.2

	PERCENTAGE UTILISATION	1985	1986	1987
1.	YARN SPINNING	45	45	45
2.	GREY CLOTH?WEAVING	45	45	45
3.	DYEING/FINISHING	80	80	80
4.	NUMBER OF SHIFTS PER DAY	3	3	3
5.	NUMBER OF DAYS WORKED PER YEAR	220	220	220

3.3.3

PRODUCTION AND SALES

		Units Per Year		
1.	Quantity Output	1985	1986	1987
I)	YARN (KG)	1146308	1236045	1329684
II)	Grey-Cloth (m)	3910643	3760184	4594443
III)	B/S & T/C (m)	3598620	2742593	3909716

2. UNIT SELLING PRICE (₦) (Est.)

Products	1985	1986	1987
I) Yarn	5.10	5.10	6.50
II) Grey Cloth	-	-	-
III) Bed Sheets (m)	6.05	7.05	7.05
IV) T/C Roll	5.20	6.00	7.00
3. VALUE OF OUTPUT(₦'000)	13,355	22,240	30,368
4. SALES TURNOVER(₦'000) (Net of excise duty)	20,690	23,500	28,500
5. DIRECT COST OF PRODUCTION (₦'000)			
I) Raw materials (Imported & local)	5,185	7,850	8,450
II) Consumable/Packaging	151	279	479
III) Production wages & Salaries	2,617	2,608	2,718
IV) Electricity	-	-	197
V) Fuel	471	1,154	1,281
VI) Water	26	58	90
VII) Repairs & Maintenance	1,954	1,880	3,906
6. INDIRECT COST OF PRODUCTION(₦'000)			
I) Administrative wages & Salaries	891	779	812
II) Administrative and General Expenses	1,245	2,139	3,017
III) Selling Expenses/ Commission	271	363	479

It should be noted that the above data is an estimation not the real figures as the time for closing company's books does not always coincide with the time actual activity unfolds.

3.4 DATA FROM PRODUCTION DEPARTMENT.

The Production Department of Funtua Textile Company is divided into four main operational units. These are the store, the spinning, the weaving and the dyeing and finishing units. We shall take each department and look at its role in the production activity up to the point when products are ready for the market. However, the production process could hardly be said to be continous or intermittent but lying between the two extreme of the production continumn.

3.4.1 The Store

The main function of this unit is to store the raw materials needed for production before passing to the next production unit. The main raw materials are: cotton, which is obtained locally or imported usually from Chad, Sudan and Brazil; Polyester Filament Fibres obtained from Nichemtex Lagos.

3.4.2 Spinning Unit

This is where the raw materials undergo the process that turn them into yarn which is the finished product of the unit and the raw material of the weaving

section. The process starts with the 'blow room' where impurities such as sand, leaf and seed fragments are removed. This section has other functions such as opening the cotton to single fibre state blending the fibres and finally mixing the fibres.

Next the 'carding' machine which complete fibre separation and liberates the residual trash (impurities) remaining in the cotton. This machine further removes the 'neps' which are pure cotton but not soft enough to undergo the next processes. By removing the neps, the fibres that result is known as sliver which is suitable for the next process.

The next process deals with the following activities:

1- Straightening the fibres,

2- Parallelizing the fibres,

3- Doubling the fibres and

4- Blending the fibres, a process which involve the mixing of the raw materials (cotton and polyester) into the required proportion. This company uses the 50/50/ p.c./cotton for its products, that is for all the products they make, cotton and polyester account for 50% each of the material. Having done the blending of the fibres the desired 'sliver' is produced.

The process that follow is by the use of 'speed frame' which insert twist by the flayer in order to produce 'roving' - form of a yarn which is thicker than the final yarn - and wind it for the next process.

The next process is closely related to the proceeding one. Here the roving which has been wound on the twist is further straightened by inserting another twist to produce the 'yarn' which is wound on the package.

The final step/process in the spinning department is the 'cone winding'. The main objectives here are:

1- To produce larger packages for subsequent processes. To tension the yarn to a uniform level and simultaneously remove weak places that could give trouble in later processes.

2- To supply lubricants and other materials to the yarn to make it more suitable for subsequent processing e.g. wax application for knitting.

3- To inspect the yarn, and to detect and remove thick places (slubs) that are detrimental to the final yarn or fabric; this process is termed as "slub catching" or "clearing" and is extremely important for quality yarns e.g. for shirts.

4- To release many thousands of ring tubes for return to the spinning rooms.

3.4.3 Weaving Unit

This section is were the yarn produced in the spinning section is woven into the 'gney cloth'. The section as in the preceeding one involves several processes. First there is the warping (direct beaming).

Here the yarns are assembled in stages, first of all the creel contains a large number of packages, each yarn being tensioned and accurately spaced, from the creel, yarns are wound side by side in layers unto the large double-flanged metal 'back beam'. During this process, the yarn is inspected and thick places that are detrimental to the final yarn or fabric are detected and removed. The creel commonly carries 446/570 packages for cotton spun yarn and or polyester/ cotton blends. With a speed of 300m to 350m per minute. Many special functions e.g. slow start, synchronized braking, photoelectric cells for automatic stop motions are built into the design.

Next in the weaving process is the 'sizing'. Here a set of these beams is prepared, and assembled together in a sizing machine. The yarns are sized and reassembled at the output end of the sizing machine to form a weaver's beam. Size mixing consists of two main ingredients:

An adhesive - this protects the yarn (thread) against abrasion in the loom. Some of this abration takes place as the yarn rubs on the back rest, drop-wires, lease rods and healds. The most serious abrasion however, occurs when the threads rub against each other during shedding.

Natural size - Sago, maize 9(corn flour), farina, cassava and wheat. Also chemically modified starches

such as cellulose derivatives e.g. solritose, methyl-cellulose, sodium-carboxy, methyl cellulose are used. Starch derivatives such as Dexlrin, Enzetex, Textiline, Glukose Gum and Amylopectin G. are often used.

2- Synthetic sizes - this is done through the use of polyvinyl alcohol (PVA) e.g. Vinagd, Elvanol Alcotex or polyacrylic acid e.g. syncol.

The process that follow the sizing is 'lubrication'. This process reduces fibre-to-yarn friction and also loom-to-yarn friction during weaving. By reducing friction, shedding is facilitated and beating-up of the weft is made easier. The popular lubricant types are: Tallow, Spermaceti, paraffin wax and leomine. Sometimes, however, Antiseptic such as 'shirlam' (salicy lanilide) may be added to prevent mildew growth on the warps or cloth, if storage of either in a damp condition for a long period is expected.

Having applied the necessary lubricant 'drying of sized warps' follows. The drying of sized warp normally utilizes heat transfered to the warp by:

1- The conduction of heat to the yarn from steam heated cylinders.

2- Free and forced convection of hot air over or through the warp sheet.

3- Radiation of heat to the warp from infra-red radiators.

The next process is the 'drawin-in'. Here the ends (warps) assembled on the weaver's beam are drawn through the drop wires, heald wires and finally the dents of the reed. The beam is then mounted on the loom and ready for weaving. Yarn from the cone is w wound unto the pirn and made suitable for weaving. This process is almost always done automatically.

After things are thus ready the actual weaving process begins. Weaving is the art of interlacing warp and weft to produce the fabric (cloth). Warp is the tread which runs along the length of the fabric while weft is the thread which runs across the width of the fabric. Weaving machine operates on three principles:

1- Shedding - the movement of the healds hafts produces a tunnel through which a shuftle carrying weft passes.

2- Picking - in this operation the shuftle is thrown across the shed(tunnel) and one pick is inserted. The picker which houses the shuftle is mounted on the picking stick. The picking stick is responsible for throwing the shuftle across the shed.

3- Beating-up - here the pick(weft) is pushed against the fell of the grey cloth by the reed.

Finally the process that comes last in the weaving procedure is 'inspection'. Here the grey cloth which will serve as the raw material for the next

production unit-dyeing/finishing - is inspected by passing it over fluorescent light, to find out whether or not it is faulty.

3.4.4 Dyeing/Finishing Unit

Having gotten the grey cloth fresh from the weaving section, the first step/process it undergoes in the finishing and dyeing unit is the singeing. In this sub-unit the grey-cloth passes over gas burners to burn off the protruding fibres thereby producing a smooth surface on the fabric suitable for dyeing. During cold singeing the burnt off fibres on the surface of the grey cloth are washed away.

After this treatment on the grey cloth, the next is 'bleaching range'. During bleaching some of the impurities such as colouring matter and some additives added during weaving are removed. In this case peroxide (H_2O_2) is used to produce a white cloth suitable for dyeing. It should however be noted here that among the items produced for sale is the plain white T/C roll. Naturally therefore when the intention is for its production, then further processes terminate and the cloth is passed directly to the cutting and rolling machine. However before this is done the bleached material whether it is for dyeing or not will pass through the washing and drying ranges.

In the washing operation, excess peroxide in the cloth is washed away using water and in the 'drying range',

the fabric from the washing range is dried by steam heated cylinders. Drying takes place by conduction of heat to the fabric from the steam heated cylinders.

After the cloth is washed and dried it passes to the next process, that is dyeing. Dyeing process takes place in three stages:

1- Padding - During padding, the cloth is passed in a dye solution and then squeezed by the squeezing roller to remove dye.

2- Dyeing - the padded fabric is passed through a chamber of hot air in which a convention of hot air is blown over the fabric. Dyeing takes place by application of heat, that is thermosol dyeing.

3- Winding - Here the dyed fabric is wound onto the roller suitable for stenter machine.

Stentering is a very important process in this unit. This is where the dyed fabric is held to its full width by the clips of the stenter machine and then passes through a chamber of hot air. The fabric is then set. This important machine can be used for other purposes such as Drying, Heat-setting and the finishing. Actually after this process the materials are ready for the final activities that will turn them into marketable items, that is, the 'printing' and 'garment'. Presently the product that undergoes the printing is the Bedsheet. This activity is done manually. The garment section handles the sewing of

PRODUCTION DEPARTMENT

1. STORE

2. SPINNING

BLOW ROOM → CARDING → DRAWING → SPEED FRAME → RING SPINNING → CONE WINDING

3. WEAVING

WARPING → SIZING → DRAW-IN → PIRN WINDDING → WEAVING → INSPECTION

4. DYEING/FINISHING

SINGEING → DESIGNS → BLEACHING → WASHING → DRYING → DYEING → STENTER → PRINTING → GARMENT

the bedsheets and of the pillow cases that go with each bedsheet.

Now let us consider the capacities of the machines that will eventually be used to provide the constraints for the data analysis.

MACHINE	CAPACITY PER (ACTUAL) PRODUCTION RUN
SINGEING	50 meters/minute
BLEACHING/SCOURING	40/50 meters/minute
WASHING	50 meters/minute
DRYING	50 metres/minute
DYEING	25 - 30 meters/minute
STENTER	80 meters/minutes
CUTTING	15 meters/minute
PRINTING	810/day.

3.5 DATA FROM SALES DEPARTMENT

The data from this department is collected through direct interview with the sales manager and records inspection.

3.5.1 Data through direct Interview

Through this means, it was gathered that the company does not engage in any scientific form of sales forecasting. There is no any system of forecasting sales whatsoever, rather sales problems are tackled whenever they present themselves. This is one of the reasons why the company has to close down every year

for a period of at most two weeks just to be able to dispense of their pile of inventories and service their machines.

It was also gathered that, in times of low demand when the company had to cut down its production, the company has a policy of not firing its workers to adjust to the circumstance but bore the burden of paying idle workers. Production wise, the weaving and spinning section run three shifts of 8 hours thereby maintaining a 24-hour production run. But the dyeing/finishing run two shifts of 12-hour period. Administrative staff however work from 8 am. to 4 p.m.

The question of whether records of inventory pile up is kept and the associated costs ascertained was not answered either through the records or the personal interviews.

The sales manager confided that even though they do not forecast sales, it is not because they felt there was no need to do so but rather due to the nature of their products which are low priced and therefore targeted at the 'masses' meaning farmers or the low class people whose trend of earning is easily predicted and the necessary adjustment in production made. However, the manager agreed to having periods of difficulty as well as of trade comfort when they cannot even meet the demand of their customers.

The fact also unfolds itself that the company does not have warehouses outside the complex where production is made in order to ease the transportation problem as their customers coming from as far a place as Onitsha and Aba. This fact ruled out the use of Transportation model of the linear program.

The sales manager also gave a conservative estimate in demand of the two products in terms of client preference. This estimate is that about $\frac{1}{3}$ of the total demand for the company's product is for bedsheet while the other $\frac{2}{3}$ for T.C. roll. This fact necessitated the company to embark upon a forced buyer policy of 50 - 50 ratio.

3.5.2 Data from Sales Records

The data of sales for four years was made available through scouting the sales invoices and presented in the table below:

YEAR / MONTH	SALES IN THOUSAND			
	1985	1986	1987	1988
January	1499	923	621	5891
February	1816	780	523	4301
March	1446	828	481	4537
April	2378	842	354	4736
May	1680	1022	269	4445
June	842	1136	618	5149
July	868	1056	347	4246
August	1068	560	431	4759
September	1129	559	1142	5520
October	1112	1092	620	6054
November	894	1334	3744	
December	708	583	4502	

1.	50" TC PLAIN DYED	105	2.25	110.25
2.	PRINTED BEDSHEET	27.61	1.39	29.00

QUANTITY BUYING DISCOUNT

MONTHLY TURNOVER UP TO:	QUANTITY COMMISSION	THUS TC PRICE	BEDSHEET PRICE
₦ 125,000.00	2%	₦108.05	₦28.42
250,000.00	4%	₦105.84	₦27.84
500,000.00	6%	₦103.64	₦27.26
750,000.00	7%	₦102.54	₦26.97
1,000,000.00	8%	₦101.43	₦26.68

3.6 MODEL SELECTION

Having looked at the nature of the data with its merits and demerits, it will be clear that some of the linear programming models could not be used. For example the transportation model of the linear programming. It will then be obvious that a model that will fairly be applicable to the wealth of information at hand would be the application of linear programming either through graphical or simplex method.

The choice of this model does not mean that it will adequately solve the problems of production scheduling as the model put forward by F. Hanssman & S.W. Hess would have if the variables were only present. So may be in the recommendation it will be highlighted that there is need to always keep every bit of information in order to assist any

scientific analysis hoped at diagonising not only production scheduling problems but other areas as personnel,inventory to name just a few.

From the foregoing the simplex method will be used in analysing the data gotten with the hope of supporting or rejecting the hypothesis generated at the end of the preceeding chapter. For this reason a good look at the method will be pertinent here not the cursory attention it was given in the second chapter with a view to providing sound understanding of the moderlities of the methods and what are necessary for its application.

3.7 THE SIMPLEX METHOD

3.7.1 Prerequisites for its application

I) There must be a well defined objective function. The outcome provided by this function will serve as the basis for decision making.

II) Set of constraints - In fact if there is no factor consitituting a constraints there is no need to waste time on this type of analysis at all. An example easily grasped as a constraints is market demand, and competitors activities.

III) Linearity - All variables that will form the objective function or the set of constraints equations/inequalities should be of the first order; hence the name linear.

IV) Proportionality in measurement - All variables should have a common base particularly the decision variables. This in essence means that having two products to produce, say, one is expressed in terms of number of machines hours per day while the other in terms of the same machines hours per week and be treated at the same time. In such situation adjustment has to be made either using hours per week or per day uniformly on the decision variables, a process which is quite simple.

REFERENCES TO CHAPTER THREE

1- L. L. Ackoff and M.W. Sasieni, Fundamentals of Operations Research, New York: John & Wiley & Sons, 1968.

2- A. Chaines and W.W. Cooper, Management Models and Industrial Applications to Linear Programming.

3- G.B. Dantzig, Linear Programming and Extension, Priceton University Press, 1963

4- L.W.T. Stafford, Business Mathematics, ELBS, AND MACDONAL AND EVANS LTD, PLYMOUTH, 1979.

CHAPTER FOUR

DATA ANALYSIS AND DISCUSSION OF RESULTS

As prerequisite for knowing what are the trends in demands, this analysis will start by sales forecasting to give an insight into the company's past performance and possibly its future preformance in terms of sales/demand to facilitate its planning production.

The method of forecasting chosen is the time services since it has been observed that there are some form of seasonal fluctuation in the sales of the company's products. As a matter of expediency all the years from which sales data was gotten will be used in the forcasting in order to diversify and reduce the error of estimation.

4.1. SALES FORECAST

The aim of this section is to analyse the data gotten from the sales department using time series method of forecasting with a view to finally determining products market demand, its trend and the necessary adjustment that will be required to give a fair estimation.

TABLE 4.1

SALES IN THOUSAND OF NAIRA					QUARTER
MONTH/YEAR	1985	1986	1987	1988	
January	1499	923	621	5891	
February	1816	780	523	4301	
March	1446	828	481	4537	First(I)
April	2378	842	357	4736	
May	1680	1022	269	4445	
June	842	1136	618	5149	Second(II)
July	868	1056	347	4246	
August	1068	560	431	4759	
September	1129	559	1142	5520	Third(III)
October	1112	1092	620	6054	
November	894	1334	3744		
December	708	583	4502		Fourth(IV)

The above sales figures form a "time series" and its behaviour is going to be studied by rearranging it in to quarters containing the figures of three month each.

TABLE 4.2

COMPANY'S SALES BY QUARTER IN N'000

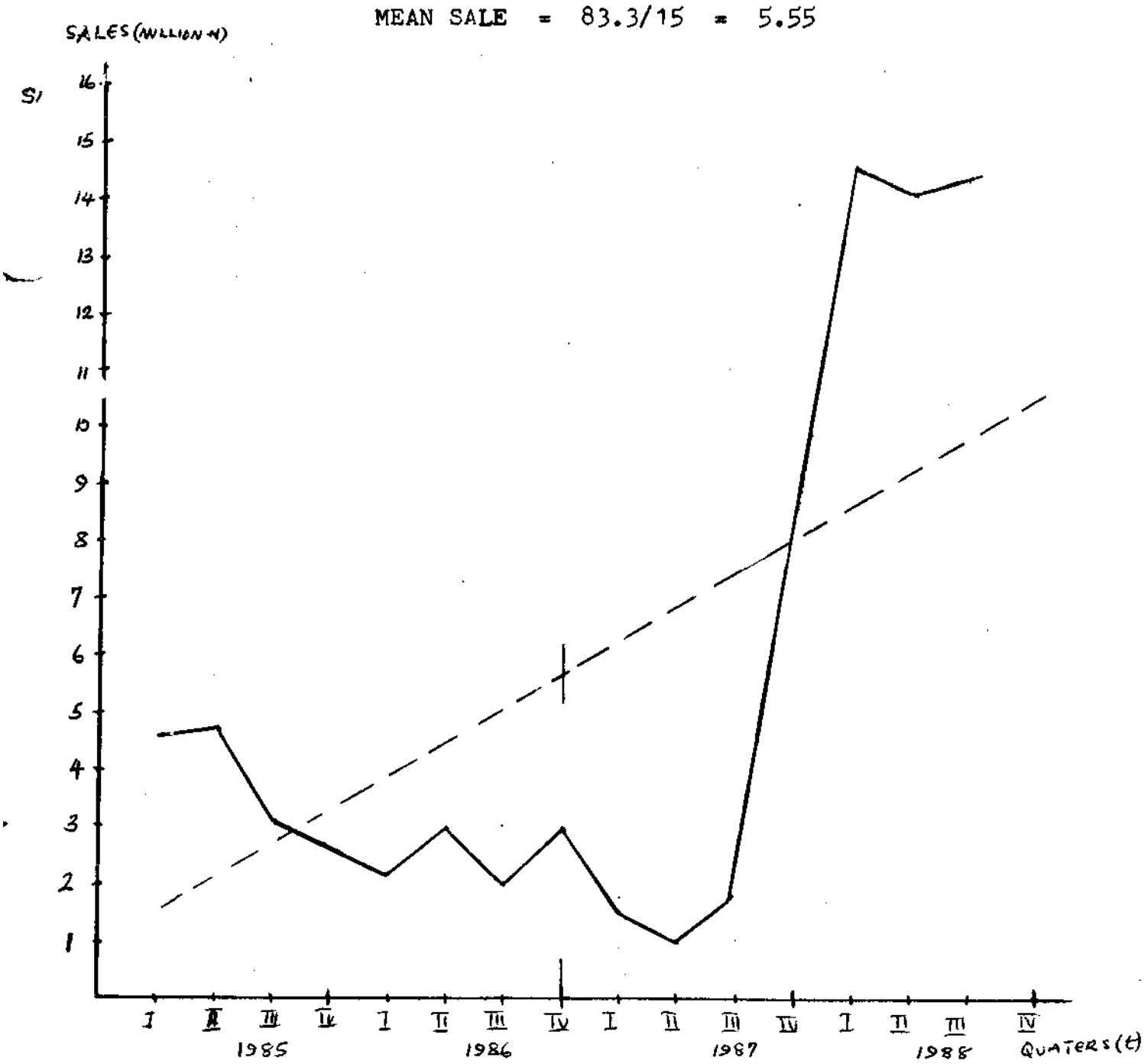
	QUARTERS			
Year	March I	June II	September III	December IV
1985	4761	4900	3065	2714
1986	2531	3000	2175	3009
1987	1625	1244	1920	8866
1988	14729	14,330	14525	-

For ease of manipulation the data is now presented in millions of Naira and rounded to 1.d.p.

TABLE 4.3

	I	II	III	IV
1985	4.8	4.9	3.1	2.7
1986	2.5	3.0	2.2	3.0
1987	1.6	1.2	1.9	8.9
1988	14.7	14.3	14.5	-

MEAN SALE = 83.3/15 = 5.55



The line of best fit is a straight line and represented by an equation of regression in the usual linear form, that is

$$y = a + bx$$

where y in this case is the sales

x is the number of quarters

a is the intercept

b is the slope of the regression line

From the analysis of regression,

'b' is given by $\dfrac{\sum(x - \bar{x})(y - \bar{y})}{\sum(x - \bar{x})^2}$

and 'a' by solving a pair of equations simultaneously.

The task of finding the line of best fit that will delineate the trend of the time series using the following method is the same as that of finding a line of best fit among the points of a scatter diagram. There is no question of choice between the two possible lines of best fit, since the deviations which the intent is to minimise are those of sales from trend, that is the vertical deviations. The problem can be further simplified if we recall that the quarterly intervals are evenly distributed (spaced) along the time azis. If we can identify the middle point of the series, and measure from the middle quarter, the time deviations above and below it will cancel out each other. The mean of

the time will then be zero.

As earlier stated:

$$b = \frac{\Sigma(x - \bar{x})(y - \bar{y})}{\Sigma(x - \bar{x})^2}$$

Now by representing the number of quarterly periods above and below the middle point of the time series by 'q' instead of x, the formula for the slope of the trend line becomes:

$$b = \frac{\Sigma(q - \bar{q})(y - \bar{y})}{\Sigma(q - \bar{q})^2}$$

Since there are an equal number of quarters above and below the middle point of the time series, then $\Sigma q = 0$ and $\bar{q} = 0$

$$b = \frac{\Sigma q(y - \bar{y})}{\Sigma q^2}$$

$$= \frac{\Sigma qy - \bar{y}\Sigma q}{\Sigma q^2}$$

but $\Sigma q = 0$, therefore

$$b = \frac{\Sigma qy}{\Sigma q^2} \qquad \text{- - - - - - 1}$$

From the normal equations for regression line of y on x we have:

$$\Sigma y = na + b\Sigma x$$

which substituting q for x, becomes:

$$\Sigma y = na + b\Sigma q$$

again since $\Sigma q = 0$

$$= \Sigma y = na$$

$$\text{and } a = \frac{\Sigma y}{n} = \bar{y} \qquad \text{------- 2}$$

These two equations give the framework for the determination of the trend line. It should however be noted that the intercept $\bar{y}$ (a) is at the new origin which is at the mid-point of the time series.

Let the symbol 'd' represent the deviations from any abitrarily chosen sales value. In the calculation which is represented in tabular the abitrary mean is taken to be 4 (4,000,000 naira).

TABLE 4.4

YEAR	QUARTER	SALES	q	d	qd	q^2
1985	I	4.8	-7	+0.8	-5.6	49.0
	II	4.9	-6	+0.9	-5.4	36.0
	III	3.1	-5	-0.9	+4.5	25.0
	IV	2.7	-4	-1.3	+5.2	16.0
1986	I	2.5	-3	-1.5	+4.5	9.0
	II	3.0	-2	-1.0	+2.0	4.0
	III	2.2	-1	-1.8	+1.8	1.0
	IV	3.0	0	-1.0	0.0	0.0
1987	I	1.6	1	-2.4	-2.4	1.0
	II	1.2	2	-2.8	-5.6	4.0
	III	1.9	3	-2.1	-6.3	9.0
	IV	8.9	4	+4.9	+19.6	16.0
1988	I	14.7	5	+10.7	+53.5	25.0
	II	14.3	6	+10.3	+61.8	36.0
	III	14.5	7	+10.5	+73.5	49.0
TOTALS		83.3	0	23.3	201.1	280

The formula given in equation 1 could be regarded as the formula for working from an assumed mean of zero and be modified thus:

$$b = \frac{\sum qd}{\sum q^2} \qquad b = \frac{201.1}{280} = 0.7182$$

Since the sales figures in these calculations are given correct to the nearest hundred thousand naira, and the y figures are consequently correct only to the first place of decimal, the value of b is taken as 0.7.

The intercept at the midpoint of the series is given by the mean sales value:

$$a = \bar{y} = \frac{\sum y}{n}$$

$$n = 15$$

$$a = \frac{83.3}{15} = 5.55 \quad 5.6$$

Therefore the trend line is thus:

$$y = 5.6 + 0.7q,$$

but using the real origin of the series about the assumed mean, the trend line becomes:

$$y = 4 + 0.7t$$

Where t is the number of quarters that have elapsed. This later function will be used in the subsequent calculations of the seasonal variation.

4.1.1 Seasonal Variation

To find the seasonal variation the actual sales figures are divided by the trend figures. To find the trend figure at any given quarter the

function $y = 4 + 0.7t$ is used with the number of quarters. That is for the first quarter of 1985 where $t = 1$, the trend figure will be $y = 4 + 0.7 \times 1 = 4.7$ (million naira). Below is the calculations for the rest of the quarters represented in tabular form. When trend figure is 4.7, The seasonal variation $= \frac{4.8}{4.7} = 1.02 = 102\%$

TABLE 4.5

YEAR	ACTUAL	TREND	QUARTER
1985	4.8	4.7	I
	4.9	5.4	II
	3.1	6.1	III
	2.7	6.8	IV
1986	2.5	7.5	I
	3.0	8.2	II
	2.2	8.9	III
	3.0	9.6	IV
1987	1.6	10.3	I
	1.2	11.0	II
	1.9	11.7	III
	8.9	12.4	IV
1988	14.7	13.1	I
	14.3	13.8	II
	14.5	14.5	III

The seasonal variation = (Actual/Trend) x 100

	I	II	III	IV	
1985	~~102~~	~~91~~	~~51~~	40	
1986	33	37	25	31	
1987	16	11	16	72	
1988	112	104	100	-	
TOTAL	161	152	141	143	
AVERAGE (TOTAL (TOTAL ÷ 3)	54	51	47	48	Bais - 200%
CORRECTED MEAN SEASONAL VARIATION(M.S.V)	81	77	71	72	

The figures that are felt far away (marked by Cross) in the series are omitted to make the determination of the average seasonal variation uniform for all the quarters. It will also be observed that there is a bais of - 200%, since if things are normal (that is actual sales equal to trend) the total ought to have been 400%. Even though this is felt a serious drawback, the necessary adjustment is made by apportioning the bais according to the actual average.

4.1.2 TREND, SEASONAL VARIATION AND RESIDUAL FLUCTUATIONS

TABLE 4.6

YEAR	SALES ACTUAL	SALES TREND	ACTUAL x100 / TREND	CORRECTED MEAN S.V.	TREND × PERCENT SV	RESIDUAL FLUCTUATION
1985	4.8	4.7	102	81	3.8	+1.0
	4.9	5.4	91	77	4.2	+0.7
	3.1	6.1	51	71	4.3	-1.2
	2.7	6.8	40	72	4.9	-2.2
1986	2.5	7.5	33	81	6.1	-3.6
	3.0	8.2	37	77	6.3	-3.3
	2.2	8.9	25	71	6.3	-4.3
	3.0	9.6	31	72	6.9	-3.9
1987	1.6	10.3	16	81	8.3	-6.7
	1.2	11.0	11	77	8.5	-7.3
	1.9	11.7	16	71	8.3	-6.4
	8.9	12.4	72	72	8.9	0.0
1988	14.7	13.1	112	81	10.6	+4.1
	14.3	13.8	104	77	10.6	+3.7
	14.5	14.5	100	71	10.3	+4.2

4.1.3 MAKING PREDICTIONS FROM THE TREND

The calculations in above table have provided us with a formula for finding the trend and percentage mean seasonal deviations, as delineated in table 4.6, for each quarter. The results therefrom can be

combined to:

1- give past data free of residual fluctuations,

and 2- extrapolate from the trend into future quarters.

The first part as already been shown in table 4.6. That is, if it is assumed that the original data is made up of the three components; trend, seasonal variation, and residual fluctuation, then the effect of the first two parameters may be represented by multiplying each of the trend figures by the appropriate seasonal variation. For example:

1985 1st quarter

Trend sales: 4.7 (million Naira)

Corrected mean seasonal variation: 81%

Trend x corrected M.S.V. = 4.7 x 81

= 3.8 (million)

The residual is gotten by subtracting the adjusted 3.8 figure from the actual sales figure for the quarter, that is:

4.8 - 3.8 = 1.0 (million naira).

The other important feature is the extrapolation through the use of the trend line to estimate sales figures for future periods for effective planning.

Taking the trend equation, $y = 4 + 0.7t$

to represent the underlying trend, then by way of taking further values of 't' as appropriate, it is possible to calculate future trend figures. For example figures of the fourth quarter of 1988 can be estimated by putting t = 16 which will give:

sales 4+ 0.7 x 16

= 4 + 11.2 = 15.2

To arrive at a fair forecast the trend sales figure is multiplied by the M.S.V. for the fourth quarter that is 15.2 x 72

= 10.9 (million naira).

In this way the estimate or forecast sales for the first quarter of 1989 and beyond can be calculated, but there is however the need of review from time to time.

Let us illustrate by giving forecast sales figure for the first quarter of 1989.

1989	time (t)	Trend	Mean Seasonal Var-tion	Forecast Trend x M.S.V.
I	17	15.9	81%	12.9
II	18	16.6	77	12.8
III	19	17.3	71	12.3
IV	20	18.0	72	13.0

4.1.4 COMMENTS ON THE PREDICTIVE ABILITY OF FORECASTING

The importance of forecasting cannot in any way be over-emphasised as it gives management a direction towards planning, deciding and control on its various activities. But, of course, there are many factors that forecasting, even in a fluctuation situation, does not take care of. Such factors could be environmental like general economic situation, social consideration, competition, availability of imputs in terms of raw materials, machines capacity and labour availability and many other contingencies that could not always be foreseen or anticipated.

But going further it is deemed necessary, as far as the company's sales forecast is concerned, to point out that the corrolation between sales and seasons of sales is possitively low that adjustment had to be made in arriving at the corrected mean seasonal variation and this fact gives the whole analysis little credence but will only be used for guidance into one of the next aspect of this analysis. That is, it will help determine the company's product demand that could be estimated at any time period.

4.2 APPLICATION OF LINEAR PROGRAMMING TO DATA COLLECTED

4.2.1 Objective:

The objective of this section is to be able, through the application of Linear programming technique to determine the combination of products to be produced in order to at least meet the market demand in the best possible way. As mentioned earlier a linear programming problem has to have an objective function which is the deciding aspect of the technique. These objectives take many forms which further prove the wide latitude for the application of the technique. But guided by the theme of this study the objective will be to maximise profits through a proper production scheduling.

From the data gathered, the prices of the two products as at January (which is the one available but it is felt its use will give the same signal as when other prices are used), 1988 are ₦110.25 and ₦29.00 for TC roll and Bedsheet respectively, having taken care of excise duty.

Therefore the objective function will look thus: $110.25X_1 + 29.00X_1 = \text{Maximum}$

where X_1 represents the TC roll and

X_2 represents the Bedsheet.

4.2.2 Constraints:

Again, in realising the above objective, the constraints have to be reckoned with. For the purpose of easy understanding, although there is no danger of altering final result, 12 hours will be considered as the production run as the second condition of linear programming model will be partially satisfied in the dyeing and finsihing department which run a 12 - hour shift.

In this vien we shall attempt to determine how much of grey material each product will consume in its production, the machines capacity in the dyeing/finishing department in terms of finished product turnover.

From the data collected in the finance department, the weaving section produced 4594443 metres of grey cloth. It is also known that 12 metres of cloth make 1 TC roll and 2 meters one bedsheet.

It therefore means that $12X_1 + 2X_2 \leq 4594443$ but since there are 220 days in a year the production of Grey-cloth per day $= \frac{4594443}{220}$

$= 20884$ metres.

In a day's production therefore

$$12X_1 + 2X_2 \leq 20884$$

Production per minute $= \frac{20884}{24 \times 60} = 14.5$ metres

If 14.5 metres is produced/mins.

1 metre is produced in $\frac{1\text{min}}{14.5}$

= 0.069 min.

Therefore 12 metres for TC is produced in

12 x 0.069 = 0.83 Min.

2 metres for Bedsheet is produced in

2 x 0.069 = 0.14 mins.

Since 12 hours (12 x 60 = 720 mins.) is taken to be the production run then,

$$0.83X_1 + 0.14X_2 \leq 720$$

Dyeing/Finishing

PRODUCTS	BLEACHING	WASHING	DRYING	DYEING	STENTER	CUTTING	PRINTING
X_1	3,000	2,100	2500	1800	4800	1800	-
X_1	18,000	12,000	15000	10800	28800	10800	810
ACTUAL CAPACITY	36,000	25,000	30000	21600	57600	21600	1620
CAPACITY RATE	50m/min	35m/min	21m/ min	30m/ min	80m/ min	15m/ min	-
ACTUAL RATE	25m/min	17m/min	21m/ min	15m/ min	40m/ min	15m/ min	1.13m/ min
TIME TAKEN TO PRODUCE 1 METRE	0.04	0.06	0.05	0.07	0.03	0.07	0.88

TIME TAKEN TO PROCESS 1 UNIT OF EACH PRODUCT ON THE MACHINES (MINUTES)

PRODUCT	BLEACHING	WASHING	DRYING	DYEING	STENTER	CUTTING	PRINTING
X_1	0.48	0.72	0.60	0.84	0.36	0.84	--
X_2	0.08	0.12	0.10	0.14	0.06	0.14	1.76
AVAILABLE TIME PER PRODUC-TION RUN	720	720	720	720	720	720	720

CONSTRAINTS

BLEAC HING: $0.48X_1 + 0.08X_2 \leqslant 720$

WASHING: $0.72X_1 + 0.12X_2 \leqslant 720$

DRYING: $0.60X_1 + 0.10X_2 \leqslant 720$

DYEING: $0.84X_1 + 0.14X_2 \leqslant 720$

STENTER: $0.36X_1 + 0.06X_2 \leqslant 720$

CUTTING: $0.84X_1 + 0.14X_2 \leqslant 720$

PRINTING: $0X_1 + 1.76X_2 \leqslant 720$

7 This implies that all the machines are equally available for the production.

Through observation however, machines, 'dyeing' and 'cutting' pose the same constraints, so one will be taken in the analysis.

Now the problem is to maximise the objective function:

$$110X_1 + 29X_2$$

Subject to the following constraints:

$$0.48X_1 + 0.08X_2 \leq 720$$
$$0.72X_1 + 0.12X_2 \leq 720$$
$$0.60X_1 + 0.10X_2 \leq 720$$
$$0.84X_1 + 0.14X_2 \leq 720$$
$$0.36X_1 + 0.06X_2 \leq 720$$
$$0.0X_1 + 1.76X_2 \leq 720$$
$$0.83X_1 + 0.14X_2 \leq 720 .$$

ADDITION OF SLACKS. TO THE CONSTRAINTS

$$0.48X_1 + 0.08X_2 + S_1 + 0S_2 + 0S_3 + 0S_4 + 0S_5 + 0S_6 + 0S_7 = 720$$
$$0.72X_1 + 0.12X_2 + 0S_1 + S_2 + 0S_3 + 0S_4 + 0S_5 + 0S_6 + 0S_7 = 720$$
$$0.60X_1 + 0.10X_2 + 0S_1 + 0S_2 + S_3 + 0S_4 + 0S_5 + 0S_6 + 0S_7 = 720$$
$$0.84X_1 + 0.14X_2 + 0S_1 + 0S_2 + 0S_3 + S_4 + 0S_5 + 0S_6 + 0S_7 = 720$$
$$0.36X_1 + 0.06X_2 + 0S_1 + 0S_2 + 0S_3 + 0S_4 + S_5 + 0S_6 + 0S_7 = 720$$
$$0.00X_1 + 1.76X_2 + 0S_1 + 0S_2 + 0S_3 + 0S_4 + 0S_5 + S_6 + 0S_7 = 720$$
$$0.83X_1 + 0.14X_2 + 0S_1 + 0S_2 + 0S_3 + 0S_4 + 0S_5 + 0S_6 + S_7 = 720$$

ITERATION PROCEDURE

	X_1	X_2	S_1	S_2	S_3	S_4	S_5	S_6	S_7		
S_1	0.48	0.08	1	0	0	0	0	0	0	720	1500
S_2	0.72	0.12	0	1	0	0	0	0	0	720	1000
S_3	0.60	0.10	0	0	1	0	0	0	0	720	1200
S_4	0.84	0.14	0	0	0	1	0	0	0	720	857
S_5	0.36	0.06	0	0	0	0	1	0	0	720	2000
S_6	0.00	1.76	0	0	0	0	0	1	0	720	0
S_7	0.83	0.14	0	0	0	0	0	0	1	720	867
C;-Z	-110	-29	0	0	0	0	0	0	0	0	0

	X_1	X_2	S_1	S_2	S_3	S_4	S_5	S_6	S_7		
S_1	0	0	1	0	0	-0.57	0	0	0	309	0
S_2	0	0	0	1	0	-0.86	0	0	0	103	0
S_3	0	0	0	0	1	-0.71	0	0	0	206	0
X_1	1	0.17	0	0	0	1.19	0	0	0	857	5041
S_5	0	0	0	0	0	-0.43	1	0	0	411	0
S_6	0	1.76	0	0	0	0	0	1	0	720	409
S_7	0	0	0	0	0	-0.99	0	0	1	9	
C;-Z	0	-10.3	0	0	0	133	0	0	0	94270	

	X_1	X_2	S_1	S_2	S_3	S_4	S_5	S_6	S_7	
S_1	0	0	1	0	0	-0.57	0	0	0	309
S_2	0	0	0	1	0	-0.86	0	0	0	103
S_3	0	0	0	0	1	-0.71	0	0	0	206
X_1	1	0	0	0	0	1.19	0	0.10	0	786
S_5	0	0	0	0	0	-0.43	1	0	0	411
X_2	0	1	0	0	0	0	0	0.57	0	409
S_7	0	0	0	0	0	-0.99	0	0	1	9
C_j-Z	0	0	0	0	0	133	0	5.87	0	98483

This is the optimum solution since there is no negative quantity in C_j- Z row.

From the last tableau, the following results can be deduced, thus:

S_1 = 309 min. = 5.15 hours

S_2 = 103 min. = 1.72 hours

S_3 = 206 min. = 3.43 hours

S_5 = 411 min. = 6.85 hours

S_7 = 9 min. = 0.15 hours.

X_1 = 786 rolls

X_2 = 409 bedsheets

Evaluation of the objective function

$110X_1 + 29X_2 = 110 \times 786 + 29 \times 409$

= 86460 + 11861

= ₦98321.

4.3 DISCUSSION OF RESULTS

First and foremost it has been found out the company does not use the technique of operations research or any of the scientific approaches to decision making. But from the result of the finding it will be seen that there is a lot to be gained by applying scientific method to production planning. The situation presently is to produce 100 TC rolls and 45 cartons containing 18 bedsheets per day with possible sales turnover of 110 x 100 + 45 x 29 x 18 = ₦34490. But from the analysis and as far as the

machines' constraints allowed, 45 cartons of bedsheets and 1572 roll of TC should be produced at a possible sales turnover of 110 x 1572 + 45 x 29 x 18 =₦196410 which showed an increase of ₦161920 or 469% increase.

The actual asales recorded in 1987 whose production is taken for this analysis was ₦13,655,000 while if this analysis was made and the findings applied, the possible sale would have been 196410 x 220 = ₦43,210,200 using the same resources. One would really begin to wonder what was wrong as the difference is such staggering. From the outset let it be clear that all the possible constraints for a perfect production scheduling program were not available and those that were, were subject to suspicion as regard their authenticity since most of the data gathered was verbal estimate. This flagrant discrepancy could also be attributed to wastage from the weaving section to the dyeing and finishing but even then, no matter the amount of wastage, it will not amount to so much deviation, but one could only conclude that it partly attributes to this anormally.

As it has been said earlier that the company does not use forecasting as a to l to its products sales forecast. This fact could also be another factor which made this deviation of theoretical analysis to the actual experience a reality. For

instance if sales are not fairly forecasted, inventory could be lying idle and in some cases the Grey-cloth that is supposed to reach the dyeing/ finishing department for further processing could never reach there but be sold as finished products to other industries or individuals.

This is almost all about what is deemed a serious discrepancy. Now to trun on the eoncomies derived from the application. If things are going to be normal, that is no machines breakdown, no shortages of raw material or individual strifes, the company will do better when the system of linear programming is applied if only to serve as a direction to the company's capability so that when there is a fair forecast of sales/demand, management will readily be in a position to take a decision without wasting much economic time. Production manager will also be in a position to advise management on his department's ability to meet whatever demand the sales department will throw upon his own department. This all centres on management having the upper hand at deciding relatively effectively compared to the time when no knolwedge of scientific analysis was made available to facilitate decision making.

The production manager will also be in a postiiton apart from being very instrumental to the

company's decisions, to initiate embarking upon other areas of production. Obviously using the scientific analysis, the production manager will be able to know the times some machines are idle and be able to calculate the opportunity cost of their remaining unproductive for such periods. This will ignite in a creative manager the desire to have other jobs assigned to the machines with enough idle times or schedule work in a good network so that the market demand could be attained without necessarily working throughout the day thereby reducing overtime cost.

As it will be seen, in a production run the Blending machine would be idle for 5.15 hours the washing machine for 1.72 hours, the drying for 3.43 hours, the Stenter machine for as many hours as 6.85 hours and the printing for only 0.15 hours. Knowledge such as this is very valuable to production manager. Like the stenter machine which is utilized for less than half of its capacity, other jobs could easily be assigned to it without having to go beyond its actual capacity or endangering the completion times of the products.

The production manager can also know the economic worth of machine in case he is consulted or even directed to give advice or buy such machines.

Having given allowance for what is termed "lack of appropriate data, still the technique has proved worthwhile to embark upon because, apart from increasing profits it also gives line of guidance to management in decision making.

4.4 ACTUAL LIMITATIONS OF THE STUDY

1. Lack of time to be able to bobserve the production processes directly instead of relying on data given on estimates and assumptions.

2. Management skeptimism towards the purpose of the study. In fact some officials are of the opinion that they see no way a study of such nature could improve their performance in the face of this dynamic economic conditions.

3. Unavailability of all the relevant data for a fairly perfect production scheduling analysis through linear programming such as inventory holding cost, cost of labour shifts, etc.

4. Because of (3) above the model used is not a new one and could be applied in any organisation, the result therefrom will not be 100% reliable but could only be used as a point of diversion for more research into the real model appropriate for a particular company with its peculiar characteristics.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

From the above results and their interpretations, notwithstanding the encountered limitations, it has been proved that linear programming is very important to production scheduling in any manufacturing concern. It is as if a born blind man having his eyes' ability back to see how beautiful his environment is. As it is quiet often assumed - rightly or wrongly - the primary aim of a business is to make (maximise) profits as a measure of performance, the application of the technique has proved of tremendous significance in this direction. It also proved its potentiality of being a strong assistance in decision making as per as a manufacturing firm like the one the research is conducted on is concerned.

From the following emperical evidence of linear programming superiority in the art of facilitating scheduling production over other unscientific modes and providing avenue for executive to decide in order to maximise shareholders' wealth or even to survive in an atmosphere of stiff competition, the following are recommended for the company in its operations. These are divided into two categories: the obvious and the implied.

The Obvious

1 - To increase the production of T/C rolls to the level indicated by this study at least as far as its demand warrants and keep the production of Bedsheet as it presently is - 45 cartons.

2- Sales department should be conducting market research and engage in sales forecasting with a view to knowing the market trend which will in turn help predict future seasons' performance. This has the beautiful advantage of avoiding some of the future adverse economic effects capable of pulverizing the company's ability to survive. In addition it will serve as a direction to the production department for necessary adjustments and the financial department for providing funds necessary in case the forecast is for increase in production.

3 - Without altering the present constraints, production department should create jobs for the machines indicated as having idle times in order to reduce or totally eliminate the opportunity cost.

4 - Embark upon intensive training and development of workers by either arranging with consulting organisations or sending them for further studies.

5 - Employ effective motivational techniques to boost the morale of workers.

6 - Record-keeping should be given more priority and handled only by competent personnel.

The Implied

1 - Through this analysis it has been shown that the company has the ability of increasing its performance through maximisation of profits. This could only be made available by conducting market analysis to identify the potentiality of the company's products as against competitors and emback upon advertisment.

2 - From one of the obvious recommendations, the company should expand its product line. This could be done through three ways: One is utilising the idle times of the machines, second is utilising the machines to their full capacity and third is by acquiring more machines and selecting more experienced personnel to handle them.

3 - Engage a professional in research and development or if it proves more costly, train one or more of their staff in operational research.

4 - More research should be conducted in the area of production scheduling using scientific approach by both academicians and the organisations themselves.

SELECTED BIBLIOGRAPHY

- A. Chaines and W.W.Cooper, Management Models and Industrial Applications to Linear Programming, 2 vols. New York: John Wiley & sons, 1961.

- A.Kaufmann, Methods and Models of Operations Research, Prentice-Hall, Englewood Cliffs, N.J., 1963.

- A.Lawal, Study on the Extent of Application of Operations Research Techniques in the Manufacturing Sector in Northern States of Nigeria, Unpublished MBA Project ABU, Zaria, 1983.

- A.W.Spivey and K.E. Boulding, Linear Programming and the Theory of the Firm. New York: Macmillan Co., 1960.

- C.P.Bonini, H.Bierman Jr. and W.H. Hausman, Quantitative Analysis for Business Decisions, Homewood, III: Richard D. Irwin, 1973.

- C.W. Churchman, The Systems Approach, New York: Dell Publishing Co., 1968.

- C.M. Paik, Quantitative Methods for Managerial Decisions, New York: McGraw Hill Book Company, 1973.

- C.W. C hurchman, R.L. Ackoff and E.L. Arnoff, Introduction to Operations Research, New York: John Wiley & Sons, 1975.

- C. Kim, Introduction to Linear Programming: New York: Holt, Rinehart and Winston, 1971.

- D.P. Surver and G.L. Thompson: Programming and Probability Models in Operations Research, Belmout, Cliff: Wadsworth Publishing Co., 1973.

- D.W.Miller and M.K. Starr, Executives Decisions and Operations Research, Englewood Cliffs, N.J. Printice Hall, 1960.

- D. Robert, P.A.Samuelson and R.M.Solow, Linear Programming and Economic Analysis. New York The Macmillan Company, 1961.

- E.S.Buffa, Modern Production Management, New York: John Wiley & sons, 1973.

- E.V. Idachaba, Production Scheduling and Control: A Comparison of Intermittent Production System and Continuous Production System, Unpublished MBA Project, ABU, Zaria, 1987.

- F.S. Hillier and G.J. Lieberman, Introduction to Operations Research, Holden - Day, 1980

- G.B. Dantzig, Linear Programming and Extension Priceton University Press, 1963.

- G.Hadley, Linear Programming Reading, Mass: Addison Wesley Publishing Co., 1962.

- H.Moskowitz and G.P. Wright, Operations Research Techniques for Management, Prentice-Hall, Englewood Cliffs, N.J., 1979.

- H. M. Wagner, Principles of Operations Research,with Application to Managerial Decisions, Englewood Cliffs, N.J. Printice Hall, 1969.

- J.E. Strum, Introduction to Linear Programming, San Francisco: Holde-Day, 1972.

- L. W. T. Stafford, Business Mathematics,ELBS, Macdonald and Evans, Playmouth, 1979.

- R.J. Thierauf and R.C. Klekamp, Decision Making Through Operations Research New York: John Wiley & sons, 1975.

- R. L. Ackoff and P. Rivett, A Manager's Guide to Operations Research, New York. John Wiley & Sons, 1963.

- R. L. Ackoff and M. W. Sasieni, Fundamentals of Operations Research, New York: John Wiley & Sons, 1968.

- S.E. David, Quantitative Business Analysis: New York: John Wiley & Sons, 1977.

- S. B. Abdullahi, Linear Optimisation Techniques as a tool for better Production Schedules: A Comparative Case Study of three companies in Kaduna State of Nigeria: Unpublished MBA Project, A.B.U. Zaria, 1984.