LINEAR PROGRAMMING AS TOOL FOR RESOURCE ALLOCATION IN THE PRINTING AND PUBLISHING INDUSTRY IN NIGERIA

BY

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MSC/ADMIN/14226/97 - 98

OCTOBER, 2003

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A THESIS SUBMITTED TO

THE POSTGRADUATE SCHOOL, AHMADU BELLO UNIVERSITY, ZARIA

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF

MASTER OF SCIENCE DEGREE IN ACCOONTING AND FINANCE

OCTOBER, 2003

DECLARATION

I declare that this work is the result of my personal efforts; that where references are made to other people's works they have been duly acknowledged; and that to the best of my knowledge, the information contained therein are reasonably and fairly accurate and correct and free from any wilful distortion, bias or misstatement.

22/07/04

OLADELE, Olugbenga Kolawole

(MSC/ADMIN/14226/97-98)

DEDICATION

This work is exclusively dedicated

to my wife,

Adenike

and
to my children,

Dominion and **Triumph**

CERTIFICATION

This thesis entitled **The Application of Linear Programming as a Tool for Resource Allocation in The Printing and Publishing Industry in Nigeria** by **Oladele, Olugbenga Kolawole** meets the regulations governing the award of the degree of **M.Sc. Accounting and Finance** of the **Ahmadu Bello University, Zaria** and is approved for its contribution to knowledge and literary presentation.

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ACKNOWLEDGEMENT

At this stage I would like to appreciate the efforts of all the people who have contributed in one way or the other to the success of this research work.

First, I want to thank my supervisor, **Dr. M. A. MAINOMA**, who is also the Head of the Department of Accounting. He painstakingly and meticulously read through the entire work and made very useful corrections without which this research work would not have been worth its onion. Sir, I am very grateful.

Next I want to thank all my lecturers who took time to teach me throughout the course work period. I particularly appreciate the contributions of Professor Ibrahim Ayagi, Mr. A. B. D. Watoseninyi, Mr. Solomon Akanet, Mr. Anthony Silva, and the Late Dr. O. T. Odiongienyi.

I also thank all my classmates: Abu Adah, Agochukwu Barnabas, Ishaya Maina, Samuel Iyere, Anthony Nebo, Hassan Yusuf, Adamu Aliyu, Kenneth, Uguh, Austin Ayila, Alloysius Vutumu (Chairman), Aliyu Yusuf, Pavtar Agir and the others. I am especially grateful to Mrs. Aniette Charles- Dikki and her husband, Dr. Charles - Dikki, who gave my family and I all the assistance we ever needed, both morally and academically. May God the Almighty meet you all at the point of your needs. Amen.

I would also like to thank all my senior colleagues in the office: Mr. A. O. Fatoye, Mr. A. A. Madubuko, Mr. A. Olatunde and Mr. C. V. Chandrashekaran (Head of Department) whose advice and constructive criticisms were very instrumental to the success of this work. My thanks also go to all other colleagues of mine in the department.

Another important group of people I cannot forget is the body of the various authors whose works were referred to in this study. I thank them all for the permissions granted me to make use of their works.

My appreciation also goes to my wife, Adenike, and my children, Dominion and Triumph, who understood with me throughout the period of my absence and gave all the encouragement I needed as a husband and a father. I use this forum to thank my parents as well for their support and prayers.

I thank my friend and pastor, Paul Haleem, for all the spiritual and moral support since I met him. I thank you so much. I am also indebted to my old friend and mentor, Mrs. Elizabeth Haastrup, who took time to type this voluminous project work virtually free of charge. My God will bless you abundantly.

Finally, I thank the Almighty God who gave me the wisdom; strength and understanding that I needed to pursue the course to a logical conclusion. I thank Him for his protection, guidance, and the grace to finish successfully. To Him be glory, honour, dominion, power and majesty forever and ever and at His feet, I bow in humble adoration.

ABSTRACT

This research work examined three problems: applicability of the linear programming method of allocating scarce resources to the allocation problems printing firms in Nigeria and its challenges; the use of the method to appropriately allocate scarce resources in the printing industry; and the determination of any other method of allocation used in the industry.

To achieve these objectives, the researcher formulated the research hypotheses. Primary data were obtained through questionnaires, interviews, and direct observation of procedures. Secondary data were obtained from texts, journals and other unpublished works. The data obtained through questionnaires were analysed and interpreted using the percentage method. In order to test the hypotheses, the researcher used the Chi-square method of statistical analysis. Other data were tested using the linear programming methods (simplex and graphical).

It was found out that linear programming is applicable to the allocation problems of a printing firm; that it can also be used to appropriately allocate their scarce resources for the achievement of optimality; that many printing firms prefer other methods tike mental judgement and the use of budgets for allocating their resources; and that many firms were not using such mathematical models because of in-exposure, and sheer unwillingness to change from the old method.

It was recommended, among other things, that printing firms in Nigeria should adopt the use of linear programming method for resource allocation; that more academic institutions in the country should include Printing Technology in their curriculum; that the government should get involved in the regulation of printing standards in the country and that operators of printing houses should employ well-educated staff.

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CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND INFORMATION

The printing and publishing industry is a relatively young industry in Nigeria. It is virtually dominated by private operators, with very little government participation.

As Kolade (2001:6) observes "there is almost no law regulating the activities going on in the industry as far as Nigeria is concerned". This perhaps is responsible for the slow development of the industry in Nigeria. He comments further: "Only few academic institutions in Nigeria incorporate printing as a course of study, in their programmes and only few government-owned printing companies exist in the country". This means no regulation and therefore no standards exist to guide production and control the quality of output.

The printing and publishing industry is essentially a service industry and resource-oriented. A printing house that is aiming at making profits must strike a very good and convenient balance between the available financial, human, marketing, material, technological and other resources and how it uses them. How well a printing house channels its resources among the various jobs is a function of what method it uses.

Linear programming is a quantitative method that has been used by many organisations for many years in the developed countries of the world. It is being applied to so many areas of human endeavour including production scheduling, hospitals, military operators etc. and used to solve resource allocation problems especially in cases where the limiting factor is more than one.

Experience shows that Linear programming, as a mathematical tool / quantitative technique, is capable of solving allocation problems and achieving optimality. It also allows users to test the results obtained for changes in one or more variables through a process called sensitivity analysis. Linear programming offers two principal methods of solution (the simplex and the graphical methods) and can handle any number of variables and constraints provided they are well defined and formulated.

In this study, the principal objective is to find out whether Linear programming, as a mathematical tool can be applied to solving the allocation problems of a printing company.

1.2 STATEMENT OF PROBLEM

Unlike its counterparts in the developed countries like U.S.A., Britain, Japan and many others, the Nigerian printing and publishing industry has grown very slowly and developed very poorly over the years. This is because; the industry is beset with so many problems ranging from the shortage of manpower to inefficient allocation of resources. These problems are compounded by the conspicuous absence of a regulatory body charged with the responsibility of controlling and regulating the activities of the firms operating in the industry, setting quality, and production standards and specifying the training and qualification requirements of the persons employed in the industry (Kolade, 2002).

In the printing industry, time as a resource is very critical to the operators. Every job that comes in does so with a sense of urgency and they are treated as such. Yet, the individual printing firm wants to keep accepting jobs and serving its customers. At the same time, other resources, like materials, production (machine capacity) and finances are not always (if at all) available in sufficient quantities.

In addition to these, the firm would like to make as much profit as possible or reduce cost to the lowest level possible and possibly achieve other organizational objectives of growth, expansion, staff- training and so on.

With all these problems (constraints or limitations) and increasing job pressure, on the one hand, and the profitability and other organizational objectives, on the other hand, how can a printing firm allocate its resources optimally among the various competing alternatives (jobs on hand) and make the highest profit possible or incur the lowest cost possible without compromising standards of quality, agreed times of delivery and other good customer service factors?

The costs in this case/context will include operating costs, opportunity costs and lost patronage.

In allocating its scarce resources among the various competing alternatives, a firm may be faced with a number of methods/approaches (scientific or unscientific). The choice of method/approach will in turn be influenced by a host of other factors such as; the objectives of the firm; the preferences of the dominant strategist, internal politics and external influences.

In this study however, the problem is how to determine the applicability of linear programming, as a resource allocation method, to the allocation problems of a printing firm. The question therefore is this: Can the linear programming method be used to appropriately allocate the resources of a printing firm and achieve optimality; are there better alternatives to this method; what are the challenges posed by the application of this method?

The answers to the above questions shall constitute the focus of this study.

1.3 OBJECTIVES OF THE STUDY

The objectives of this study can be stated as follows:

a. To determine the applicability of linear programming method to the allocation problems of a printing firm as well as the challenges posed by the method.

b. To find out if the method can be used to allocate the scarce resources of a printing firm appropriately in order to achieve optimality.

c. To find out the various methods of resource allocation currently used in the printing industry in Nigeria.

d. To make appropriate recommendations based on the findings of the study.

1.4 SCOPE OF STUDY

The principal focus of this study is to find out whether or not the linear programming method can be applied to the allocation problems of a printing company. Therefore, for the purpose of the study research efforts will be limited to the printing firms in Kaduna metropolis.

For this purpose, all the 85 registered printing firms in Kaduna will be selected for the study.

In addition, the study will cover the period between 1990 and 2002, which is 13 years.

Finally, the study will be limited to application of the linear programming method of resource allocation only as it affects the allocation problems of printing firms in Nigeria.

1.5 SIGNIFICANCE OF STUDY

Linear programming, as a method of allocation, has been used in many areas of human endeavour, and found to be relevant and useful to management in decision-making.

In Nigeria however, there is limited usage of linear programming method for solving Nigerian problems although there may be other quantitative methods in use.

This study is of great significance because it will help to understand whether the linear programming method can be used to appropriately allocate the resources of a printing company and achieve optimality. It will also help to understand the extent to which it is applicable, the challenges it poses as well as what to do to overcome the challenges.

If all these are achieved, then the students of printing technology, the operators of printing businesses will learn a new way of handling allocation problems and associated challenges – where it is applicable. Where it is found in-applicable, then it will also show which alternatives are available for handling their allocation problems. Therefore, whatever the findings are, the study shall have been a major contribution to knowledge for all stakeholders in the industry and other interested parties.

1.6 STATEMENT OF HYPOTHESIS

The hypotheses of this study are stated as follows:

H_o: There is no significant relationship between the application of linear programming method and the achievement of optimality in resource allocation by the printing firm.

H_a: **There is a significant relationship between the application of linear programming method and the achievement of optimality in resource allocation by the printing firm.**

The hypotheses will be tested using the Chi-square method of hypothesis testing at 95% level of significance. Hence the value of alpha (α) (percentage of error allowable) will be 0.05 i.e. $\alpha = 0.05$.

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CHAPTER TWO

REVIEW OF LITERATURE

2.0 INTRODUCTION

This chapter focuses on the theoretical discussion of linear programming as a branch of operations research and as a tool for resource allocation. The chapter is divided into two parts, which are:

1. the concept of linear programming
2. Allocation of resources

In the first part, the researcher discusses the concept of a linear programme, its properties, features and the general definition of the linear programming model. The part also discusses the various methods of solving linear programming problems, the various solution outputs, and sensitivity analysis. Also included in this part is discussion on the special case of the linear programming problem, special linear programming models, the application of computers to linear programming as well as the problems and limitations of linear programming.

In the second part, the researcher dwells mainly on resource allocation covering such areas as procurement of resources, the various approaches to resource allocation, the means of resource allocation, the factors affecting the allocation of resources, the difficulties in resource allocation as well as the problems with the unscientific methods of resource allocation

At the end of the chapter, the researcher closed the generation gap by drawing conclusions based on the review of related literature.

2.1 CONCEPTUALIZATION OF LINEAR PROGRAMMING

The term **Linear Programming** has been defined in a number of ways by many authors. For instance, Taha (1976) defines linear programming as "a class of mathematical Programming models concerned with the efficient allocation of limited resources to known activities with the objective of meeting a desired goal (profit maximization or loss minimization)". Hongren (1982) however, sees linear programming as a "a short-run model, which assumes that a fixed set of resources is available that generates a specified level of fixed costs with the objective of deciding on what types and amounts of products or services to produce or sell in the face of revenue and cost behaviour regarding the given set of resources". In the words of Fabrycky et al (1984),

> *Linear programming is a mathematical modelling 'system', which has found widespread use in providing decision makers with an efficient means of resolving complex operational alternatives. It is applicable to the general category of problems that require the optimization of a linear effectiveness function subject to linear constraints, which exist because the activities under consideration usually compete for scare resources.*

Lucey (1992) summarizes it thus: "Linear programming is a mathematical technique to optimize the allocation of scare resources". To end the list of definitions, Lowes and Sparkes (1993) underscore the fact that "linear programming is a technique for utilizing limited resources to meet a desired objective, such as minimizing cost or maximizing profit where the resource limits are expressed as constraints"

These definitions throw a serious light on the subject of linear programming as both a mathematical model/technique and a tool for decision-making and then reveals the properties of linear programming that help to understand in a better way what linear programming is.

2.2 PROPERTIES OF LINEAR PROGRAMMING

Vazsonyi and Spirer (1984) examine the properties of linear programming and submit that:

a. A linear program must have a linear relationship. This implies proportionality i.e. if it takes 3 hours to make a unit, then 6 hours will be needed to make 2 units etc.

b. Fractional solution is allowed: such that it is possible to arrive at a solution that allows the manufacture of 2.5 rings. Hence, in linear programming, all variables must be continuous.

c. Constants are known in a deterministic manner. This means that linear programming does not make use of probabilities. Thus, the value of each of the constants is assigned with a reasonable certainty. Uncertainty is not allowed.

d. A single pay off is minimized/maximized: this means it is not possible to maximize sales, profits, etc at the same time. Only one can be handled at a time.

Lucey (1992) accedes to the above but has this to add.

e. The problems to be solved must be capable of being stated in numeric terms.

f. The problems must permit a choice(s) between alternative courses of action.

g. There must be one or more restrictions on the factors involved.

In solving a linear-programming problem, it is necessary to express the problem in a standard form. This involves the separation of the linear program into objective function (the goal to achieve) and limitation (constraint).

2.3 FEATURES OF A LINEAR PROGRAM

a. **The Objective Function:** Every linear program has an objective function. It is the objective of the problem stated in mathematical form. This may be the maximization or minimization of a function E.g.

If X_1 represents the number of biros produced and

X_2 represents the number of pens produced

Then X_1 and X_2 in linear programming terminology are called **decision variables** because the value of the objective function is a function of the decision variables. It is used to measure the profit or cost of a particular solution.

b. **Constraints:** This is the limitation imposed by the limited resources. An equation or inequality rules out certain combinations of variables as feasible solutions.

c. **Non-Negativity Constraint:** An important feature of linear programming is the non-negativity constraint. These constraints ensure that the solution to our problem will contain non-negative values for the decision variables. They are thus of a set of constraints that require all decision variables to be non-negative. E.g. $X_1 \geq 0, X_2 \geq 0$ means **X_1 and X_2 are each greater than or equal to zero.**

Thus, a linear program is a mathematical model with a linear objective function, a set of constraints and non-negativity constraints. This is illustrated in the example below.

Maximize	$4X_1 + 8X_2$	**Objective Functions**
Subject to:	$1X_1 + 4X_2 \leq 8$	**Constraints**
	$1X_1 + 4X_2 \leq 25$	
	$X_1, X_2 \geq 0$	**Non-negativity Constraints.**

According to Fabrycky, et al (1984), "the general linear programming model may be formulated mathematically as requiring the optimization of the linear effectiveness function".

2.4 GENERAL DEFINITION OF THE LINEAR PROGRAMMING MODEL

According to Taha (1976), "real- life examples show that a linear program may be the maximization or minimization type. The constraint may be of the type **(≤), (=),** or **(≥)** and the variables may be non-negative or unrestricted in sign". In any case, the general linear programming model may be defined as follows:

Maximize (or minimize) $X_0 = C_1X_1 + C_2X_2 + \ldots + C_nX_n$

Subject to:

$$a_{11}X_1 + a_{12}X_2 + \ldots + a_{1n}X_n (\leq, =, \text{or} \geq)\ b_1$$
$$a_{21}X_1 + a_{22}X_2 + \ldots + a_{2n}X_n (\leq, =, \text{or} \geq)\ b_2$$
$$\vdots$$
$$a_{m1}X_1 + a_{m2}X_2 + \ldots + a_{mn}X_n (\leq, =, \text{or} \geq)\ b_m$$
$$X_1, X_2, \ldots, X_n \geq 0$$

Where:

C_j, b_i **and** a_{ij} (for $i = 1,2\ldots m$; and $j = 1,2\ldots n$) are constraints determined from the technology of the problem, and X_1 **and** X_2 are decision variables.

Only one sign holds for each constraint and although all variables are declared non-negative, it can be shown that every unrestricted variable can be converted into its non-negative equivalent.

The non-negative restriction is very essential for the development of the solution for linear programming.

Often, linear programming models represent "allocation" problems, which involve the allocation of limited resources to a number of activities. Given the above formulation therefore, the coefficients $\mathbf{b_i}$, $\mathbf{a_{ij}}$ and $\mathbf{C_j}$ can be physically interpreted as follows:
If $\mathbf{b_i}$ is the amount of resource **i** available, then $\mathbf{a_{ij}}$ is the amount of **i** that must be allocated to each unit of activity **j**. The "worth" per unit of activity **j** is equal to $\mathbf{C_j}$.

The decision-maker has direct control over the vector of the variable $\mathbf{X_j}$. Not directly under control are the vectors of effectiveness coefficient $\mathbf{C_j}$, the matrix of constraint $\mathbf{a_{ij}}$, and the vector of the constant $\mathbf{b_i}$. The model structure follows the form of the general effectiveness function with constraints. They add that:

> *This mathematical statement of the general Linear Programming model may be explained in geometric terms. There exist **n** - variables that define an **n**-dimensional plane. Each constraint corresponds to a **hyper-plane** in this space. These constraints surround the region of feasible solutions by **hyper-surfaces**, so that the region is the interior of a **convex polyhedron.** Since the effectiveness function is linear in the **n**-variable, the requirement that functions have some constant value gives a hyper-plane, which may or may not cut through the polyhedron. If it does, one or more feasible solutions exist. Changing the value of this constant generates a family of planes parallel to each other in which case, the **orthogonal distance** from the origin to a member of this family is proportional to the value of the effectiveness function.*

Fabrycky, et al. (1984) state further that "two limiting **hyper-planes** are identifiable which are:

1. The one corresponding to the largest value of the effectiveness function for which the hyper-plane just touches the polyhedron, and;

2. The one corresponding to the smallest value of the effectiveness function for which the hyper-plane just touches the polyhedron. The limiting hyper-planes just touch a single vertex of the limiting polyhedron. In most cases, this **outermost limiting point** identifies the values of n - variable that optimize the effectiveness function "

Although it is possible to give a verbal description of the geometric structure of linear programming, it is not applicable to a linear program that has more than three decision variables.

Usually linear programming models come in the nature of the above formulation, so it is necessary to modify these forms so that they can fit into the solution procedures, which will be presented later. For this purpose, two forms are introduced which are:

a. The canonical form of linear programming
b. The standard form of linear programming

The Canonical Form:

The general linear programming formulation above can always be represented canonically. This canonical form can be very useful in presenting the **duality theory**. (See primal and dual problems) and takes the following form:

$$\textbf{Maximize} \quad X_0 = \sum_{J=1}^{n} C_j X_j$$

$$\textbf{Subject to:} \quad \sum_{J=1}^{n} a_{ij} X_j \leq b_i, \qquad i = 1,2\ldots, m$$

$$X_j \geq 0, \qquad j = 1, 2,\ldots, n$$

The canonical form has the following characteristics:

1. All decision variables are non-negative
2. All constraints are of the less- than- or- equal- to **(≤)** type
3. The objective function is the maximization type.

A linear programming problem can be put in the canonical form by the use of five elementary transformations.

1. The minimization of a function, **f (x),** is mathematically equivalent to the maximization of the negative expression of the function, **-f (x).**
For example, the linear objective function

Minimize: $X_0 = C_1X_2 + C_2X_2 + \ldots + C_nX_n$

Is equivalent to:

Maximize $g_0 = -X_0 = -C_1X_1 - C_2X_2 - \ldots - C_nX_n$

Where $X_0 = -g_0$

Therefore in any linear programming problem, the objective function can be put in the maximization form.

2. An inequality in one direction **(≤ or ≥)** may be changed to an inequality in the opposite direction **(≥** or **≤)** by multiplying both sides of the inequality by **(-1).**
For example, the linear constraint:

$$a_1X_1 + a_2X_2 \geq b$$

Is equivalent to:

$$-a_1X_1 - a_2X_2 \leq -b$$

Also,

$$p_1X_1 + p_2X_2 \leq q$$

Is equivalent to:

$$-p_1X_1 - p_2X_2 \geq -q$$

3. An equation may be replaced by two (weak) inequalities in opposite direction.

For example:

$$a_1x_1 + a_2x_2 = b$$

Is equivalent to the two simultaneous constraints:

$$a_1x_1 + a_2x_2 \leq -b \text{ and } a_1x_1 + a_2x_2 \geq b$$

or

$$a_1x_1 + a_2x_2 \leq -b \text{ and } -a_1x_1 - a_2x_2 \leq -b$$

4. An inequality constraint with its left–hand side in the absolute form can be changed into two regular inequalities.

Thus for $b \geq 0$,

$$a_1X_1 + a_2X_2 \leq b$$

Is equivalent to:

$$a_1X_1 + a_2X_2 \geq -b \text{ and } a_1X_1 + a_2X_2 \leq b$$

Similarly, for $q \geq 0$,

$$*P_1X_1 + P_2X_2* \geq q$$

Is equivalent to:

$$P_1X_1 + P_2X_2 \geq q \text{ and } P_1X_1 + P_2X_2 \leq -q$$

5. A variable, which is unconstrained in sign (that is positive, negative or zero), is equivalent to the difference between two non-negative variables.

Hence if **X** is unconstrained in sign, it can be replaced by $(X^+ - X^-)$ where $X^+ \geq 0$ and

$X^- \geq 0$. For example by fourth transformation:

$$5X_2 + 8X_3 \leq 100$$

is equivalent to:

$$5X_2 + 9X_3 \leq 100 \quad \text{and} \quad 5X_2 + 8X_3 \geq -100.$$

by the firth transformation:

$$X_3 = X_3^+ - X_3^-$$

Where $X_3^+ \geq 0$ and $X_3^- \geq 0$.

The Standard Form

The standard form is normally used to solve the model directly and has the following characteristics:

1. All constraints are equations except the non-negativity constraints, which remain as inequalities **(≥ 0)**.
2. The right-hand side element of each constraint equation is non-negative.
3. All variables are non-negative.
4. The objective function is of the maximization or the minimization type.

Inequality constraints can be changed to equations by augmenting (adding or subtracting) the left-hand side of each constraint by a non-negative variable. These variables are called **slack variables** or **surplus variables**. Slacks variables are added if the constraints are **(≤)** type and surplus variables are subtracted if the constraints are **(≥)** type.

The right-hand side of the constraint can always be made positive whenever necessary by multiplying the resulting equation by **(-1).**

The remaining characteristics can be realized by using the elementary transformations in the canonical form. For example to illustrate the concept of slack variable, the constraint

$$a_1 X_1 + a_2 X_2 > b, \qquad b \geq 0$$

Is changed in the standard form to:

$$a_1 X_1 + a_2 X_2 - S_1 = b$$

Where

$$S_1 \geq 0.$$

Also the constraint

$$P_1 X_1 + P_2 X_2 - b \leq q, \quad q \geq 0$$

Is changed to:

$$P_1 X_1 + X_2 + S_2$$

Where

$$S_2 \geq 0$$

The standard form plays an important role in the solution of linear programming problem. Hence, the canonical form of the linear program with all (#) constraints like:

$$\textbf{Maximize} \quad X_0 = \sum_{J=1}^{n} C_j X_j$$

$$\textbf{Subject to} \quad \sum_{j=1}^{n} a_{ij} X_j \leq b_i \quad (b_i \geq 0), i = 1, 2, \ldots, m$$

$$X_j \geq 0, \; j = 1, 2, \ldots, n$$

Is expressed in the standard form as:

$$\textbf{Maximize} \quad X_0 = \sum_{J=1}^{n} C_j X_j$$

Subject to:

$$\sum_{j=1}^{n} a_{ij} X_j + S_i \leq b_i$$

$$b_i \geq 0, \quad i = 1, 2, \ldots, m$$

$$X_j \geq 0, \quad j = 1, 2, \ldots, n$$

$$S_i \geq 0, \quad i = 1, 2, \ldots, m$$

The standard form reduces the linear program to a set of inequalities in **m + n** unknowns. The solution to these equations will be interesting only if it satisfies the non-negativity requirements of $X_j \geq 0$ and $S_1 \geq 0$ for all **j and** i. The optimum solution can then be given by the feasible solution that maximizes X_0.

2.5 METHODS OF SOLVING LINEAR PROGRAMMING PROBLEMS

There are two methods of solving linear programming problems. They are:

a. The Graphical Method

b. The Simplex Method

Graphical Optimization Methods

According to Fabrycky et al. (1984), "A good introduction to the structure and nature of linear programming problems can be obtained by utilizing the graphical optimization methods although, a graphical approach is not feasible for operations with more than three activities competing for scare resources."

i. Graphical Maximization for Two Activities

When two activities compete for scarce resources, a two – dimensional space is defined with each restriction corresponding to a line on this surface.

These restrictions identify a region of feasible solutions. The effectiveness function is also a line, its **orthogonal distance** from the **origin** being proportional to its value. The optimum value of the effectiveness function occurs when it is located so that it just touches an extreme point of the **region.**

ii Graphical Maximization for Three Activities

When three activities compete for scarce resources, a three – dimensional space is defined with each constraint forming a plane in the space and all constraints together identify a volume of feasible solutions. The effectiveness function is also a plane, its orthogonal distance from the origin being proportional to its value. The optimum value for the effectiveness function occurs when this plane is located at the extreme point of the volume of feasible solutions.

Summary of the graphical procedure for maximization procedures:

a). Prepare a graph of the **Feasible Solution Point** for each of the constraints.

b). Determine the **Feasible Solution Region** of identifying the solution points that satisfy all the constraint simultaneously.

c). Draw a profit line (**iso-profit**) showing all the values of **X** and **Y** variables that yield a specified value of the objective function.

d). Move parallel profit lines towards higher profits, (away from the region until further movement would take the profit line completely outside the feasible region.

e). Determine at least approximately, the optimal values of the decision variables by reading off the values of **X** and **Y** at the optimal solution point directly from the graph.

iii Graphical Minimization for Two Activities

The objective here is to determine the product mix that will yield the minimum cost. This requires minimizing.

The set of linear constraints will define a region of feasible solutions. This region is of the **greater-than-or-equal-to** type because the problem requires minimization. There is a family of the **iso-cost** lines one of which will have at least one point in the region of feasible solutions and will have the minimum distance from origin. The member that satisfies this condition intersects the region of feasible solutions at the extreme point. Hence, there will be no lower cost than that. In addition, **no alternative optimal solution exists**.

The graphical solution procedures in a minimization problem are as listed below:

1. Prepare a graph of **Feasible Solution Point** (FSP) for each of the constraints.
2. Determine the **Feasible Solution Region** (FSR) by identifying the solution points that satisfy all the constraints simultaneously.
3. Draw a cost line **(iso-cost line)** showing all the values of **X** and **Y** variables that yield a specified value of the objective function.
4. Move parallel lines toward lower cost (usually towards the origin) until further movement will take the cost line completely outside the feasible region
5. The vertex that is touched by the lowest possible cost line is the **Optimal Solution.**
6. Determine, at least approximately, the **Optimal Values** of the decision variables by the reading off **X** and **Y** values at the **Optimal Solution Points** directly from the graph.

iv. Iso-Profit (Iso-contribution) Lines

Another way of determining the optimal solution especially using the graphical approach is the use of iso-profit lines. **Iso** means **equal.** Thus, **iso-profit lines** mean **Equal Profit Lines.**

One can observe that the profit lines are parallel to one another irrespective of the amount of the contribution. Thus, the important thing to do is to draw an iso-profit line and find the gradient (or slope) of the line. This holds for any level of contribution. We must note however, that, the further away from the origin of the graph (i.e. where **X = 0 and Y = 0**), the greater the feasible region and hence the total profit. In using the iso-profit line to determine the optimal solution, the following steps must be taken.

a. Establish the slope of the profit line. This can be achieved as described above for any given level of profit. The only significance of this is to show the slope of every contribution for the objective function;

b. Use a ruler and move it gradually rightwards as far as possible away from the origin noting carefully, the corner of the feasible region at which the farthest contribution line possible can be drawn at a tangent to the polygon representing the feasible region.

c. Use the method of simultaneous linear equations to determine the values of **X** and **Y** that will optimize the objective function.

The same principle can be applied to minimization problems. Iso – cost of a profit in much the same way. However, instead of looking for the point furthest away the origin, we look for that point of the feasible region that is closest to the origin (i.e. where **X =0 and Y = 0).** This point represents the minimum cost.

Simplex Method

This algorithm makes the numerical solution of the general linear programming problems with three activities or fewer, possible, as is the graphical optimization model. The simplex method is an iterative process that begins with a feasible solution, tests for optimality and then proceeds towards improved solution. It can be shown that the algorithm will finally lead to optimal solution, if such a solution exists. In the simplex method, reference to the graphical model to helps explain certain facets of computational procedures.

Given that:

C row = row of **Coefficients of the Objective Function**

b column = column of **Right Hand Side** values of the constraint equations

A matrix = **m** rows and **n** columns of **Coefficients Of Variables** in the constraint equation.

C row	
A matrix	**b column**
Z row	**Z**

A simplex tableau can be constructed as follows:

	C_1	C_2	.	.	.	C_n	b_I
	a_{11}	a_{12}	.	.	.	a_{1n}	b_1
	a_{21}	a_{22}	.	.	.	a_{2n}	b_2
	.	.	.	.	.	.	.
	.	.	.	.	.	.	.
	.	.	.	.	.	.	.
	a_{m1}	a_{m2}	.	.	.	a_{mn}	b_n
$Z_j = \sum_{i=1}^{n} C_{n+i} b_i$	$Z_j = \sum_{i=1}^{n} C_{n+j} a_{ij}$						Z
ΔZ	$C_j - Z_j$						

The typical format of a simplex tableau.

In order to prepare a linear program for solution by the simplex method, the following steps will be taken.

1. Formulate a linear programming model of the real world problem and obtain a mathematical representation of the problem.
2. Define an equivalent linear program by:
   a. Multiplying negative right-hand side of the constraints by (-1) and changing the direction of the inequalities.
   b. If it is a minimization problem, change to maximization.
3. Set up the standard form representation of the linear program i.e. change all the inequality signs to equality signs.
4. Set up the initial tableau form/representation of the linear program.
5. Set up the initial simplex tableau.
6. Choose the variables with the largest $\mathbf{C_j - Z_j}$ row value to introduce into the basis.
7. Compute the $\mathbf{b_i/a_{ij}}$ ratios for $\mathbf{a_{ij} > 0}$ and choose the row with the smallest ratio. This is the pivot row. It tells us the variables to leave the basis when $\mathbf{X_j}$ enters.
8. Perform the necessary row operations to convert **column j** to a **unit column**.
   a. Multiply the **pivot row** by the constraint necessary to make the pivot element **1**.
   b. Obtain **zeros** in all the other rows by multiplying the new pivot row by an appropriate constraint and adding it to the appropriate row.
9. Test tableau for optimality. If $\mathbf{C_j - Z_j \leq 0}$ for all columns, we have the optimal solution. Else, return to step (6).

2.6 PRIMAL AND DUAL PROBLEMS

Lucey (1992) gives a more straightforward explanation on dual and primal problems. He asserts thus, "Every linear programming problem has an equal but opposite formulation. For every maximizing problem, there is an equal but opposite minimizing problem and for every minimizing problem, there is an equal but opposite maximizing problem". This means that either of the formulations can be used to obtain the same result. For this purpose, the original formulation is called the **primal problem,** while the equal but opposite formulation in called the **dual problem** or the ***inverse***.

Dual formulation is mostly required when there is the need to solve a particular minimization problem using the simplex method (although simplex method goes for both minimization and maximization problems). The simplex method is a more straight forward and convenient process. It is therefore necessary to convert a minimizing problem to a maximizing one and solve the resulting dual problem by the simplex method.

The following observations can be made from the **dual formulation** of the problem.

a. The **original quantity column** is now the **objective function.**

b. The **original costs** have become the **maximum values** of the constraints.

c. The constraints formats have changed from the **greater - than or – equal - to** type **to less - than-or -equal – to** type.

We can then solve the dual problem using the normal simplex method.

2.7 SHADOW PRICES

Shadow price of a resource, according to Lucey (1992) refers to the opportunity cost of that resource.

It is the increase in the value of the objective function resulting from the availability of one more unit of the scarce resource.

Shadow prices can guide managers into deciding the cost of relaxing the existing constraints but this will only apply in situations where changes are relatively small. Where changes will be of significant magnitude, it will be necessary to resolve the problem using the new shadow prices and the revised resource levels.

It is worth noting at this point that a constraint can only have a shadow price when it is binding. This is true because it will be out of place to increase the amount of a resource of which there is already a surplus. Thus, where a resource is not fully utilized, shadow price is zero. However, the shadow price of the binding constraint can be used to prove the contribution.

Calculating Shadow Prices

The simplex method produces the shadow prices as automatic by – product. However, when the graphical method is used especially with two (2) unknowns, shadows prices must be calculated because the graph does not provide any information about shadow prices.

Again, since every primal problem has a dual. The dual formulation of a primal problem also gives the shadow prices. So, for a two – variable problem, all that is required is the formulation of the dual problem and the simultaneous solution of the resulting equations.

The calculation of shadow or dual prices is based on the assumption that there is a marginal increase or decrease in the availability of one scarce resource, but with the availability of other resources and demand being held constant.

2.8 SENSITIVITY OR POST OPTIMALITY ANALYSIS (Taha's Model)

Having obtained the optimal solution to a linear programming problem, it is sometimes necessary to evaluate the effects of discrete changes in the different coefficients of the problem on the current optimal solution.

This may be achieved by solving the problem afresh, but may involve many computations. However, one can take advantage of the properties of the simplex method and considerably reduce the computations involved. The aim of post optimality analysis therefore is to find out what happens to the optimal solution if any of the coefficients of the linear program changes.

Some of the changes studied by this analysis include:

a. The tightness of the constraint, that is, changes in the right-hand values of the constraints.

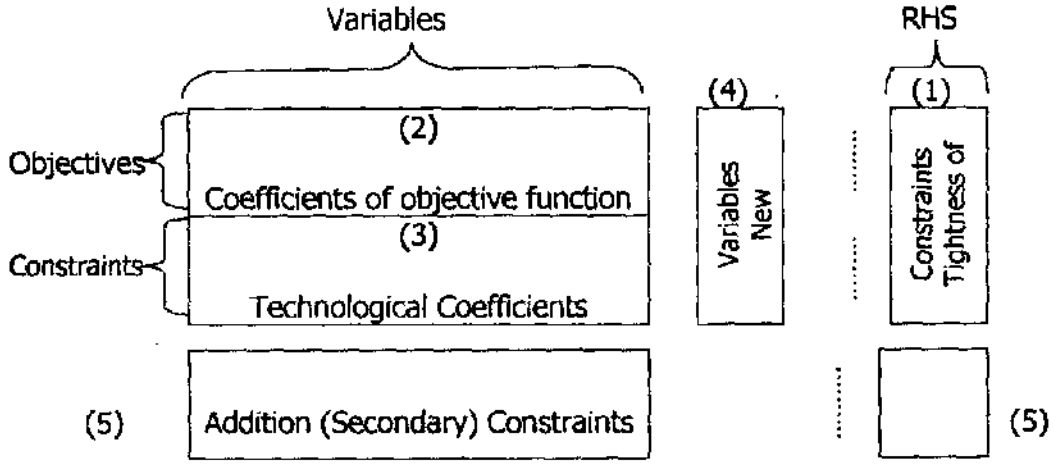
b. The coefficient of the objective function (profit or cost).

c. The technological coefficients of decision variables.

d. The addition of new variables to the problem.

e. The addition of new constraints i.e. secondary constraints.

This can be schematically represented thus:



Taha's Schematic representation of sensitivity analysis

Source: Taha (1976: 100)

According to Taha (1976), these changes may, generally speaking, result in one of three cases:

1. The optimal solution remains unchanged.
2. The basic variables remain the same but their values are changed.
3. The basic solution changes completely.

The detection of these cases by the sensitivity analysis rests solely on the primal-dual properties of a linear program. A study of these properties shows that:

1. Changes in the tightness of the constraints in the primal (dual) can only affect the feasibility of the primal (dual) or equivalently, the optimality of the dual (primal).

   This means that for any change to the right hand side of the constraints, the solution will remain basic and feasible as long as the changes in the resources concerned will increase the value of the objective function.

   This resource should be increased in order to achieve the largest marginal increase in objective function. This means that as long the change in the resource will cause the value of the objective function to experience a positive change, the solution remains feasible. (That is, change is > 0) otherwise the solution becomes infeasible (that is, change is < 0) because it will decrease the objective function value.

2. Changes in the objective coefficients in the primal (dual) can only affect the optimality of the primal (dual) or equivalently, the feasibility of the dual (primal). Here differentiation must be made between basic and non-basic coefficients.

   In the case of basic coefficients, the simplex multipliers (dual values) depend on the coefficients of the basic variable in the objective function.

Thus for optimality to be maintained, new simplex multipliers must be established that will yield a new objective equation with all the left-hand side coefficients satisfying the conditions for optimality.

In the case of non-basic coefficients, the simplex multipliers are independent (do not change) of the changes in coefficients of the objective function. Hence, the available multipliers can be used to check optimality directly by checking the feasibility of the corresponding dual constraints with their right-hand side values changed to the new values.

However, simultaneous changes in both basic and non-basic coefficients can be handled by first finding new multipliers, and checking the coefficients of the starting basic variable in the objective function for non-optimality and second, by checking the new dual constraints for feasibility.

This combined effect of basic and non-basic changes may lead, in general, to a completely different solution.

4. Changes in the technological coefficients of a problem can affect the left-hand side of its dual constraints and hence the feasibility of the dual (or equivalently, the optimality of the primal). The issue here is that if the technological coefficient of a basic variable changes, it will directly affect the matrix elements in the initial solution and since this matrix plays an important role in all sensitivity analysis computations, the new changes may make the current solution infeasible or non-optimal. It may even cease to be basic. Except for a few cases, such problems make the systematic consideration of the effects of changes in the technological coefficients of basic variables on the optimal solution difficult and even in the few special cases; the analysis does not provide ready information about the feasibility or optimality of the new problem. Hence, only the changes in the technological coefficients of non-basic variables are normally considered.

5. When a new variable is added to the problem, it has the same effect as that of looking at simultaneous changes in coefficients of the objective function and the changes in the technological coefficients of a non-basic variable, which were all initially equal to zero. Therefore, the addition of a new variable can only affect the optimality of the problem and the new variable will come into the solution if and only if it improves the objective function value. Otherwise, the new variable becomes non-basic at zero level.

6. Addition of a new constraint can affect the feasibility of the current optimal solution only if it is active or binding on the optimal solution. Thus it becomes necessary to check whether or not the new constraint is satisfied by the current optimal solution. If it is satisfied, then the new constraint is **redundant** and the optimal solution is unchanged otherwise the new constraint must be added.

   The use of this test in sensitivity analysis is to be found in the fact that treating additional constraints can be tedious. It is therefore only reasonable to drop the constraints that appear redundant since the computational effort is a function of the number of constraints. Working with fewer constraints leads to a quicker arrival at optimal solution. After this, one can test the optimal solution if the deleted constraints will affect the feasibility to the optimal solution. These constraints are called **secondary constraints.**

These remarks provide the key ideas in post optimality analyses of linear programming problems.

2.9 SPECIAL CASES OF LINEAR PROGRAMMING

Degeneracy

The rule for determining the variable to leave the basis under the simplex method specifies that the variable that will leave the basis is the one that binds or restricts the solution.

However, when there is a tie, the variable that corresponds to one of the binding constraints should be removed. Under certain circumstances however, the wrong variable may be removed and this will cause the algorithm to go round the same loop indefinitely with the same variable coming into and leaving the basis. The effect of this is that the optimal solution will never be reached. This condition is known as **Degeneracy**. Fortunately, this problem rarely occurs in practice. Thus, it is easy to ignore it under theoretical conditions. This does not pose any particular problem in the graphical approach. But in the simplex method, a degenerate situation can be recognized by the presence of zero values in the basic solution.

Multiple Solutions (Alternate Optimal Solutions)

When a linear program has two or more optimal solutions, it is said to have **'attenuate optima'** (a multiple solution). This can be recognized in the graphical method when the objective function line (iso-profit or iso-cost line) is parallel to one of the binding constraints. In the simplex tableau however, alternate optimal solutions can be recognized when the net evaluation row has zero value for one or more of the variables not in the solution.

This means such a variable can be brought into the solution without changing the value of the objective function. In such a situation, it may become possible to maximize a second objective function and even more. Thus, there may be infinitely many solutions to a linear programming problem.

No Feasible Solution

When using the **Big M Method**, it may happen that there is no way to get rid of an **artificial variable**. This shows that there is no feasible solution to the real problem and that the model does, probably, not fit into reality. Hence, the error in the formulation must be corrected. In this situation, the infeasibility is recognized by the fact that the solution to the problem does not satisfy all the constraints and non-negativity conditions simultaneously. Graphically, this case is recognized by the **absence of a feasible region**.

Unbounded Solutions

For maximization problems, it may happen that the value of the solution may become infinitely large without violating any of the constraints. Hence, a variable can be introduced into the solution and increase in value indefinitely without any variable leaving. This situation is called **unboundedness**. This may be recognized, from a graphical point of view, when the **feasible region extends to infinity in one direction**. The simplex tableau in its own case shows that **all the a_{ij} are ≤ 0 in column j**, and the simplex method indicates that variable X_j is to be brought into the solution. The result is that there will be no upper limit to the value of the objective function.

In reality, this type of problem does not occur in cost minimization or profit maximization problems because it is not possible to reduce cost to minus infinity ($-\infty$) and it also not possible to increase profit to plus infinity ($+\infty$). Therefore, if this type of problem occurs, it means again that the model does not fit into reality and the error in the formulation must be corrected.

2.10 SPECIAL LINEAR PROGRAMMING MODELS (Special Forms of Linear Programming)

In this section, the models of goal, transportation, assignment, and transhipment problems are developed. These linear programming models are singled out for special treatment because of their important applications in various types of practical situations.

1. Goal Programming Models

Linear Programming models are limited to a single objective that is maximization or minimization. However, managers sometimes face the situations, which require the achievement of more than one objective.

Goal programming has been developed as a procedure for handling multiple objective situations within the general framework of linear programming. A problem formulation permits the solution of the basic goal problem as an ordinary linear program. Also developed are the extensions of the basic model to accommodate pre-emptive priorities. Each objective is seen as a goal. Then managers attempt to develop decisions that provide the best solution in terms of coming as close as possible to the goal based on the usual resource limitations. The characteristics of goal programming models can be summarized as follows:

a. Each goal appears in a separate constraint with the right-hand side value corresponding to the target value of the goal.

b. Deviation variable d_i^+ and d_i^- are included for each goal to reflect the possible over-achievement or under-achievement of the goal.

c. Other constraints, reflecting source capacities or other restrictions, are included just as they would be in any linear programming model.

d. The objective function requires maximizing the weighted sum of the deviation variables where the weights (coefficients) for the deviation variables in the objective function show the relative cost or penalty for each unit deviation from the corresponding target goal's value.

The linear programming model formulation with **m** goals.

$$\textbf{Minimize} \sum_i \sum_k P_k \quad (W_i^-, {}_k\, d_i^- + W_i^+, {}_k\, d_i^+)$$

Subject to Linear Constraints

$$\sum_j a_{ij} X_j + d_i^- - d_i^+ = b_i \qquad i = 1, 2, \ldots, m$$

$$X_j, d_i^-, d_i^+ \geq 0$$

Where:

P_k = ranking coefficient for all deviations having the kth priority of being avoided.

$W_{i,k}^{-}$ = relative weight of the d_i^- in the kth rank.

$W_i^{+}{}_{,k}$ = relative weight of the di^+ in the kth rank.

d_i^+ = Positive deviation from the ith goal (over achievement)

d_i^- = negative deviation from the ith goal (under achievement)

a_{ij} = the amount of i that must be allocate to each unit of j.

b_i = amount of resource i available.

X_j = variable of the jth activity

m = No of goals to be achieved.

2. Transportation Models

Transportation problems arise frequently in planning for the distribution of goods and services from several supply locations to several demand locations. Usually, the quantity of goods available at each location **(origin)** is fixed, and there is a specified order quaintly (demand) at each user's location **(destination)**. Given a number of shipping routes and differing associated costs, the objective is to determine the number of units that will be shipped from each origin to each destination, such that all destinations demands are satisfied fully at the **lowest possible cost**. However, variations of the basic transportation model may involve one or more of the following.

a. Total supply, not being equal to total demand.

b. Maximization objective function rather than minimization

c. Constraints on specific routes, such as route capacities or route minimum shipment guarantees.

d. Unacceptable routes.

However, with slight modification in the linear programming model, these situations can be taken into consideration in arriving at the optimal solution to the transportation problem.

The general definition of the transportation problem may be given as follows:

Given **m – origins** and **n – destinations**, the transportation problem is given as follows:

Minimize:

$$\sum_{j=1}^{m}\sum_{j=1}^{n} C_{ij}\, X_{ij}$$

Subject to:

$$\sum_{j=1}^{n} X_{ij} = a_i, \quad i = 1, 2, \ldots, m \quad (S_i)$$

$$\sum_{i=1}^{m} X_{ij} = b_j, \quad j = 1, 2, \ldots, n \quad (D_j)$$

$$X_{ij} > 0 \text{ for all } i \text{ and } j$$

Where **i = Index for origins** **i = 1,2... , m**

j = Index for destinations **j = 1,2 ..., n**

X_{ij} = **Number of unit shipped from origin i to destination j**

C_{ij} = **Cost per unit shipping from origin i to destination j**

S_i = **Supply or capacity in units at origin i**

D_j = **Demand in units at destination j**

3. Assignment Models

Assignments problems arise in a variety of decision-making situations. This may involve the assignment of jobs to machines or assigning workers to tasks or projects, Sales Personnel to territories, contracts to bidders and so on. A major characteristic of the assignment problem is that only one job is assigned to one machine, one worker to one project and so on. Thus, we specifically look for the assignment decisions that will optimize a stated objective such as minimization of time or cost or the maximization of profits.

It is important to note at this point that the assignment problem is very similar to the transportation problem in many ways and can in fact be treated as one special case of the transportation problem where all the **supplies and demands are equal to 1**. For this reason, all the special considerations that apply to transportation problems also apply to assignment problems.

In assignment problems, the alternatives are stated in terms of profit or revenue, rather than time or cost. The linear formulation can be solved then as a maximization problem and if one or more of the assignments are unacceptable, the corresponding decision variable can be removed from the linear program. An example of this is when a project leader does not have the experience required fro one or more of the client assignments.

Given **m – objectives** and **n – tasks**, if X_{ij} is set equal to 1 or 0 according to whether object **i** is assigned to task **j** or not and C_{ij} is the cost of assigning object **i** to task **j**, then the general assignment problem can be defined as follows:

$$\textbf{Minimize} \quad X_o = \sum_{j=1}^{m}\sum_{j=1}^{n} C_{ij}\, X_{ij}$$

Subject to:

$$\sum_{j=1}^{n} X_{ij} = 1, \quad i = 1,2,\ldots, m$$

$$\sum_{j=1}^{m} X_{ij} = 1, \quad j = 1, 2 \ldots n$$

or more specifically, X_{ij} **= 0 or 1 for all i and j**

If the number of tasks, **n,** exceeds the number of objectives, **m**, (that is demand exceeds supply), a ***dummy object*** with a capacity of $n - m$ must be added in order to obtain the optimal solution.

4. Transhipment Models

Situations do arise where it is uneconomical to ship directly from source to destinations. Thus, the commodity may have to pass through other sources and destinations before eventually getting to its destination. This case is known as the transhipment problem. This problem cannot be handled directly by the transportation model. However, slight modifications will permit the use of the same technique.

The underlying principle here is that **intermediate nodes** are added to account for locations such as warehouse where goods can be temporarily stored before being shipped to their destinations. Therefore, in this more general type of distribution problem, shipments can take place between any pair of three general types of nodes, which are origin nodes, transhipment (intermediate) nodes and destination nodes. For instance, shipment can take place from one origin to another origin, from one transhipment location to another and from one destination to another.

Also in the transhipment problem, the quantity goods available at each supply location (origin) is fixed or limited. In addition, demands are known or fixed. The objective of the transhipment problem therefore, is to determine the number of units that should be shipped from one location to another in order to satisfy all destinations demands at the lowest cost. The general definition of the transhipment model is similar to that of the transportation model defined earlier.

2.11 LINEAR PROGRAMMING AND COMPUTERS

Computer programs designed to solve linear programming problems have been released and are now widely available on the market. Most large companies and tertiary institutions have access to these computer programs the most popular of which is the **LINDO** (an acronym for **Linear Interactive and Discrete Optimizer**) developed by Linus E. Schrage of the University of Chicago. This package allows the user to interact with the computer in a controversial mode. It is available in versions that can be used on large mainframe computers as well as on personal computers. Other packages for solving linear programming problems include Microsoft Excel, Corel Quattro Pro, Quantitative Methods and TORA Optimization Systems.

The development effort for these software packages has come primarily from computer manufacturers and/or software service companies. All the packages are available for sale or lease and users need only a very short period to familiarize themselves with the specific features of the package in order to be able to solve their linear programming problems. Today, problems involving thousands of constraints and variables can be solved routinely with many computer packages. In actual sense, the much larger linear programs take a few minutes while the smaller ones come with optimal solutions in a matter of seconds.

2.12 IMPORTANCE OF LINEAR PROGRAMMING: (APPLICATIONS)

This study is concerned with obtaining major ideas about linear programming as a tool for the allocation of scarce resources and the methodology it employs. For the ideas conveyed herein to be meaningful however, efforts will have to be made to learn the methodology. The purpose of this section of the study is to show some selected real world decision-making problems that have been formulated and solved using Linear programming. In practice, linear program has proved to be one of the most successful quantitative aids for managerial decision-making. Numerous applications have been reported in the chemical, airline, steel paper, petroleum, and other industries.

The specific problems studied include production scheduling, capital budgeting, plant location, transportation, media selection and many others. As may be suggested from above, linear programming is a flexible problem – solving tool with applications in many disciplines, which include marketing, finance, accounting and management, as well as the standard linear programming applications in blending and diet problems. In addition, an application involving environmental protection is presented.

1. FINANCIAL APPLICATIONS

a. Portfolio Selection:

The financial manager must select specific investments (e.g. bonds or stocks) from a variety of investment alternatives in this financial management problem. This is often the problem encountered by managers of mutual funds, credit unions, insurance companies, and banks. The objective function for these types of problems is usually the maximization of expected returns or minimization of risk, while the constraints usually take the form of restrictions on the type of permissible investments, state laws, company policy maximum risk allowed etc. Similar problems have been formulated and solved using a variety of mathematical programming techniques. However, where it is possible to formulate a linear objective function and linear constants, then linear programming can be used. A good case in point is Welte Mutual Funds Inc., New York City, U.S.A. This Fund has been able to use linear programming to provide investment recommendations for the management of the Fund that shows how funds are divided among investment opportunities (securities) while at the same time giving the projected annual rate of return. Welte Mutual Funds' top financial analyst had earlier recommended that all new investments should be made in the oil industry, steel industry, or government bonds. (Anderson et al, 1986).

b. Financial Mix Strategy

This involves the selection of means for financing company projects, inventories, production operations and various other activities. Here, a decision must be made, for example, as to how much production is to be supported by internally generated funds and how much with external funds. (Bhaskar, 1978).

Here, we show how linear programming has been used to solve this type of problem. The Jefferson Adding Machine Company, U.S.A. was to begin the production of two models of electronic adding machines and had set a 3-month time horizon. Because it would have to expand the current production operation, secure operating funds to cover material, labour, and selling expenses at the initial production period. Revenue would not be available until the end of the period. Thus the company must arrange financing for these operating expenses before production could start.

The result was a four-variable, seven-constraint linear program, which has alternate optimal solutions either of which management could implement. The company was able to know the appropriate proportions of internal and external funds to use in financing the operation. (Anderson, et al, 1986).

2. MARKETING APPLICATIONS

a. Media Selection:

The application of linear programming in this case, is aimed at helping marketing managers allocate the fixed advertising budget across the various media.

The media may include Newspapers, Magazines, Radio commercials, television commercials, direct mailing, etc. The objective is to maximise the audience exposure while constraints take the form of allowable allocation, company policy, contact requirements, and media availability.

A good case in point is Relax-and-Enjoy Lake Development Corporation. This company wants to develop a lakeside community at a privately owned lake and sells property for vacation and/or retreat cottages to middle and upper income families. Relax and Enjoy had engaged an advertising company, Boone, Philips, and Jackson to design the promotional campaign for the project. After due consideration of the costs, market coverage and possible advertising media, the firm had restricted the first months advertising to five sources. This resulted in the formulation of a five-variable, nine-constraint linear program. The result was a rough approximation of the best decision which, when combined with management evaluation, bought about the selection of an overall effective advertising strategy. (Gass, 1970).

b. Marketing Strategy:

This usually involves the optimal allocation of sales force and advertising effort. Here, the objective is to maximise profit or sales. A case for illustration is that of Electronic Communications Inc., a manufacturer of a two-way communication radio system. The company's profit and cost vary according to the distribution alternatives. Production and sales also vary according to order. The company's management wants at least 100 units distributed throughout the discount stores in the next three months. Advertising budget was $5000 and a maximum of 1200 sales force time would be available. Production capacity was 600 units.

Formulating a three- variable, four- constraint linear program solved this problem. With that management as able to establish a profitable marketing strategy. (Gass, 1970)

3. MANAGEMENT APPLICATIONS

a. Production Scheduling

This involves the determination of the production levels that will allow the company to meet product demand requirements, given limitations on production capacity, labour capacity, and storage space. The aim may be the minimization of the total cost of carrying the task. This will enable the manager to establish an efficient low-cost production schedule for one or more products over several time periods such as weeks, months and so on.

Ballinger Electronics Company is a company that has constantly applied linear programming to scheduling its production. It produces two different electronic components for a major airplane engine manufacturer. The order for these components comes every three months. With the application of linear programming, Ballinger Electronics has been able to develop a program for solving the problem for each recurring period. The idea is that a linear program will have many applications (Gass, 1970).

b. Labour Planning

Problems occur when managers face the problem of deciding departmental staffing requirements for a given period. This is particularly true where labour assignment is flexible and some labour efforts can be assigned to more than one job. In this case, linear programming can be used to determine both optimal product mix and optimal labour allocation for various departments.

The case of McCastly's Everyday Glass Company is a good illustration. This company was able to use linear programming to solve the normal product mix problem for its planning period and allocate the total labour resource to all its departments in such a way that profits were maximized using a 6-variable, 10-constraint linear program. (Anderson et al, 1986).

3. ACCOUNTING APPLICATIONS

a. Audit Staff Assignments

One common faced by small and large audit firms is the effective utilization of work- force resources. It is often difficult to keep all employees engaged in productive assignments at certain times of the year because there is often more work to do than there are people to do them. The objective here is to develop an efficient auditor – client schedule for the staff. That is to minimize the total hour requirements. A case in point is that of a Certified Public Accounting Firm of Scott and Warner who just had three new clients: Cincinnati Drugs; Pruitt Trucking and Storm Foods, all in the USA.

The firm had wished to take the new clients even though the current audit staff is already overloaded. A review of the current audit progress report showed there were four senior accountants who could be assigned to supervise the new clients. However, because each was busy, he could not accommodate more than one client at the most. To solve this problem, a 12- variable, 7-constraint linear program was formulated and with that, the firm was able to provide the auditor assignment plan that minimized the total number of staff hours expended. (Summers, 1972).

4. INGREDIENT MIX APPLICATIONS

a. The Blending Problem

This problem usually occurs in the petroleum industry (e.g. blending of crude oil to produce different octane gasoline); chemical industry (e.g. blending of chemicals to produce fertilizers, weed killers, etc) and food industry (e.g. blending input ingredients to produce soft drinks, food, etc). In these situations, the resources contain one or more essential ingredients that must be blended in such a way that the final products will contain specific percentages of the essential ingredients. Thus, the manager must decide how much of each specifications and product demand at minimum cost.

Beauty Suds Incorporated is a manufacturer of Wonderful Hair Shampoo and wished to introduce a new product, Wonderful Plus Hair Shampoo, which is a blend of the company's standard shampoo, base product, a new dandruff preventive, a perfume and deionised water. Having specified the characteristics of the final product per gallon, a four-variable, eight-constraint linear program was formulated to solve the problem. At last, Beauty Suds was able to know the way of blending the available resources to meet the product specifications and determine the exact cost of doing so, (Anderson et al, 1986).

b. The Diet Problem

This is similar to and is the general case of the blending problem (as seen above). Here the objective is to specify a food or feed ingredient combination that will satisfy some minimal nutritional requirements at a minimum total cost. An example of this is the case of Bluegrass Farms Inc. in Lexington, Kentucky (Anderson et. al, 1986).

Bluegrass wanted to experiment with a special diet for its racehorses. The components available were a standard horse feed product; a vitamin-enriched oat product; and a new vitamin and mineral feed additive. Having set out the diet characteristics, a 3-variable, 4-constraint linear program was formulated and solved to give the management an idea about the component mix and the associated total cost

5. ENVIRONMENTAL PROTECTION APPLICATION

Here linear programming is seen as applied to the problems faced in the areas of health care, environmental protection and a variety of other problems. A good case in point is the problem faced by Skillings Industrial Chemicals Inc., a refinery located in South Western Ohio, near the Ohio River. (Anderson, et al, 1986). Skillings has been producing a liquid waste, which it dumps directly into the Ohio River, and a recent governmental pollution guideline released by the Environmental Protection Agency would now allow the dumping to continue. The company wishes to establish a most profitable production and pollution control plan by choosing from among three alternatives. The objective was later achieved by the formulation and solution of a 4-variable, 3-constraint linear program.

6. OTHER MISCELLANEOUS APPLICATIONS

Linear programming has been applied in many other areas of human endeavour. As outlined by Taha (1976), these areas include.

a. **Trim Loss Problems**: In which paper mills use the linear programming models to determine the production schedule and cutting pattern that minimizes the trim loss while satisfying a given demand.

The model is also readily applicable to similar problems in Saw Mills where orders are filled by sawing of standard logs to desired lengths.

b. **Water – Quality Management:** In a situation where it is desired to maintain a minimum level of stream quality so that pollution can be controlled effectively, linear programming can be used to determine the optimum treatment efficiency of each treatment plant involved in the water treatment project that will minimize the total treatment costs and still meet the stream quality standard. This is especially so when the cost of treatment is directly proportional to the treatment efficiency of plant.

c. **Assembly Balancing:** Where many departments are involved in a production process that allows each department to use a different method for manufacturing components with the requirements and other parameters specified, a linear programming model can be used to determine the number of production runs for each department which will maximize the total number of complete units of the final product.

d. **Inventory Control:** In manufacturing, it is sometimes possible to produce more than the required quantity in a given period and the surplus will be carried forward to meet the demand for one or more succeeding periods. If shortages are not allowed in any period, it means all period demands must be met. Whatever it is, an inventory holding cost will be incurred for all units held over to the next period. For determining the optimal production schedule such that the total cost of the production inventory system is minimized, linear programming model is again recommended.

e. **Marketing Plan:** Marathon Oil Company, Ohio, USA has successfully applied linear programming to its marketing plan problem. The model used was a combination of a blending model and a transportation model. The result was the optimization of the gasoline blend for each refinery and the accomplishment of the gasoline demand structure. In the final analysis, Marathon Oil Company was able to minimize the cost of meeting a given demand structure, taking into account sales price, pipeline tariffs exchange contract costs. Product demand, terminal-operating costs, refining costs and product purchases with a linear programming Matrix size of approximately 1800 rows by 6000 columns! (Anderson, et al, 1986).

f. **Setting Performance Goals:** McKenna Office Supplies Inc. has been able to use linear goal programming to establish monthly performance quota for its sales force. (Weingartner, 1974).

g. **Transportation (Distribution) of Goods:** Forster Generators Inc. U.S.A. is a good example of a company that has successfully used linear programming models to plan the distribution and transportation of its generators from its 3 plants (Cleveland, Bedford and York) to its 4 warehouses (Boston, Chicago, St. Louis and Lexington). This objective was achieved by the formulation of a 12-variable, 7-constraint linear program taking into account, the unit transportation cost from the plants to the warehouses, the plants and warehouse capacities. The result was the minimization of transportation cost associated with the optimal transportation schedule. (Anderson et al, 1986).

h. **Transhipment Problem:** Unlike transportation problems, transhipment problems allow intermediate modes (or transhipment modes). Ryan Electronics, Inc. another U.S.A Company has been able to use linear programming to solve its transhipment problems. With the costs, requirements and capacities specified. Ryan was able to ship final products from its plants located in Denver and Atlanta to it regional warehouses in Kansas City and Louisville from where they are taken to the retail outlets in Detroit Miami, Dallas and New Orleans by formulating a 12-variable, 8-constraint linear program in order to achieve the optimal transhipment arrangement.

OTHER USES OF LINEAR PROGRAMMING

Drury (1992) explores the uses of linear programming in management accounting. According to him, linear programming can be used in the following areas:

a. **Calculation of relevant costs:** Relevant cost is necessary for decision-making, when a resource is scarce there will be alternative uses of that resource that will yield contribution and thus, an opportunity cost is incurred. The relevant cost is given as:

Acquisition Cost of Resource + Opportunity Cost

When more than one scarce resource is used, the opportunity cost will be established using linear programming.

b. **Selling different products:** If a company is willing to sell a modified version of a product, it must decide whether to manufacture it or not. The conventional accounting information does not provide the information needed for the decision because the new product can only be made if we restrict the output of other products due to the input constraints and the opportunity cost of releasing the scarce resource to the new product must be calculated. This is only possible with linear programming.

c. **Maximum payment for additional scarce resources:** The opportunity cost determined through linear programming provides additional important for companies wishing to obtain additional scarce resources although at a premium.

d. **Control:** Opportunity costs are important for cost control and standard costing can be improved by building opportunity costs into variance calculations. This process will highlight the true costs of the inefficient usage of scarce resources and encourage managers to pay special attention to the control of scarce factors of production especially the firm has adopted the **Optimized Production Technology (OPT)** approach.

e. **Transfer Pricing:** Linear programming can also be used to determine the correct transfer price when goods are transferred between the divisions of the same company.

f. **Sensitivity Analysis:** Opportunity costs are important to management decisions but productions constraints are not permanent. Hence, opportunity costs are not permanent. There is therefore the need to determine the range over which the opportunity cost applies for each group. The final matrix of the linear program readily provides the information.

2.13 PROBLEMS/LIMITATIONS OF LINEAR PROGRAMMING

Linear programming models, according to Taha (1976) are the simplest and most efficient models from a computational point of view. It is however limited in the following areas as observed by the several authors on the subject.

1. **The Objective Function:** The models illustrate either the maximization or minimization of some function. The units of the objective function are not necessarily in Naira terms. They may represent other quantities e.g. final assembly units etc.

In addition, linear programming can only maximize or minimize one function at a time. In other words, it is not possible to minimize a function and maximize another function at the same time with a linear program. (Deam et al, 1975).

2. **Linearity Assumption:** Linear programming makes uses of linear approximations, which means that the objective function assumes a constant contribution per unit of output, irrespective of the level of activity. However, in real life situations, strict linearity does not exist. The mathematical model is only an abstract representation of reality and one of those evils that analysts must accept and live with. (Johnston, 1972).

3. **Simplicity:** Linear programming models are simple and efficient models for computational purposes. In practice, models are likely to be far more complex. They can be large having thousands of variables and constraints. The Marathon Oil Company model is a good example. (Baumol, 1977).

4. **Non-Negativity Constraint:** Linear programming models require all variables to be non-negative. Real situations however, exist where the variable may be free or unrestricted in sign. Typical examples may occur in which the variable $Z_i = X_i - X_i - 1$ could be positive, zero or negative since it represents the increase, no change or decrease in the amount X_i produced in period **i** relative to the amount $X_i - 1$ produced in period $X_i - 1$. (Taha, 1976).

5. **Integers:** The physical properties of the problem usually require that the values of the variables be integers. However, a linear programming solution is not guaranteed to be integer except in special cases. The only remedy for this problem is to round the continuous optimum solution and this is acceptable only if the optimum values of the variables are large. (Carsberg 1979).

6. **Iteration:** Most linear programming models require long processes for their solutions. Much of these processes is repetitive in nature and makes it boring and cumbersome. This problem can however, be overcome with the use of computers especially where models are very large and complex.

7. **Complexity:** Obtaining solutions to linear programming models involve a great deal of complex calculations especially when the simplex method is used. It is doubtful if it can be understood or comprehended by non-accountants or non-engineers let alone illiterates. The use of computers can however overcome this problem.

2.14 RESOURCE ALLOCATION

Resource allocation deals with the commitment and distribution of resources. When the management of an organization draws up a strategic plan, it becomes the hopes and aspirations of the management. The implementation of that plan will make room for the creations of the necessary infrastructure that will enable them actualize the plan. However, nothing really happens until resources are procured and allocated to tasks for the achievement of the organization's objectives. Thus, resource allocation deals with the procurement and commitment of financial, human, and physical resources to strategic tasks for the achievement of the firm's goals.

Resource allocation is both a one time and a continuous process. Resources will be needed for a new project. In addition, an on-going project will need resources periodically. Hence, the implementation of a strategic plan will involve both types of resource allocation.

2.15 PROCUREMENT OF RESOURCES

Different types of resources – financial, physical and human are derived from different sources. Kazmi (1992) explores these sources and submits thus.

"Finance is generally considered to be the primary source; it is used for the creation and maintenance of other resources". According to him,

> *Finance is both short-term and long-term. Long-term finance is needed for the creation of capital assets while short-term finance is for working capital. Both can be from internal and external sources and each has its own problems and benefits. Internal sources include depreciation; retained earnings etc. while external sources include equity and loans. A firm will generally prefer internal sources but much depends on the management policy.*

The procurement of financial resources facilitates the procurement of physical and human resources. Sources include local and international markets.

Procurement of long-term finance may involve the Capital Market through the Stock Exchange and/or the Securities and Exchange Commission while the Commercial Banks are the main providers of short-term finances.

Once the resources are procured, management proceed to implement their plans.

2.16 APPROACHES TO RESOURCE ALLOCATION

The main instrument that guides the allocation of resources is the budget. Kazmi (1992) identifies the three approaches to allocation of resources as follows:

a. **Top-Down Approach:** Here, resources are distributed down the levels through a process of segregation. That is the corporate management decides requirements and distributes resources accordingly. This is common to the entrepreneurial mode of strategy implementation.

b. **Bottom-Up Approach:** Here, resources are allocated after a process of aggregation from the operational level.

c. **Strategic Budgeting:** This is a mix of the first two approaches and involves an iterative form of decision making between different levels of management.

2.17 MEANS OF RESOURCE ALLOCATION

There are four (4) basic means of resource allocation. Kazmi (1992) identifies these as follows:

a. ***Strategic Budgeting:*** Budgeting is a common technique employed by management for the purpose of planning, coordination, and control. Here, the difference lies in the way budgeting exercise is done in an iterative manner between different management levels and the assumptions made before the formulation of the budget. In this case, position papers are prepared on different aspects such as environment, distinctive competence, marketing, past performance etc., presented to the top management for the formulation of policy guidelines, and stating long- and short-term objectives. Meanwhile, the operating management prepares operational plans and sets targets, which are coordinated with corporate objectives through the executive management. Based on resource availability and corporate guidelines, the executive management prepares the strategic budget and presents it to the top management for approval. The budget is then communicated down wards where resources are then allocated for task implementation.

b. **Boston Consulting Group (BCG) Based Budgeting:** the BCG Matrix can also be used for resource allocation. In the BCG Matrix, Four Strategic Business Units (SBU's) are identified as **stars, question marks, cash cows, and dogs**. For the purpose of this study these SBU's are explained as follows:

- **Stars** are high-growth – high-market share businesses, which may or may not have sufficient cash flows. This corresponds to the growth stage of the product life cycle.

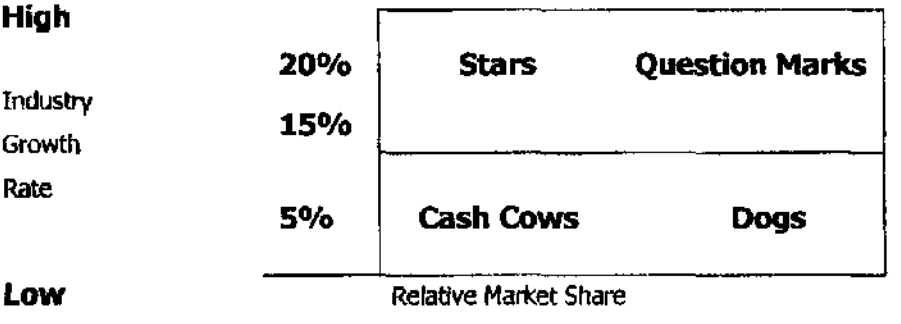
- **Question Marks** are businesses with high industry growth but low market share. They are usually new products or services, which require large amounts of cash to maintain or gain market share.

- **Cash Cows** are businesses, which generate large amounts of cash, but their growth rate is slow. They are generally mature products or businesses, which are reaping the benefits of experience curve.

- **Dogs** are businesses, which are related to slow growth industry and have low market shares. They neither generate nor require large amounts of cash. They relate to product in late maturity or declining stage.

Based on this classification investments and cash flow decisions can be made on the basis of the type of strategic business unit. For example, resources can be diverted from a 'cash cow' to a 'question mark' or a 'star'

A TYPICAL BCG MATRIX



Source: Business Policy by kazmi Azhar (1992) P.187

c. **PLC – Based Budgeting:** Resource allocation can also be based on the different stages in a **Product's Life Cycle (PLC).** For instance, a product in the introduction and growth stages may attract more resources that may have been diverted from high profit yielding products that have reached the maturity stage of the life cycle.

d. **Capital Budgeting:** Resource allocation could also be done on this basis. For example, existing projects, in case of restructuring and modernization, could use this approach for allocating resources.

e. **Zero-Based Budgeting (ZBB):** This is a budgeting system in which a departmental head is required to justify the resources allocated demand on the 'grounds zero' i.e. a fresh cost is calculated each time a plan is to be implemented. In this case, Zero-Based Budgeting can be used for effective resource allocation among competing units based on priorities since costs are related to the benefits of each task carried out.

f. **Parta System:** This, according to Sharma (1988), is an indigenous form of control device used for exercising control. It is a control tool used for the daily assessment of dividends. The budget parta is a pre-determined amount set via agreement between the Chief Executive and the departmental head. It thus represents a daily budgeting and reporting system.

2.18 FACTORS AFFECTING RESOURCE ALLOCATION

Having examined the various methods used in resource allocation, we shall now examine the factors at play when it comes to resource allocation.

Resources are usually scarce. Therefore, the decision and process of allocation are very complex.

In addition, because, priorities are not always clear, the strategists in a firm face the problems of how to allocate the resources in order to achieve optimality. This is particularly difficult because setting clear priorities is, in the first place, a Herculean task. This is so because many factors have to be taken into consideration before an equitable allocation is made of the resources among the various competing ends. Some of these are:

a. **The Objectives of the Firm:** Setting objectives is a complex process. Some objectives are official (explicit) some are operative (implicit). Therefore, the objective of a firm plays an important role in resource allocation because the more important objectives get better attention in terms of the resources allocated to them. Usually, operative (implicit) objectives tend to affect the pattern of resource allocation to the maximum extent possible.

b. **Dominant Strategists Preference:** In any organisation, the dominant strategist is usually the Managing Director/Chief Executive Officer. His preference tends to affect the pattern of allocation of resources. Because departmental heads recognize the importance and weight of such preferences, they tailor their requests to suit his preferences for easy approval.

c. **Internal Politics:** Sometimes resources are mistaken for power; hence, the ability of some heads to get more resources allocated to them is interpreted as a power influence on the allocation process. More resources mean more power. This perception makes resource allocation a rational political process. (Hills and Mahoney, 1970).

d. **External Influence:** These arise due to government policy and stipulations, the demands of shareholders, financial institutions, communities, creditors etc.

For instance, the conditions imposed in the letter of intent issued to a company may require additional investments in pollution control and safety equipment before its conversion into industrial licence. In addition, shareholders may expect higher dividends or bonus meaning that resources may have to be diverted to them.

Looking at these factors, one could easily recognize that when priorities are not clearly defined, the process of resource allocation will be greatly distorted. Balanced allocation of resources is a function of an explicit corporate objective and setting down of strategic priorities. Therefore, the links between objectives and budgeting and resource allocation should be strengthened.

2.19 DIFFICULTIES IN RESOURCE ALLOCATION

The factors described in the previous section coupled with the fact that resource allocation process is complex create difficulties for those charged with the responsibility for resource allocation. Some of these difficulties are highlighted below.

a. **Scarcity of Resources**

Financial, human, and physical resources are scarce and hard to find. Finance is difficult to procure and where it is available, the cost of capital is a constraint.

Developing countries like Nigeria will need to import capital goods like machines and equipment but government can only provide limited foreign exchange.

In the same vain, labour seems to be available everywhere, but the special skills required are scarce. Thus, there is a serious restriction on firms wishing to attract or retain personnel. Thus, scarcity of resources creates real problem in resource allocation

b. Internal Problems

i. The traditional budgeting system puts restriction on generating resources for newer units or those with growth potentials because of the allocation to the existing departments.

ii. In a system where the bottom-up approach is being used to allocate resources, there is always the problem of overstatement of needs.

iii. Where some departments are more favoured by the allocation process, the less favoured ones may resort to envy and this resulting strife may disrupt the smooth achievement of corporate goals.

iv. The use of the strategic budgeting system may rob some power units of resources in favour of potential units. This may lead to 'Budget Battles' if vested interests are affected.

It must be emphasized that the Chief Executive has a major role to play in managing the process of resource allocation. When the management allows participation and communicates the corporate plan to all concerned, a congenial environment is created where resource allocation decisions are taken amicably.

2.20 PROBLEMS WITH UNSCIENTIFIC METHODS

The major problems with the unscientific methods of resource allocation lie mainly in the fact that they are based on subjective or mental judgements. This often results in over-or under-estimation of needs and may have serious impacts on the firm's operational performance.

Another problem with the unscientific methods is that those in charge can deliberately inflate budgets at the expense of others. This creates the problem of unfairness in the allocation process.
Finally, it is difficult to assess them for optimality or post optimality analysis.

Hence, a more scientific method like the linear programming method is favoured above the unscientific ones.

2.21 CHAPTER SUMMARY

From the foregoing, it is clear that linear programming is not just a theoretical tool; a number of firms have found it a useful technique for planning their activities. In the researcher's opinion, the use of linear programming in establishing the optimum level of output that maximizes profit cannot be over-emphasized and that for other business problems such as transport routing, productions scheduling and personnel planning, the objective function of the linear programming model will be to minimize costs.

In Nigeria however, very few literature exists on the use of linear programming by the relevant sectors apart from the normal classroom work. For the purpose of this study, no literature on local use was found to be included in the review of related literature. As a result, all the examples used are foreign. This is sad enough because the level of technological achievement and literacy in the country is high enough to permit the use of linear programming by, at least, the manufacturing and the technological sectors.

Despite this development, it is still an incontrovertible fact that the Nigerian printing industry stands to benefit a lot if the firms in the industry will make use of the linear programming method to plan their operations, profit and costs.

Today however, a number of linear programming software packages can be purchased and the complexity of developing in-house programs is no longer a barrier to using linear programming to solve business problems in valuing allocation of scarce material, economic and financial resources.

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CHAPTER THREE

RESEARCH METHODOLOGY

3.1 INTRODUCTION

Research by definition is the process by which problems are solved through a planned and systematic collection, analysis, and interpretation of data.

According to Nlewedim (1987), research is a "diligent inquiry or investigation carried out for the purpose of discovering new knowledge. Thus, it is a man's way of discovering new knowledge and spreading the knowledge to promote the progress and development of his environment".

However, for any problem to be solved, data concerning the subject matter must be gathered and evaluated to generate the relevant information. Moreover, the success of any research work depends on the nature, type and the source of the data generated and used in the research work. It is therefore imperative that if the outcome of the research must be good and reliable, the information sought, the methods used in obtaining the information sought, methods used in analysing the data must be carefully and systematically presented to avoid any form of ambiguity. This chapter therefore is devoted to explaining the methods of collecting and analysing the data needed for this study, the identification of the sample size, the research design, and the justification of tools, instruments and methods chosen for the study.

3.2 RESEARCH METHODS

Research methods refer to those natural and scientific means, modes, and processes of finding facts. These methods include historical descriptive, experimental and survey methods. (Osuala, 2001).

3.2.1 HISTORICAL RESEARCH METHOD

Historical is any integrated narration or description of past events or facts written in the spirit of critical enquiry for the whole truth. It embraces the whole field of human past and is as broad as life itself.

Historical research deals with the determination, evaluation, and the examination of past events for the purpose of obtaining a clearer understanding of the present and making reliable predictions about the future. It is unique because based on historical data; it is based on already accumulated facts. It provides us with a greater appreciation of the role of culture, the role which new knowledge can play in the progress of the society and a hypothesis for the solution of current problems.

Historical sources of data may be classified in to two namely (1) documents and (2) relics. Documents are usually written whereas relics are generally archaeological or geological remains such as tools, and utensils.

3.2.2 DESCRIPTIVE RESEARCH METHOD

This method of research specifies the nature of a given phenomenon. In other words, the data collected is for the purpose of describing and interpreting the existing condition with the central objective of discovering meaning. The phenomenon specified could be simple or complicated but it gives a picture of the situation or population under study. The fact that the specification has to be systematic shows that the situation is not simple, but the accurate description of the situation is imperative for a wide range of decisions and policies to be made.

Descriptive research is basic for all types of research in assessing the situation as a pre-requisite to drawing inferences and generalization. However, it is not in itself sufficiently comprehensive to provide answers.

3.2.3 EXPERIMENTAL RESEARCH METHOD

This is the most scientifically sophisticated method and is the most often confused by the non-professional who equates experiment with the physical sciences and further equates physical science with science itself. This stems from the fact that the first steps in setting up any experiment were taken from the physical sciences.

This type of research is usually done under laboratory situations (field or science laboratories) where it is possible to set up controls and usually involves the formulation of hypotheses.

The purpose of experimentation is to derive verified functional relationships among the variables under controlled conditions. That is, identify the conditions underlying the occurrence of a given phenomenon. It also enables the researcher to improve the conditions under which he observes and thus arrive at results that are more precise. This is the essence of the scientific method.

3.2.4 SURVEY RESEARCH METHOD

This method studies both large and small populations by selecting and studying samples chosen from the population to discover the relative incidence, distribution, and inter-relations of sociological and psychological variables.

A clear line of demarcation can be drawn between survey studies and historical studies based on time. Historical research deals with the past while survey research deals with the present. In addition, it differs from experimental studies in purpose: while surveys are oriented towards the determination of the status of a given phenomenon, experiments isolate consultative factors. Survey does more than merely opening up data. It interprets, synthesizes them, and points to the implications of their inter-relationships.

The method also avails the researcher, the many opportunities of displaying ingenuity and scholarliness in the interpretation of the data and in the understanding of their strengths and weaknesses; their inter-relations and their implications.

3.3 RESEARCH DESIGN

Research design refers to the strategy for finding out facts about an event or a phenomenon. It states precisely what the mission of the researcher is and how best the researcher wants to find out his facts or achieve his objectives (Yusuf, 1996).

For the purpose of this study, both the descriptive and experimental approaches were adopted because, on the one hand, it was necessary to examine the existing procedures, their trends and effects in the printing firms. It was also necessary to study the conditions, beliefs and the other practices currently prevailing in the industry. Hence the study was centred on finding out the methods of resource allocation currently being used in the printing and publishing industry, evaluating them for adequacy effectiveness and efficiency; proposing and highlighting the importance of linear programming in resource allocation in the printing and publishing industry; and identifying the reasons, if any, why printing firms were not using or might not want to use any mathematical models in resource allocation. On the other hand, the study will be experimental because, appropriate tests were carried out on the various hypotheses to determine their validity or otherwise. Study population is the totality of the printing firms in Kaduna, kaduna State, Nigeria.

For this purpose, primary and secondary data were obtained using the interview, questionnaire and observation/documentation methods and existing literature on the subject matter. Statistical tests of the hypothesis involved the use of the Chi-square method for drawing appropriate conclusions.

3.4 CHARACTERISTICS OF THE STUDY POPULATION

This study aims at finding out whether or not linear programming is applicable to the allocation of resources in the printing industry in Nigeria. Therefore, the population selected for this study will be the printing firms that make up the industry in Kaduna, Kaduna State, Nigeria.

Kolade (2001:6) takes a critical look at the industry and observes, "The printing industry is a service industry that fuels commercial enterprises and social interaction". According to him, "the industry has passed from one stage of technological development to another in the last 50 years, with increasing government participation and involvement. In addition, the industry now employs graduates of printing technology as professionals. The industry is influenced greatly by the external environment like legal economic, political, social, and technological environments". Thus, the industry is characterized as follows:-

- Firms in the industry are categorized as government-owned and privately owned. Further categorization includes large printing firms and small printing firms.
- Most of the firms are scattered over the places and operate on mostly medium scale.
- Even the big firms employ a sizeable number of able and academically qualified personnel. Hence, recruitment is both by apprenticeship and normal selection procedures.
- The age distribution of people in the industry is between 10 and 60 years.
- Most firms have at least three (3) departments and at least a small printing machine. Some however, have up to date facilities like computers, colour separating machines, and latest printing machines.

With this background, information about the study population one expects to be able to come to reasonable and reliable conclusion at the end of the study.

3.5 SAMPLING DESIGN AND PROCEDURES

Sampling is described as a procedure, which permits every element in the population to have a known probability of being selected independently.

The population of this study is the printing and publishing in Nigeria. For the purpose of this study, it was not possible to access all the firms in Nigeria and even in Kaduna State alone. Therefore, the research effort was spread across Kaduna metropolis. It was not particularly possible to ascertain the exact number of printing firms in Kaduna Metropolis. However, the researcher was able to obtain the list of registered printing firms from the Secretariat of the Association of Nigerian Printers (ANP), Kaduna Branch. The register shows that only 128 firms attended their periodic meetings. 117 firms were actually into printing and/or publishing while 11 firms were into either graphic design or sale of printing materials/accessories. Of the 117 printing firms, only 85 registered with the Association. 32 firms did not register at all. In addition, the researcher decided to include only the registered firms in the sample especially since almost all the 32 unregistered firms were very small and operated from one-room offices. As a result, most of them did not actually fit into the framework for this study. For the purpose of the study therefore, the researcher covered all the 85 registered firms notwithstanding the time, effort and money required to carry out the study. It was on these bases that the researcher distributed the questionnaires and conducted interviews.

TABLES SHOWING THE DISTRIBUTION OF PRINTING FIRMS IN KADUNA

(a) DISTRIBUTION BY CLASS OF BUSINESS

BUSINESS	NO IN CATEGORY
PRINTING AND/OR PUBLISHING	117
NON – PRINTING	11
TOTAL	**128**

Source: ANP Kaduna Branch Office, Kaduna, 2003

(b) **DISTRIBUTION BY REGISTRATION**

STATUS	NO IN CATEGORY
REGISTERED	85
NOT REGISTERED	32
TOTAL	**117**

Source: ANP Kaduna Branch Office, Kaduna, 2003

Based on the data (list) obtained from the Kaduna office of the Association of Nigerian Printers, the researcher was able to sub-divide the Kaduna metropolis into 8 clusters according to the location of the registered printing firms. The distribution according to clusters is show below.

(c) **DISTRIBUTION BY CLUSTERS**

S/N	AREA	NO
1	ANGWAN RIMI	1
2	DOKA	72
3	KABALA COSTAIN	1
4	KAWO	6
5	MAKERA	1
6	MALALI	1
7	TRIKANIA	1
8	TUDUN WADA	2
	TOTAL	**85**

Source: ANP Kaduna Branch Office, Kaduna, 2003

3.6 DATA COLLECTION METHODS

Methods of collecting data vary according to the types and sources of data (Nnamdi, 1991). They are as discussed below.

Methods of collecting Primary Data:

1. Survey Method

In this case, information is gathered by interviewing a limited number of people. It requires careful planning, may be expensive, time-consuming and information given may be inaccurate. This method was not used in this study.

2. Observation Method

This is a very important primary tool of scientific research. Good and Hatt (1952), point out "science begins with observation for its final validation."

It is a direct means of studying the overt behaviour of people. Observation could be controlled, uncontrolled, or mechanical. In controlled observation, we systematically describe only the important stages and may require the test of casual hypothesis. In the case of the uncontrolled observation, there are no laid down rules, the researcher only takes his clues from unexpected events especially in explanatory studies. Mechanical observation uses electrical impulses to record the given phenomena.

For its success, objectives must be clear as well as the conditions, the records must be checked for validity, and reliability and the researcher must be free from biases and selective perception. Observation method can be accurate and digitally or electronically accomplished. At the same time, it could be expensive and limited in application.

For the purpose of this research work, the researcher divided the Kaduna metropolis into 8 clusters and selected a firm from each area for observation. That also formed the basis for the collection of production data for the purpose of data analysis in the next chapter if this study.

3. Experimental Method

This involves the establishment of controlled experiments, which simulates the project situation as much as possible. This method helps remove defects before coming out with the result. It also permits results to be measured mathematically and is real. However, it is expensive and requires long, careful planning and administration. This method was not very relevant to this research work. Accordingly, the researcher did not make use of the experimental approach for the purpose of data collection.

4. Interview Method

This is a technique used for collecting information from others in a face-to-face arrangement. It is useful for obtaining valid and reliable information in the form of verbal responses in order to confirm or reject a hypothesis. There are four types of interviews, which are:

i. **A structured interview:** Is the one in which questions are rigidly standardized and formal. The same questions go to all respondents in the same order and the choice of responses restricted to a pre-determined list.

ii. **Unstructured interview:** Is the one in which questions are flexible and with few restrictions on answers. Respondents are free to express their thoughts and order of question is alterable to suit the situation.

iii. **Non-directive Deep Interview:** In this case, instead of asking direct or prepared questions, respondents are allowed to talk freely and fully on a particular topic.

iv. **Focused Interview:** In this case, the respondent is asked to focus his attention on a particular event or experience.

For the purpose of this study, the researcher selected 8 firms randomly from each cluster for the conduct of interviews. The interviews were conducted in the same firms selected for observation. The type of interview conducted derived from the peculiar situation of each firm as observed by the researcher.

5. Questionnaire Method

This is a device for getting information by way of preparing questions in a particular format and printing them on forms. Those forms are later distributed to respondents to complete by themselves.

The questionnaires could be distributed directly or mailed to the respondent. In any of the cases, the questions should:

- be simple
- not be technical
- not involve calculations or tests of memory
- not be personal, offensive or misleading.

The questionnaire should be as short as possible, have simple answer categories and questions should be asked in a logical order.

Direct distribution method guarantees fewer bias responses or refusals while mailing method guarantees quick and wider distribution at a relatively low cost if the postal system is reliable and efficient.

Questionnaires guarantee respondents' anonymity and put them under no (or less) pressure. At the same time however, the answers could be biased and cannot be used with illiterates.

For the purpose of this study, the researcher designed and administered 95 questionnaires containing 18 questions each. The questionnaires were targeted at the Production Managers/Supervisors and/or the Accountants of the printing firms. The researcher administered all the 95 questionnaires in Kaduna metropolis. However, the researcher found it necessary to give more than one questionnaire to some well-established and older firms with clearly defined departments and roles with the aim of obtaining the opinion of more than one person from such firms especially where the opinion of an individual may not adequately represent the view of the entire organisation. In addition, the researcher did this to ensure that as many questionnaires as possible were completed and returned for the purpose of the study. Thus the number of questionnaires administered were more than the sample selected for the study.

Methods of Collecting of Secondary Data

As it has been discussed already, secondary data are those, which have been used for some purposes earlier and still have some relevance to the current study. They are most available in libraries, research centres, higher institutions of leaning, employment gazettes, government offices, web sites and so on. A good way of obtaining this information is to obtain the official publications of these organisations, visit them, or check the libraries.

For the purpose of this study however, primary and secondary data were used. Primary data were obtained through questionnaires, personal interviews, and direct observation of the processes in the printing houses while taking notes of relevant occurrences. Existing records of production were also examined for that purpose.

Secondary data were obtained from texts, journals and the Internet (on a limited basis).

3.7 METHODS OF DATA ANALYSIS

Data analysis refers to the strategies and procedures for exploring and summarizing relationships among the variables on which data have been collected. Thus the analysis of data is a means of answering research questions and testing the hypotheses stated. Therefore, analysis can be defined as the systematic breakdown of data into its constituent parts, making interpretations, drawing inferences, which are pertinent to the research relations studied and conclusions about them.

Due to the nature of this research, the cluster method of sampling was used. This permitted all the areas of the metropolis to be represented in the sample and it formed the basis of questionnaire distribution and interviews.

For analysing the data, tables more than any other tool were used to lay out the data for both analytical and comparative purposes. Where it became necessary, other tools like charts or graphs were to analyse data and used to draw inferences and conclusions.

3.7.1 CHI-SQUARE METHOD

The principal tool used for testing the stated hypothesis was the Chi-square method of hypotheses testing because the variables of the research were measured on a nominal scale. The Chi-square test was more favoured for this because of its suitability for the nature of the test to be carried out.

For the purposes of this study, questionnaires distributed were retrieved and sorted out according to their areas or clusters and connected to percentages or proportions. These figures were then used to compute the observed and expected frequencies needed for testing the hypothesis.

As it was stated earlier on, in chapter 1, the hypothesis was tested at 95% level of significance. This formed the basis for accepting or rejecting the hypothesis.

Since there was one hypothesis to be tested, the modus operandi was to extract from the questionnaire, the questions relevant to the hypothesis and do the analysis accordingly. At the end, the conclusions reached were used to draw inferences on the study and then the idea was used to draw a general conclusion on the study.

For the purpose of this analysis, the Chi-square (χ^2) was defined by the expression:

$$\chi^2 = \frac{\sum (f_o - f_e)^2}{f_e}$$

Where : $\chi^2 = Chi - square$

$f_o = Frequency\ observed$

$f_e = Frequency\ expected$

$df = Degree\ of\ freedom$

$k = No\ of\ categories$

$I = Constant$

The Chi-square (χ^2)test has decision rules just like any other test. Its own decision rule is that: When the calculated (χ^2)value is larger or greater than the table value of χ^2, then the Null Hypothesis should be rejected. However, when the calculated value is less than the table value of χ^2, we accept the null hypothesis and reject the alternate hypothesis.

This statistical test method has certain assumptions even though it is a non-parametric statistical method, which does not have stringent assumptions.

These assumptions are:

a. Where two or more than two samples are used, they should be independent of one another.

b. The samples must be randomly selected

c. The data must be classifiable and satisfy the nominal level of measurement requirement.

d. The sample size should be between 25 and 250.

The advantages of the Chi-square method are as follows:

a. it is easy to apply to categories data

b. it is a **goodness of fit** statistic that reveals the significance associated with the fit between what is observed and what can be expected from the character distribution of frequencies

c. a table of critical Chi-square values is available for the instant interpretation of the significance of any observed X^2 for either one-tailed or two-tailed tests.

The method however, has some **limitations**, which are as follows:

a. The test is sensitive to very large or very small sample size. If the sample seize is less than 5 or larger than 250, the resulting X^2 becomes distorted and thus misleading

b. It is also very sensitive to very small expected frequencies. Thus for the application to be valid, the expected frequencies should be larger than 5

c. Another limitation is the sample size. Some authorities have recommended a correction for sample sizes ranging from 25 – 75 with the aim of reducing the magnitude of the calculated X^2 value, thus, making it a little more difficult to reject the null hypothesis.

One such correction is **Yate's Correction for Continuity**. This is achieved by reducing the magnitude of the difference between each observed frequency and the corresponding expected frequency by 0.5 $\left(i.e.\ f_o - f_e - 0.5\right)$. This is however, only applicable where:

i. the sample seize is between 25 and 75 and

ii. the data are arranged in a 2 x 2 table.

3.7.2 LINEAR PROGRAMMING METHOD

The other method used to test the production data obtained for the purpose of this research work especially those affecting the allocation of resources by the firms under study was the Linear Programming Method (LMP). This was the principal objective of this research work. That is to see how the method of linear programming could be applied to solving the allocation problems in the printing and publishing industry.

For this reason, the specific production information or data obtained were analysed and defined in terms of:

a. What the objective of the firm was, that is maximization or minimization of some function.

b. The limitations faced by the firm in terms of material, labour, time, finances etc.

c. The number of jobs the firm was handling and the requirements of each job.

d. The process (es) the job(s) had to pass through. This will depend on the nature of each job and the number of functional departments the firm had.

e. The time space within which the job must be concluded.

Specifically, the objective function (mathematical statement of the objective), the constraints and the non-negativity constraints were defined in terms of the number

of jobs on hand, the cost or profit per unit and the requirements of each unit per resource per department or process. Therefore:

a. The objective function, which can be maximization, or minimization function was stated thus:

$$Maximize \quad X_o = \sum_{j=1}^{n} C_j X_j$$

Note: The minimization of the function $f(x_o)$ is the mathematical equivalent of the negative expression of the maximization i.e. $-f(x_o)$. Therefore, the where the objective is to minimize cost or other function, the statement becomes:

$$Minimize \quad X_o = C_1X_1 + C_2X_2 + ...C_nX_n$$

If we replace x_o *with* $-g_o$

It becomes: $Maximize \quad g_o = -X_o = C_1X_1 - C_2X_2 - ...C_nX_n$

$$Maximize \quad X_o = \sum_{j=1}^{n} (-C_j X_j)$$

Where $x_o = -g_o$

b. The constraints were stated in in-equality form like this:

$$\sum_{j=1}^{n} a_{ij} X_j \leq b_i, \quad i = 1,2,...,m$$

c. The non-negativity constraints were:

$$X_j \geq 0, \quad j = 1, 2, \ldots, n$$

When the three, (a), (b) and (c) above are combined, the complete linear program was mathematically stated as follows, in the canonical form.

$$\textit{Maximize} \qquad X_o = \sum_{j=1}^{n} C_j X_j$$

$$\textit{Subject to:}$$

$$\sum_{j=1}^{n} a_{ij} X_j \leq b_i, \quad i = 1,2,\ldots, m$$

$$X_j \geq 0, \quad j = 1, 2, \ldots, n$$

This form was suitable for the graphical solution method of linear programming where the decision variables were two (2).

When the simplex method was required however, the linear program had to be formulated in the standard form. It was mathematically stated as follows:

$$\textit{Maximize } X_o = \sum_{j=1}^{n} C_j X_j$$

$$\textit{Subject to:}$$

$$\sum_{j=1}^{n} a_{ij} X_j + S_i = b_i, \quad i = 1,2,\ldots, m$$

$$X_j \geq 0, \quad j = 1, 2, \ldots, n$$

$$S_i \geq 0, \quad i = 1, 2, \ldots, m$$

In both the canonical and standard forms:

i = *a unit of resource i*

b = *the amount of resource i available*

a = *the amount of resource i thet must be allocated to activity j*

C = *the worth per unit of activity j*

X = *decision variable for activity j*

S = *slack or surplus variable for resource i*

j = *a unit of activity*

In the canonical form, all constraints are inequalities the decision variables are non-negative; and the objective function is that of maximization.

In the standard form however, all constraints are equations except for the non-negativity constraints; the right hand side of each constraint equation is non-negative, all variables (decision, slack or surplus) are non-negative, and the objective function of the maximization or minimization type.

The simplex method of solving linear programming of problems involves the use of tableau(x). The typical tableau format of a complete linear program aim is as shown below.

Basis	C_1	C_2	.	.	.	C_n	b_i
	a_{11}	a_{12}	.	.	.	a_{1n}	b_1
	a_{21}	a_{22}	.	.	.	a_{2n}	b_2
	.	.	.	.	.	.	.
	.	.	.	.	.	.	.
	.	.	.	.	.	.	.
	a_{m1}	a_{m2}	.	.	.	a_{mn}	b_n
$Z_j = \sum_{i=1}^{n} C_{n+i} b_i$	$Z_j = \sum_{i=1}^{n} C_{n+j} a_{ij}$						Z
ΔZ	$C_j - Z_j$						

When the decision variables are more than three, only the simplex method can be used to solve the problem. The simplex method can also be used where decision variable are just two or three.

The assumptions of this method of data analysis and problem solution are:

a. Constraints represent linear in-equalities, which imply proportionality.

b. All variables are continuous

c. Uncertainty is not allowed

d. It is not possible to achieve two goals simultaneously

e. Problems can be stated in numeric items

f. There are alternative courses of action

g. More than one restriction exists.

The advantages of this method are:

a. The value of each of the constants can be assigned with reasonable certainty.

b. Permits the statement of problems in numeric terms.

c. Permits a choice (or choices) among alternative courses or action.

d. It is applicable to virtually all allocation problems.

e. It is a sound optimization technique

f. It permits the measurement of the effect of a change in the value of each coefficients of the objective function or changes in any of the constraints that is sensitivity analysis.

The **problems or limitations** of the linear programming method are:

a. Only one goal can be achieved at a time

b. The units of the objective function may represent other quantities than naira.

c. Models are a mere abstract representation of reality. Real life problems are far more complex than the models present them to be.

d. The assumption of non-negativity may not always hold in all real life situations.

e. Physical properties require integer values but linear programming solution is not guaranteed to be integer. Variables are continuous

f. Iteration: solution requires long repetitive processes.

g. Complexity: Obtaining solution involves a great deal of complex calculations.

3.8 JUSTIFICATION OF METHODS AND INSTRUMENTS

Justification is the rationale for using the methods and instruments explained earlier in this chapter. The interview and questionnaire methods of data collection facilitated the collection of genuine and unbiased data because the anonymity of the respondents was preserved.

The observation method, in its own case, will enhance the descriptive nature of this study.

For the purposes of data analysis, the tabular method/approach was used to analyse and compare data because it afforded a very neat and clear data presentation. In addition, it made it easy to detect mistakes in calculations and saved a lot of time and space. The tabular approach also facilitates quick understanding.

The researcher must test the hypothesis if he must reach any meaningful conclusion. He must also properly interpret the results. In order to test the hypothesis and interpret the results, the chi-square method was chosen because it established the goodness of fit between the frequencies observed and those expected and provided the basis for computing the contingency coefficient as a measure of assessing the relationship between the variables involved.

The assumptions of the Chi-square method or its conditions were minimal but not stringent. Since this study and its parameters fully satisfied these conditions and did not fall within its limitations, there was no reason to doubt the efficiency of the method in bringing out the inferences, which were eventually used to draw generalized conclusions for the study.

While the Chi-square method would used to test the hypothesis and the qualitative information of the study, the quantitative data were tested using the linear programming method. The reason for this was that, it was the principal focus of this research work.

Without it, the whole effort would not have been meaningful, and the objective of this research work would not have been achieved.

3.9 SUMMARY

Methodology procedure helps in examining the validity and reliability of research instruments. This is because the method of study is crucial and choice of method will assist in evaluating the adequacy and efficacy of the research findings. Therefore in this chapter, the issues of design, population of study and sample, choice or research methods and techniques, data collection methods and data analysis were duly addressed and it is believed that they would lead to some useful and reliable but logical conclusions upon which the generalized idea would be based.

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CHAPTER FOUR

DATA PRESENTATION, ANALYSIS AND INTERPRETATION

4.1 INTRODUCTION:

This research work is concerned with the allocation problems of a printing firm. The principal objective is to determine the applicability of linear programming method to the allocation problems of a printing firm as well as the challenges posed by the method. It is also aimed at finding out if the method can be appropriately used to allocate scarce resources in order to achieve optimality and finding out whether there are other methods of allocating such resources.

In order to achieve these objectives, primary data were collected via questionnaires, interviews and direct observation of operations of some printing firms based in Kaduna. For the purpose of the research work, 85 questionnaires were distributed to the various printing firms in Kaduna Metropolis.
The 85 questionnaires retrieved form the printing firms were distributed as follows:

Some were, however, not properly completed while some were not touched at all – they were returned blank! Thus from the good ones the researcher selected the best completed questionnaires in accordance with the pre-determined sample size as shown below:

8 firms (1 from each area) were selected randomly for interviews and observation. Data were obtained from these firms concerning their production runs and organisational set up. The responses were quite encouraging and *motivating, although some were initially repulsive and uncompromising.* Based on the available information, the data for this research work will be presented, analysed and interpreted as presented after the table below.

AREA	QUANTITY
ANGWAN RIMI	1
DOKA	72
KABALA COSTAIN	1
KAWO	6
MAKERA	1
MALALI	1
TRIKANIA	1
TUDUN WADA	2
TOTAL	**85**

4.2 DATA PRESENTATION, ANALYSIS AND INTERPRETATION:

In this section, the data obtained through questionnaires are presented in tabular form, analysed and interpreted as follows: however only the questions, which are relevant, are analysed and presented in this section.

Question 5: What is the minimum qualification for a Unit or Departmental Head?

Table 1:

	None	SSCE	OND /HSC	HND /BSC	PGD & ABOVE	TOTAL
Response	8	6	26	15	20	85
%	9	19	31	17	24	100

This shows that a handful of the people employed in the printing industry are first school leavers. As the table indicates, 48% of the firms will employ at least

Ordinary National Diploma graduates while 24% will require the services of people with higher degrees. This shows that most of the firms are either medium in size or business volume.

Question 6: What method(s) do you employ in allocating your human, material and financial resources?

This question aims at finding out the various methods of resource allocation currently being used in their firms and hence, the industry.

Table 2:

	Mental Judgement	Budgetary Procedure	Linear Programming	Others	Total
Response	63	22	0	0	85
%	74	26	0	0	100

Table 2 above shows the response pattern. It is clear from the table that 74% of the firms rely on mental judgement for resource allocation while only 26% uses budgetary procedures. None uses any clearly defined quantitative method.

Question 7: Is the method of allocation adequate and effective?

The response to this question was in the affirmative for all categories. None admitted any form of inadequacy or ineffectiveness.

Question 9: Would you say that illiteracy on the part of staff will hinder the use of a clearly defined mathematical model for resource allocation?

Table 3:

	Agreed	Disagreed	TOTAL
Response	41	44	85
%	48	52	100

The response pattern shows that 48 % of the respondents agreed that illiteracy was a major hindrance to the application of a clearly defined mathematical model for resource allocation. 52 % however, disagreed. This suggests that illiteracy may not be the reason why most firms in the industry do not use quantitative methods for resource allocation. This may be due to other reasons.

Question 10: Have you heard about Linear Programming?

Table 4:

	Yes	No	TOTAL
Response	68	17	85
%	80	20	100

The response pattern is rather staggering. 80% of the respondents were either aware of or had the knowledge of linear programming as a tool for resource allocation. This is probably due to the general fact that most employees in the industry are educated beyond the Ordinary National Diploma level.

Question 11: Do you think that linear programming is relevant at all to your Company's activities?

This question aims at finding out the respondents' view about the relevance of linear programming to the allocation problems of a printing firm. Table 5 below shows the response pattern.

Table 5:

	Very relevant	Relevant	Not very relevant	Not relevant at all	TOTAL
Response	40	27	11	7	85
%	47	32	13	8	100

From the response, a total of 67 respondents (79%) agreed that linear programming method is relevant to the activities of a printing firm while only 14

(21%) disagreed with that view. The conclusion, therefore, is that the Linear Programming method of allocation is relevant and applicable to the allocation problems of a printing firm.

Question 12: Have you ever tried using Linear Programming to allocate your resources?

Table 6:

	YES	No.	TOTAL
Response	0	85	85
%	0	100	100

This table shows that out of the 68 respondents that claimed awareness of the Linear Programming method (Table 4 above), none of them (0%) of the sample) has actually tried using the method to allocate their resources. This shows that the method is currently not in use in the industry.

Question 13: Would you prefer it to your present method of allocation?

Table 7:

	YES	No.	TOTAL
Response	44	41	85
%	52	48	100

The response pattern shows that 44 respondents (52%) prefer the use of Linear Programming, 41 (48%) prefer the other methods in existence. This is a case of divided opinion. The preference of 52% of the respondents may be due to sheer curiosity since they have neither heard about nor used the method before. It may also be due to any problem(s) they experience with the methods they are currently using.

Question 14: Do you think this mathematical model is more effective and efficient than your current method of allocation?

Table 8:

	YES	No.	TOTAL
Response	68	17	85
%	80	20	100

The response pattern swung in favour of linear programming as a more effective and efficient method of resource allocation. 80% supports the method while 20% were against it. Hence it was concluded that for resource allocation, linear programming is a more efficient and effective method than any other method.

Question 15: Do you think that your organisation will perform better if it uses Linear Programming?

Table 9:

	YES	No.	TOTAL
Response	61	24	85
%	72	28	100

72% of the respondents agreed that their firms would perform better if they used Linear programming while 28% did not agree. It was concluded therefore that organisations would do better in resource allocation if they use linear programming. This also confirms the responses to question 14.

Question 16: Do you think that firms using linear programming will perform better than those using other methods?

Table 10:

	Big Difference	Small Difference	No Difference	TOTAL
Response	62	11	12	85
%	73	13	14	100

73% of the respondents were of the view that firms using linear programming would perform better than the firms, which do not use it.

13% agreed that it would only make a little difference while 14% did not see how it would make any difference. It was therefore concluded that organisations that use linear programming method would record better performances than those using other methods for resource allocation.

Question 17: Do you think more training and/or exposure will stimulate the staff' interest in such a method as linear programming for resource allocation?

Table 11:

	YES	NO	TOTAL
Response	61	24	85
%	72	28	100

Most respondents agreed that training and exposure would stimulate the interest of their staff in the use of mathematical models, but 28% of them disagreed. Based on the response pattern, it was concluded that most people or firms, which do not use any form of mathematical model for resource allocation actually lack the basic educational training, skills and exposure required for such. Therefore, they need more training and exposure to be able to use mathematical models for resource allocation in their various organisations.

4.3 HYPOTHESIS TESTING

The principal objective of this study is:

To determine the applicability of Linear Programming to the allocation problems of a printing firm and the challenges posed by the method.

In order to achieve this objective, a hypothesis was formulated and for that purpose, questionnaires were distributed to obtain data representing the respondents' view on the subject matter. The data relating to this subject were obtained via questions 11 to 16. The responses gave rise to two subsidiary hypotheses in the course of testing the main hypothesis. All the three hypotheses were tested and results obtained and interpreted accordingly as shown in the following sections.

RE-STATEMENT OF THE MAIN HYPOTHESIS:

H_o: There is no significant relationship between the application of linear programming method and the achievement of optimality in resource allocation by the printing firm.

H_a: There is a significant relationship between the application of linear programming method and the achievement of optimality in resource allocation by the printing firm.

In testing this hypothesis, data obtained from question 14 of the questionnaire (table 8) were used. Responses were categorized as **Yes** and **No** for the independent variable (**Linear Programming Method**) while the dependent variable (**Achievement of Optimality**) was categorised as **Efficient** and **Not Efficient.** Then based on the sample of 85 (being the total no of registered printing firms in Kaduna) the contingency table for the observed frequencies (responses) was drawn as shown below in table 12.

Table 12: Contingency Table of Observed Frequencies

	Achievement of Optimality			**TOTAL**
Linear Programming Method		**Efficient**	**Not Efficient**	
	Yes	63	9	**72**
	No	8	5	**13**
	TOTAL	**71**	**14**	**85**

In order to test the hypothesis using the Chi-Square method, it was necessary to compute the expected frequency for each cell of the contingency table and the value of the Chi-Square.

Given that the total number of observations, **N**, is **85**, the expected frequencies were calculated as follows:

For Cell a_{ij},

$$Expected\ Frequency\ (f_e) = \frac{Row\ Total\ X\ Column\ Total}{Total\ Number\ of\ Observations}$$

Hence, for:

$$Cell\ a_{11},\ f_e = \frac{72x\ 71}{85} = 60.14$$

$$Cell\ a_{12},\ f_e = \frac{72\ x\ 14}{85} = 11.86$$

$$Cell\ a_{21},\ f_e = \frac{13\ x\ 71}{85} = 10.86$$

$$Cell\ a_{22},\ f_e = \frac{13\ x\ 14}{85} = 2.14$$

Next was the computation of the Chi-Square value. This is shown in table 13 below.

Table 13: Computation of Chi-Square (χ^2) Value

Cell	fo	fe	fo - fe	$(fo - fe)^2$	$(fo - fe)^2/fe$
a_{11}	63	60.14	2.860	8.180	0.136
a_{12}	9	11.86	-2.860	8.180	0.690
a_{21}	8	10.86	-2.860	8.180	0.753
a_{22}	5	2.14	2.860	8.180	3.822
			0		**$\chi^2 = 5.401$**

From table 13,

$$\chi^2 = \sum \frac{(f_o - f_e)^2}{f_e} = 5.401$$

Where: f_o = *Frequency Observed*

f_e = *Frequency Expected*

Next, the degree of freedom was calculated

$$df = (c-1)(r-1)$$

Where: c = *No of columns*

r = *No of rows*

$\therefore \quad df = (2-)(2-1) = 1$

Given that level of significance is **95%,**

Then: $\propto$ = **0.05** (allowing a maximum of 5% error)

In order to test the calculated value of Chi-Square for significance at **df = 1** and $\propto$ = **0.05**, the table value of χ^2 was obtained to be **3.841** and compared with the calculated value.

Using the **Microsoft Excel Application Package,** the Chi-square value was calculated thus:

Table 14

COMPUTATION OF CHI-SQUARE VALUE

CELL	fo	fe	ChiSqDist
a11	63	60.14000	0.136009312
a12	9	11.86000	0.689679595
a21	8	10.86000	0.753186004
a22	5	2.14000	3.822242991
			5.401117901

k	4
Chi_Square	5.4011179
df	1
Alpha	0.05
Crit_Value	3.8414553

Decision rule:

If the table value of χ^2 is less than the calculated value of χ^2, the null hypothesis will be rejected.

Decision:

The table value of χ^2 **(3.841)**, is less than its calculated value, **(5.401)**. Therefore, **the null hypothesis was rejected.**

Interpretation:

The implication of rejecting the Null Hypothesis is the acceptance of the Research Hypothesis. It means, therefore, that **the application of linear programming method to the allocation problems of a printing firm will significantly improve the firm's ability to achieve optimality in resource allocation.**

TESTS OF SUBSIDIARY HYPOTHESES

The two subsidiary hypotheses that came up were also tested as follows:

Subsidiary Hypothesis 1:

It was used to attest to the conclusion of the Primary Hypothesis. It was stated thus:

H_o: The application of linear programming is not relevant to the operations of a printing firm.

H_a: The application of linear programming is very relevant to the operations of a printing firm.

This hypothesis was based on question 11 and the responses are shown in table 15 below. It helped the researcher to verify the relevance or otherwise to the operations of printing firm.

Table 15

	Relevance to Operations			TOTAL
Linear Programming Method		Relevant	Not Relevant	
	Yes	58	12	70
	No	6	9	15
	TOTAL	64	21	85

Given that the total number of observations, **N**, is **85**, the expected frequencies were calculated as follows:

For Cell a_{ij},

$$Expected\ Frequency\ (f_e) = \frac{Row\ Total\ X\ Column\ Total}{Total\ Number\ of\ Observations}$$

Hence, for:

$$Cell\ a_{11},\ f_e = \frac{70x\ 64}{85} = 52.71$$

$$Cell\ a_{12},\ f_e = \frac{70\ x\ 21}{85} = 17.29$$

$$Cell\ a_{21},\ f_e = \frac{15\ x\ 64}{85} = 11.29$$

$$Cell\ a_{22},\ f_e = \frac{15\ x\ 21}{85} = 3.71$$

Then the χ^2 value was computed as shown in table 16 below:

Table 16: Computation of Chi-Square (χ^2) Value

Cell	fo	fe	fo - fe	$(fo - fe)^2$	$(fo - fe)^2/fe$
a_{11}	58	52.71	5.290	27.984	0.531
a_{12}	12	17.29	-5.290	27.984	1.619
a_{21}	6	11.29	-5.290	27.984	2.479
a_{22}	9	3.71	5.290	27.984	7.543
			0		$\chi^2 = 12.172$

From table 16,

$$\chi^2 = \sum \frac{(f_o - f_e)^2}{f_e} = 12.172$$

Where : f_o = *Frequency Observed*

f_e = *Frequency Expected*

Next, the degree of freedom was calculated

$$df = (c-1)(r-1)$$

Where : c = *No of columns*

r = *No of rows*

$\therefore$ $df = (2-)(2-1) = 1$

Given that level of significance is **95%,**

Then, α = **0.05** (allowing a maximum of 5% error)

In order to test the calculated value of Chi-Square for significance at **df = 1** and α = **0.05**, the table value of χ^2 was obtained to be **3.841** and compared with the calculated value.

Using the **Microsoft Excel Application Package,** the Chi-square value was calculated thus:

Table 17

COMPUTATION OF CHI-SQUARE VALUE

CELL	fo	fe	ChiSqDist
a11	58	52.71000	**0.530906849**
a12	12	17.29000	**1.618513592**
a21	6	11.29000	**2.478662533**
a22	9	3.71000	**7.542884097**
			12.170967071

k	**4**
Chi_Square	12.1709671
df	**1**
Alpha	0.05
Crit_Value	**3.841455338**

Decision rule:

If the table value of χ^2 is less than the calculated value of χ^2, the null hypothesis will be rejected.

Decision/Interpretation:

The table value of χ^2 **(3.841)** is less than its calculated value, **(12.172)**. Therefore, **the null hypothesis was rejected.** On this basis, it was concluded that **linear programming is very relevant to the operations of a printing firm.**

Subsidiary Hypothesis 2:

The aim of this hypothesis is to find out whether there is any difference between the firms using linear programming and those who do not use the method with respect to their performances.

It was stated thus:

H_o: **There is no significant difference in performance between the firms using linear programming and those who are not using the method for resource allocation.**

H_a: **There is a significant difference in performance between the firms using linear programming and those who are not using the method for resource allocation.**

The researcher made use of responses to Question 16 in the questionnaire to test the hypothesis. The responses are shown in table 18 below:

	Difference in Performance		TOTAL
	Difference	No Difference	
Using the L P Method	63	5	**68**
Not using the LP Method	7	10	**17**
TOTAL	**70**	**15**	**85**

Given that the total number of observations, **N**, is **85**, the expected frequencies were calculated as follows:

For Cell a_{ij},

$$Expected\ Frequency\ (f_e) = \frac{Row\ Total\ X\ Column\ Total}{Total\ Number\ of\ Observations}$$

Hence, for:

$$Cell\ a_{11},\ f_e = \frac{68\ x\ 70}{85} = 56.00$$

$$Cell\ a_{12},\ f_e = \frac{68\ x\ 15}{85} = 12.00$$

$$Cell\ a_{21},\ f_e = \frac{17\ x\ 70}{85} = 14.00$$

$$Cell\ a_{22},\ f_e = \frac{17\ x\ 15}{85} = 3.00$$

Then the χ^2 value was computed as shown in table 19 below:

Table 19: Computation of Chi-Square χ^2) Value

Cell	fo	fe	fo - fe	$(fo - fe)^2$	$(fo - fe)^2/fe$
a_{11}	63	56	7	49	0.875
a_{12}	5	12	-7	49	4.083
a_{21}	7	14	-7	49	3.500
a_{22}	10	3	7	49	16.333
			0		**χ^2 = 24.791**

From table 19,

$$\chi^2 = \sum \frac{(f_o - f_e)^2}{f_e} = 24.791$$

Where : f_o = *Frequency Observed*

f_e = *Frequency Expected*

Next, the degree of freedom was calculated

$$df = (c-1)(r-1)$$

Where : c = *No of columns*

r = *No of rows*

$\therefore$ $df = (2-)(2-1) = 1$

Given that level of significance is **95%,**

Then, α = **0.05** (allowing a maximum of 5% error)

In order to test the calculated value of Chi-Square for significance at **df = 1** and α = **0.05**, the table value of χ^2 was obtained to be **3.841** and compared with the calculated value.

Using the **Microsoft Excel Application Package**, the Chi-square value was calculated thus:

Table 20:

CELL	fo	fe	ChiSqDist
a11	63	56.00000	0.875000000
a12	5	12.00000	4.083333333
a21	7	14.00000	3.500000000
a22	10	3.00000	16.333333333
			24.791666667

k	4
Chi_Square	24.7916667
df	1
Alpha	0.05
Crit_Value	3.841455338

Decision rule:

If the table value of χ^2 is less than the calculated value of χ^2, the null hypothesis will be rejected.

Decision/Interpretation:

The table value of χ^2 **(3.841)**, is less than its calculated value, **(24.791)**. Therefore, **the null hypothesis was rejected.** It was therefore concluded that there is a significant difference in performance between printing firms that use Linear Programming and those who do not use the method.

The two subsidiary hypotheses helped the researcher to establish the fact of the applicability of linear programming to the allocation problems of a printing firm. The first one helped to establish the relevance of the method to the operations of a printing firm while the second one helped to establish the fact that firms that use linear programming method do better in resource allocation and achievement of optimality than other firms. These can only be possible if and only if the linear programming method is applicable to the operations of a printing firm.

4.4 APPLICATION OF LINEAR PROGRAMMING IN PRINTING

The second objective of this research work is **to find out if the linear programming method can be used to appropriately allocate the scarce resources of a printing firm in order to achieve optimality.** In order to achieve this objective, the researcher obtained production data from selected printing firms in Kaduna, Zaria and Jos and applied the linear programming method to the allocation problems.

These are as shown in the following sections:

Problem 1: Maximization

IDEAL MULTI PRESS Limited in Kaduna had a job order for the printing of two textbooks for publication and eventual sale among the students of Kaduna Polytechnic and other higher institutions in the North Central part of the country. The author had the intention of producing 1000 copies of each book at this first batch of production and more copies later on as need arises. The first book has 350 pages while the second book has 430 pages. The delivery of the first batch of production is expected in the next three months. The Production Manager analysed the production requirements as shown in the following table.

Table 21:

Job	Planning & Design	Colour Separation	Pre-press	Press	Finishing	Profit /Unit
Book 1	5	2 ½	3	5	2	₦150
Book 2	6	2 ½	2.5	8	1½	₦200
Available Time	12000 Man-hours	5250 Man-hours	5550 Man-hours	15200 Machine-hours	3450 Man-hours	

The Manager also knew that in order to break-even at least 500 copies of each book. The management wanted to know how many copies of each book could be printed within the available resources knowing that they are fixed for the time being:

Solution:

Let: Book 1 = X_1

Book 2 = X_2

Then the linear program for the Ideal Multi Press problem was formulated thus:

Objective Function		₦150 X1	+	₦200 X2		
Subject to:						
Constraint 1	Planning & Design	$5 X_1$	+	$6 X_2$	≤	12000 Man-hours
Constraint 2	Colour Separation	$2\frac{1}{2} X_1$	+	$2\frac{1}{2} X_2$	≤	5250 Man-hours
Constraint 3	Pre-press	$3 X_1$	+	$2\ 1/2\ X_2$	≤	5550 Man-hours
Constraint 4	Press	$5 X_1$	+	$8 X_2$	≤	15200 Man-hours
Constraint 5	Finishing	$2 X_1$	+	$1\frac{1}{2} X_2$	≤	3450 Man-hours
Constraint 6	Book 1	$1 X_1$	+	$0 X_2$	≥	500 Copies
Constraint 7	Book 2	$0 X_1$	+	$1 X_2$	≥	500 Copies
Non-Negativity Constraint		X_1	,	X_2	≥	0

Since the problem involved only two decision variables X_1 and X_2, two methods were available to the researcher. These were:

The Graphical method; and

The Simplex method.

Method 1: The Graphical Approach

The coordinates of X_1 and X_2 were computed and the results were plotted on the graph as follows:

(i) *Planning and Design Constraint*:

$$5X_1 + 6X_2 \leq 12000$$

$$Let\ X_2 = 0,\ then,\ 5X_1 = 12000$$

$$\therefore\ X_1 = 2400$$

$$Let\ X_1 = 0,\ then,\ 6X_2 = 12000$$

$$\therefore\ X_2 = 2000$$

$$\therefore\ (X_1, X_2)(2400, 2000)$$

(2) *Colour Separation Constra* int :

$$2\frac{1}{2}X_1 + 2\frac{1}{2}X_2 \leq 5250$$

Let $X_2 = 0$, *then*, $2\frac{1}{2}X_1 = 5250$

$\therefore \quad X_1 = 2100$

Let $X_1 = 0$, *then*, $2\frac{1}{2}X_2 = 5250$

$\therefore \quad X_2 = 2100$

$\therefore \quad (X_1, X_2)(2100, 2100)$

(3) Pre-*press Constra* int :

$$3X_1 + 2\frac{1}{2}X_2 \leq 5550$$

Let $X_2 = 0$, *then*, $3X_1 = 5550$

$\therefore \quad X_1 = 1850$

Let $X_1 = 0$, *then*, $2\frac{1}{2}X_2 = 5550$

$\therefore \quad X_2 = 2220$

$\therefore \quad (X_1, X_2)(1850, 2220)$

(4) Press *Constra* int :

$$5X_1 + 8X_2 \leq 15200$$

Let $X_2 = 0$, *then*, $5X_1 = 15200$

$\therefore \quad X_1 = 3040$

Let $X_1 = 0$, *then*, $8X_2 = 15200$

$\therefore \quad X_2 = 1900$

$\therefore \quad (X_1, X_2)(3040, 1900)$

(5) *Finishing Constra* int :

$$2X_1 + 1\frac{1}{2}X_2 \leq 3450$$

Let $X_2 = 0$, *then*, $2X_1 = 3450$

$\therefore \quad X_1 = 1725$

Let $X_1 = 0$, *then*, $1\frac{1}{2}X_2 = 3450$

$\therefore \quad X_2 = 2300$

$\therefore \quad (X_1, X_2)(1725, 2300)$

(6) *Book* 1 *Constra*int :

$$1X_1 + 0X_2 \leq 500$$
$$\textit{Then,}\quad X_1 = 500$$
$$\textit{and}\quad X_2 = 0$$
$$\therefore\quad (X_1, X_2)(500, 0)$$

(7) *Book* 2 *Constra*int :

$$0X_1 + 1X_2 \leq 500$$
$$\textit{Then,}\quad X2 = 500$$
$$\textit{and}\quad X_1 = 0$$
$$\therefore\quad (X_1, X_2)(0,500)$$

Choosing a scale of ***1cm to 200 units on both axes,*** the co-ordinates of X_1 and X_2 were plotted as shown in Graph 1(see Appendix 1).

Evaluation of the Feasible Region Vertices and the Determination of Their Coordinates

[a] Determination of Coordinates:

Vertex (*a*): C6 & C7

C6: $X_1 = 500$

C7: $X_2 = 500$

$\therefore\quad (X_1, X_2)(500,500)$

Vertex (*b*): C5 & C7

C5: $2X_1 + 1\frac{1}{2}X_2 = 3450$

C7: $X_2 = 500$

By substitution in C5.

$X_1 = [3450 - 750]/2$

$= 1350$

$\therefore\quad (X_1, X_2)(1350,500)$

Vertex (c): C1 & C5

$$C1: \quad 5X_1 + 6X_2 = 12000 \ldots x\,1$$
$$C5: \quad 2X_1 + 1\tfrac{1}{2}X_2 = 3450 \ldots x\,4$$

$$\begin{aligned} 5X_1 + 6X_2 &= 12000 \\ 8X_1 + 6X_2 &= 13800 \\ \hline 3X_1 &= 1800 \\ \therefore \quad X_1 &= \underline{600} \end{aligned}$$

By substituting for X_1 in C5,

$$X_2 = [3450 - 1200]/1.5$$
$$= 1500$$
$$\therefore \quad (X_1, X_2)(600, 1500)$$

Vertex (d): C1 & C6

$$C1: \ 5X_1 + 6X_2 = 12000$$
$$C6: \ X_1 = 500$$

By substitution in C1,

$$X_2 = [12000 - 2500]/6$$
$$= 1583.33$$
$$\therefore \quad (X_1, X_2)(500, 1583.33)$$

[b] Evaluation of the Vertices of the Feasible Region

It was found that the optimal solution lay on one of the vertices of the feasible region. The values of X_1 and X_2 in each of the vertices were substituted in the objective function to determine the highest profit. This shown below.

Objective Function = Max (z) N150 X_1 + ₦200 X2.

a	Vertex A	₦150 (500) + ₦200 (500)	=	₦175,000
b	Vertex B	₦150 (1350) + ₦200 (500)	=	₦302,500
c	Vertex C	₦150 (600) + ₦200 (1500)	=	₦390,000
d	**Vertex D**	**₦150 (500) + ₦200(1583)**	=	**₦391,600**

From the computations, it was found that the optimal solution was in Vertex D.

Decision Rule:

The vertex corresponding to the highest profit is the optimal solution.

Decision:

The management of Ideal Multi Press Limited, Kaduna should print only **500 Copies of Book 1** and **1583 Copies of Book 2** in order to make a maximum profit of **₦391, 600.00**

Method 2: The Simplex Approach

Program: Linear Programming

Problem: IDEAL MULTI PRESS PROBLEM (Computer Solution)

******* Input Data *******

Objective Function: (Max. Z) = ₦150 X1 + ₦200 X2

Subject to:

Constraint 1	Planning & Design	$5 X_1$	+	$6 X_2$	≤	12000 Man-hours
Constraint 2	Colour Separation	$2.5 X_1$	+	$2.5 X_2$	≤	5250 Man-hours
Constraint 3	Pre-press	$3 X_1$	+	$2.5X_2$	≤	5550 Man-hours
Constraint 4	Press	$5 X_1$	+	$8 X_2$	≤	15200 Man-hours
Constraint 5	Finishing	$2 X_1$	+	$1.5 X_2$	≤	3450 Man-hours
Constraint 6	Book 1	$1 X_1$	+	$0 X_2$	≥	500 Copies
Constraint 7	Book 2	$0 X_1$	+	$1 X_2$	≥	500 Copies
Non-Negativity Constraint		X_1	,	X_2	≥	0

In order to use the simplex method, it was necessary to set up the standard form of the Linear Program as follows:

Max (Z) 150 X_1 + 200 X_2 + OS_1 + OS_2 + OS_3 + OS_4 + $0S_5$ + $0S_6$

+ $0S_7$ - Ma_1 – Ma_2

Subject to:

$5X_1 + 6X_2 + 1s_1$	=	12000
$2.5X_1 + 2.5X_2 + 1s_2$	=	5250
$3X_1 + 2.5X_2 + 1s_3$	=	5550
$5X_1 + 8X_2 + 1s_4$	=	15200
$2X_1 + 1.5X_2 + 1s_5$	=	3450
$1X + - 1s_6 + 1a_1$	=	500
$1X_2 - 1s_7 + 1a_2$	=	500
$X_1 X_2, S_1, S_2, S_3, S_4, S_5, S_6, a_1 a_2$	≥	0.

***** **Program Output** *****

Simplex Tableau : 3

Cj / CB	Basis	Bi	150.000 X_1	200.00 X_2	0.000 S_1	0.000 S_2	0.000 S_3	0.000 S_4	0.000 S_5	0.000 S_6	0.000 S_7	-M A6	-M A7
0.000	S_7	1083.333	0.000	0.000	0.167	0.000	0.000	0.000	0.000	0.833	1.000	-0.833	-1.000
0.000	S_2	41.667	0.000	0.000	-0.417	1.000	0.000	0.000	0.000	0.417	0.000	-0.417	0.000
0.000	S_3	91.667	0.000	0.000	-0.417	0.000	1.000	0.000	0.000	0.917	0.000	-0.917	0.000
0.000	S_4	33.333	0.000	0.000	-0.333	0.000	0.000	1.000	0.000	-1.667	0.000	1.667	0.000
0.000	S_5	75.000	0.000	0.000	-0.250	0.000	0.000	0.000	1.000	0.750	0.000	-0.750	0.000
150.000	X_1	500.000	1.000	0.000	-0.000	0.000	0.000	0.000	0.000	-1.000	0.000	1.000	0.000
200.000	x_2	1583.333	0.000	1.000	-0.167	0.000	0.000	0.000	0.000	0.833	0.000	-0.833	0.000
	Zj	391666.667	150.000	200.000	33.333	0.000	0.000	0.000	0.000	16.667	0.000	-16.667	0.000
	Cj - Zj		0.000	0.000	-33.333	0.000	0.000	0.000	0.000	-16.667	0.000	-M	-M

Final Optimal solution

Z = 391666.667

Variable	Value	Reduced Cost
X 1	500.000	0.000
X 2	1583.333	0.000

Constraint	Slack/Surplus	Shadow Price
C 1	0.000	33.333
C 2	41.667	0.000
C 3	91.667	0.000
C 4	33.333	0.000
C 5	75.000	0.000
C6	0.000	-16.667
C7	1083.333	0.000

Objective Coefficient Ranges

Variables	Lower Limit	Current Values	Upper Limit	Allowable Increase	Allowable Decrease
X_1	No Limit	150.000	166.667	16.667	No Limit
X_2	180.000	200.000	No Limit	No Limit	20.000

Right Hand Side Ranges

Constraints	Lower Limit	Current Values	Upper Limit	Allowable Increase	Allowable Decrease
C 1	5500.000	12000.000	12025.000	25.000	6500.000
C 2	5208.333	5250.000	No Limit	No Limit	41.667
C 3	5458.333	5550.000	No Limit	No Limit	91.667
C 4	15166.667	15200.000	No Limit	No Limit	33.333
C 5	3375.000	3450.000	No Limit	No Limit	75.000
C6	480.000	500.000	600.000	100.000	20.000
C 7	No Limit	500.000	1583.333	1083.333	No Limit

***** **End of Output** *****

The computer solution to the simplex method shows that for the company to maximize profit, it must print **500 copies** of **Book 1** and **1583 copies** of **Book 2**. The total profit corresponding to this printing mix is **N391, 666.67**. This was the same the same as the solution to the graphical approach, the difference being due to rounding error.

With this combination, the company will have

a. 0 surplus man-hours in Planning and Design Department.
b. 41.667 surplus man-hours in Colour Separation Department.
c. 91.667 surplus man-hours in Pre- press Department.
d. 33.333 surplus machine-hours in the Press.
e. 75 surplus man-hours in Finishing Department
f. exactly 500 copies of Book 1
g. 1083 surplus copies of Book 2.

The shadow price for each man-hour in the Planning and Design Department is N33.33 and Book is –N16.67. It means one additional unit of man-hour will cost the firm N33.33 to procure while each additional copy of Book 2 will increase the value of the objective function by N16.67.

PROBLEM 2: MAXIMIZATION

The Regent Printing and Publishing Limited based in Kaduna is one of the biggest printing houses in the areas covered by the study. The company had orders for the printing of four items: Admission Brochures, Small Advert Posters, Large Advert Posters and Receipt/Invoice Booklets. The company had budgeted 2 weeks within which the job must be completed and delivered. Management was not sure of being able to do all the jobs after doing the analysis of production requirements and wishes to decide which of the jobs should be accepted and which should be rejected or postponed because of the current production limitations. The Production Manager supplied these as follows:

	Paper Reams	Machine 1 Hours	Machine 2 Hours	Finishing Hours	Packaging Hours	Unit Profit
Brochures	2	4	2	2	1	N20
Small Posters	2	1	1	1	2	N20
Large Posters	4	2	2	2	2	N18
Receipt Booklet	3	1	1	1	1	N15
Available Resources	2000 Reams	2700 Hours	1500 Hours	1500 Hours	1200 Hours	

In order to determine the job the company should accept and what quantities can be handled efficiently. The Linear Programme was set up and computer solution obtained as follows:

a. Linear Program:

Let: Brochures = X_1

Small Posters = X_2

Large Posters = X_3

Receipt Booklets = X_4

Hence: Objective function Max (z) N20 X_1 + N20 X_2 + N18 X_3 + N15 x 4

Subject to:

Constraints: Paper Constraint: $2X_1 + 2X_2 + 4X_3 + 3X_4 \leq$ 2000 Reams

Machine 1 Constraint: $4X_1 + 1X_2 + 2X_3 + 1X_4 \leq$ 2700 Hours

Machine 2 Constraint: $2X_1 + 1X_2 + 2X_3 + 1X_4 \leq$ 1500 Hours

Finishing Constraint: $2X_1 + 1X_2 + 2X_3 + 1X_4 \leq$ 1500 Hours

Packaging Constraint: $1X_1 + 2X_2 + 2X_3 + 1X_4 \leq$ 1200 Hours

$X_1, X_2, X_3, X_4 \geq 0.$

Standard Form:

Max (z) = $20 X_1 + 20 X_2 + 19 X_3 + 15 X_4 + OS_1 + OS_2 + OS_3 + OS_4$

Subject to:

C1: $2 X_1 + 2 X_2 + 4 X_3 + 3 X_4 + 1 s_1 = 2000$

C2: $4 X_1 + 1 X_2 + 2 X_3 + 1 X_4 + 1 s_2 = 2700$

C3: $2 X_1 + 1 X_2 + 2 X_3 + 1 X_4 + 1 s_3 = 1500$

C4: $2 X_1 + 1 X_2 + 2 X_3 + 1 X_4 + 1 s_4 = 1500$

C5: $1 X_1 + 2 X_2 + 2 X_3 + 1 X_4 + 1 s_5 = 1200$

$X_1, X_2, X_3, X_4, S_1, S_2, S_3, S_4, S_5, \geq 0.$

Solution:

The final optimal solution was obtained through the computer as follows:

Program: Linear Programming

Problem Title: The Regent Printing and Publishing Limited - Kaduna

***** **Input Data** *****

MAX. Z = 20 X 1 + 20 x 2 + 18 X 3 + 15 x 4

Subject to:

C1 2x1 + 2x2 + 4x3 + 3x4 < = 2000

C2 4x1 + 1x2 + 2x3 + 1x4 <= 2700

C3 2x1 + 1x2 + 2x3 + 1x4 < = 1600

C4 2x1 + 1x2 + 2x3 + 1x4 < = 1500

C5 1x1 + 2x2 + 2x3 + 1x4 < = 1200

***** **Program Output** *****

Simplex Tableau: 0

Cb/Cj	BASIS	Bi	20 X 1	20 X 2	18 X3	15 X 4	0 S1	0S 2	0 S 3	0 S4	0. S5
0	S 1	2000	2	2	4	3	1	0	0	0	0
0	S 2	2700	4	1	2	1	0	1	0	0	0
0	S 3	1600	2	1	2	1	0	0	1	0	0
0	S 4	1500	2	1	2	1	0	0	0	1	0
0	A 5	1200	1	2	2	1	0	0	0	0	1
	Zj	0	0	0	0	00	0	0	0	0	0
	Cj-Zj		20	20	18	15	0	0	0	0	0

Simplex Tableau: 1

Cb/Cj	BASIS	Bi	20. x 1	20 x 2	18 x 3	15 x 4	0. s1	0. S 2	0. S 3	0. S4	0. 55
0	S 1	650	0	1.500	3.000	2.500	1	-0	0	0	0
20	X 2	675	1	0.250	0.500	0.250	0	0	0	0	0
0	S 3	250	0	0.500	1.00	0.500	0	-0	1	0	0
0	S 4	150	0	0.500	1.00	0.500	0	-0	0	1	0
0	A 5	525	0	1.750	1.500	0.750	0	-0	0	0	1
	Zj	13500	20	5	10	5	0	5	0	0	0
	Cj-Zj		0	15	8	10	0	-5	0	0	0

Simplex Tableau: 2

Cb/Cj	BASIS	Bi	20. x 1	20 x 2	18 x 3	15 x 4	0. s1	0. S 2	0. S 3	0. S4	0. S5
0	S 1	200	0	0	0	1	1	1	0	-3	0
20	X 2	600	1	0	0	0	0	0.500	0	-0	0
0	S 3	100	0	0	0	0	0	0	1	-1	0
20	X 4	300	0	1	2	1	0	-1	0	2	0
0	S 5	0	0	0	-2	-1	0	1.500	0	-3	1
	Zj	18000	20	20	40	20	0	-10	0	30	0
	Cj-Zj		0	10	0	-30	0	0	0	0	0

Simplex Tableau: 3

Cb/Cj	BASIS	Bi	20. x 1	20 x 2	18 x 3	15 x 4	0. s1	0. S 2	0. S 3	0. S4	0. S5
0	S 1	200	0	0	1.333	1.667	1	0	0	-0	-0.667
20	X 2	600	1	0	0.667	0.333	0	0	0	0	-0.333
0	S 3	100	0	0	0	0	0	0	1	-1	0
20	X 2	300	0	1	0.667	0.333	0	0	0	-0	0.667
0	S 2	0	0	0	-1.333	-0.667	0	1	0	-2	0.667
	Zj	1800	20	20	26.667	13.333	0	0	0	6.667	6.667
	Cj-Zj		0.000	0	-8.667	1.667	0	0	0	-6.667	-6.667

Simplex Tableau: 4

Cb/Cj	BASIS	Bi	20. x 1	20 x 2	18 x 3	15 x 4	0. s1	0. S 2	0. S 3	0. S4	0. S5
0	X 4	120	0	0	0.800	1.000	0.600	0	0	-0	-0.400
20	X 1	560	1	0	0.400	0	0.600	0	0	0.800	-0.200
0	S 3	100	0	0	0	0	-0.200	0	0	-1	0
20	X 2	260	0	1	0.400	0	0.200	0	0	-0.200	0.800
0	S 2	80	0	0	-0.800	0	0.400	1	0	-2.600	0.400
	Zj	18200	20	20	28	15	1	0	0	6	6
	Cj-Zj		0	0	-10	0	-1	0	0	-6	-6

Final Optimal Solution

Z = 18200

Variable	Value	Reduced Cost
X 1	560	0
X 2	260	0
X 3	0	10
X 4	120	0

Constraint	Slack/Surplus	Shadow Price
C 1	0	1
C 2	80	0
C 3	100	0
C 4	0	6
C 5	0	6

Objective Coefficient Ranges

Variables	Lowe Limit	Current Values	Upper Limit	Allowable Increase	Allowable Decrease
X 1	12.500	20	25	5	7.500
X 2	12.500	20	25	5	7.500
X 3	No Limit	18	28	10	No Limit
X 4	13.333	15	30	15	1.667

Right Hand Side Ranges

Constraints	Lowe Limit	Current Values	Upper Limit	Allowable Increase	Allowable Decrease
C 1	1800	2000	3300	13000	200
C 2	2620	2700	No Limit	No Limit	80
C 3	1500	1600	No Limit	No Limit	100
C 4	800	1500	1530.769	30.769	700
C 5	1000	1200	1500	300	200

***** **End of Output** *****

The Computer solution of the Regent problem shows that the Company can only take 3 of the orders. The production mix will be as listed below.

X_1 (Brochure) = 560 copies

X_2 (Small Posters) = 260 copies

X_3 (Large posters) = 0 Copies

X_4 (Receipt Booklets) = 120 Copies

The total profit (highest) associated with this mix was **N18, 200.00.**

The Company should therefore postpone the order for the printing of large posters.

With this solution, the company would have a slack or unused 80 hours of machine 1 and 100 hours of machine 2. All the available reams of paper as well as all the available time in Finishing and Packaging departments would be used up.

The solution shows a shadow price of N1 for the ream constraint while each of Finishing and Packaging constraints has a shadow price of N6. This means each additional ream of paper is worth N1 to the Regent Printing Company while each additional hour of Finishing and Packaging would be worth N6 to the company.

PROBLEM 3: MINIMIZATION

Alpha Digital Press Limited, Kaduna had four different types of jobs to handle over a period of two weeks. Each job had different material input, which cannot be kept for long in store. They must be used up within the next two weeks in order to avoid any form of wastage. The press manager produced the estimate for each job and summarized the production requirements as follows:

Table 24

	Journal	Calendars	Manual	Requirement
Colour 1	2	3	1	5000 Litres
Colour 2	2	4	1½	6535 Litres
Chemical	1½	2	1½	3565 Litres
Varnish	1½	3	2	5250 Litres

The Manager also came up with the following conditions:

a) At least 300 journals, 600 calendars and 400 manuals must be printed;
b) The average costs of production are Journal, N150; Calendar, N80; and Manual, N60.

The Management wanted to determine the minimum cost associated with the production mix because any unused material cannot be stored fur further use.

Solution:

Let Journal = X_1
Calendar = X_2
Manual = X_3

Objective Function N150 X_1 + N80 X_2 + N60 X_3

Subject to:

Colour 1	2 X_1	+	3 X_2	+	1 X_3	≥	5000	Litres
Colour 2	2 X_1	+	4X_2	+	1 ½ X_3	≥	6535	Litres
Chemical	1 X_1	+	2 X_2	+	1 ½ X_3	≥	3565	Litres
Varnish	1 ½ X_1	+	3 X_2	+	2 X_3	≥	5250	Litres
Journals	1 X_1	+	0 X_2	+	0 X_3	≥	300	Copies
Calendar	0 X_1	+	1 X_2	+	0 X_3	≥	600	Pieces
Manual	0 X_1	+	0 X_2	+	1 X_3	≥	400	Copies
Non-negativity Constraint				X_1, X_2, X_3		≥	0	

Since the problem involved three basic variables, only the simplex method was applicable to the problem.

The Simplex Approach:

To use the simplex method, we must change the minimization problem to maximization and set up as follows:

Max Z = - N150 X_1 + N80 X_2 + N60X_3 +OS_1 + OS_2 + OS_3 + OS_4 + OS_5 + OS_6 + OS_7 –Ma_1 –Ma_2 - Ma_3 –Ma_4 –Ma_5 – Ma_6 –Ma_7

Subject to:

$2X_1 + 3X_2 + 1X_3 - 1s_1 + 1a_1 = 5000$

$2X_1 + 4X_2 + 1½X_3 - 1s_2 + 1a_2 = 6535$

$1X_1 + 2X_2 + 1½X_3 - 1s_3 + 1a_3 = 3565$

$1½X_1 + 3X_2 + ¼X_3 - 1s_4 + 1a_4 = 5250$

$1X_1 + 0X_2 + 0X_3 - 1s_5 + 1a_5 = 300$

$0X_1 + 1X_2 + 0X_3 - 1s_6 + a_6 = 600$

$0X_1 + 0X_2 + 1X_3 - 1s_7 + 1a_7 = 400$

$X_1, X_2, S_1, S_2, S_3, S_4, S_5, S_6, S_7, a_1, a_2, a_3, a_4, a_5, a_6, a_7 \geq 0.$

The computer solution to the Simplex formulation was obtained as follows:

Program: Linear Programming

Problem Title: Alpha Digital Printers Limited, Kaduna

******* Input Data *******

Min. Z = N150 X_1 + N80 X_2 + N60 X_3

Subject to:

C1	2 X_1	+	3 X_2	+	1 X_3	>=	5000
C2	2 X_1	+	4X_2	+	1.5 X_3	>=	7535
C3	1 X_1	+	2 X_2	+	1.5 X_3	>=	3565
C4	1.5 X_1	+	3 X_2	+	2 X_3	>=	5250
C5	1 X_1	+	0 X_2	+	0 X_3	>=	300
C6	0 X_1	+	1 X_2	+	0 X_3	>=	600
C7	0 X_1	+	0 X_2	+	1 X_3	>=	400

***** **Program Output** *****

Simplex Tableau: **10**

Cj / Cb	BASIS	Bi	150 X1	80 X2	60 X3	0.000 S 1	0.000 S 2	0.000 S 3	0.000 S 4	0.000 S5	0.000 S6	0.000 S7
150.000	X 1	300.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	-1.000	0.000
0.000	S 5	733.750	0.000	0.000	0.000	0.000	-0.250	0.000	0.000	1.000	0.500	0.375
60.000	X 3	400.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	-1.000
0.000	S 3	2.5000	0.000	0.000	0.000	0.000	-0.500	1.000	0.000	0.000	0.000	-0.750
80.000	X 2	1333.750	0.000	1.000	0.000	0.000	-0.250	0.000	0.000	0.000	0.500	0.375
0.000	S 1	1.250	0.000	0.000	0.000	1.000	-0.750	0.000	0.000	0.000	-0.500	0.125
0.000	S 4	1.250	0.000	0.000	0.000	0.000	-0.750	0.000	1.000	0.000	-0.000	-0.875
	Zj	175700.000	150.000	80.000	60.000	0.000	-20.000	0.000	0.000	0.000	-110.000	-30.000
	CJ - Zj		0.000	0.000	0.000	0.000	-20.000	0.000	0.000	0.000	-110.000	-30.000

Cj / Cb	BASIS	Bi	MA 1	MA 2	MA 3	MA 4	MA 5	MA 6	MA 7
150.000	X 1	300.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000
0.000	S 5	733.750	0.000	0.250	0.000	0.000	-1.000	-0.500	-0.375
60.000	X 3	400.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000
0.000	S 3	2.5000	0.000	0.500	-1.000	0.000	0.000	0.000	0.750
80.000	X 2	1333.750	0.000	0.250	0.000	0.000	0.000	-0.500	-0.375
0.000	S 1	1.250	-1.000	0.750	0.000	0.000	0.000	0.500	-0.125
0.000	S 4	1.250	0.000	0.750	0.000	-1.000	0.000	0.000	0.875
	Zj	175700.000	0.000	19.984	0.000	0.000	0.000	110.000	30.000
	CJ - Zj		-M	-M	-M	-M	-M	-M	-M

Final Optimal Solution
Z = 175700.000

Variable	Value	Reduced Cost
X 1	300.000	0.000
X 2	1333.750	0.000
X 3	400.000	0.000

Constraint	Slack/Surplus	Shadow Price
C 1	1.250	0.000
C 2	0.000	-20.000
C 3	2.500	0.000
C 4	1.250	0.000
C 5	733.750	0.000
C 6	0.000	-110.000
C 7	0.000	-30.000

Objective Coefficient Ranges

Variables	Lower Limit	Current Values	Upper Limit	Allowable Increase	Allowable Decrease
X 1	40.000	150.000	No Limit	No Limit	110.000
X 2	0.000	80.000	160.000	80.000	80.000
X 3	30.000	60.000	No Limit	No Limit	30.000

Right Hand Side Ranges

Constraints	Lower Limit	Current Values	Upper Limit	Allowable Increase	Allowable Decrease
C 1	No Limit	5000.000	5001.250	1.250	1525.000
C 2	6533.33	6535.000	No Limit	No Limit	No Limit
C 3	No Limit	3565.000	3567.500	2.500	No Limit
C 4	No Limit	5250.000	5251.250	1.250	No Limit
C 5	No Limit	600.000	1333.750	733.750	No Limit
C 6	297.500	300.000	1767.500	1467.500	300.000
C 7	398.571	400.000	410.000	10.000	400.000

***** **End of Output** *****

· The Computer solution to the ALPHA problem shows that for the firm to minimize the cost of this production mix, it must print only 300 copies of the Journal, 1334 copies of the Calendar and only 400 copies of the Manual. The minimum cost associated with this is ₦175, 700.00.

There are 754 calendars over and above what is required. There will be unused 1.250 litres of colour 1, 2.500 litres of the chemical substance and 1.250 litres of varnish. These represent the amount of wasted resources associated with the production plan. They are not critical to the entire production plan. Hence, they are said to be REDUNDANT. However, Colour 2, Journals and the Manual constraints are binding on the optimal solution. That is why they have shadow costs of ₦20.00, ₦110.00 and ₦30.000 respectively.

4.5 SUMMARY OF FINDINGS

After analysing the data obtained for the purpose of this research work, testing the hypotheses (main and subsidiary) and applying linear programming method to the test data, the findings of this research work can be summarised as follows.

a. Majority of the firms in the printing and publishing industry are actually engaged in only the printing business. In fact most do not know what publishing is all about.

b. Most of the firms in the industry are very young having been in business for less than 5 years. As a result, they are limited in scope of operations, capacity and personnel recruitment. Of the firms surveyed, only 55 (about 37%) were up to 10 years or more, only 31% had at least one General Manager and only 32% had up to 5 departments/units or more.

c. The level of literacy in the industry is encouraging. 17% of the firms surveyed employed first-degree holders while 24 employed persons with higher qualifications. Only 9% of the firms employed persons with no formal education.

62% of the firms employed school certificate and Ordinary National Diploma holders.

d. Most firms in the industry use the mental judgement for resource allocation. About 74% of them do this. The remaining 26% use budgetary procedures. No other method of allocation was in use. Although most firms agreed to the superiority of linear programming model, they were not willing to change from the current practice.

e. The use of mathematical model is only known to a good number of people in the industry as a result of low level of inadequate training and exposure.

f. The use of linear programming is very relevant to the activities of the printing firm. It can be effectively used to allocate resources either for cost minimization and/or profit maximization.

g. Linear programming method could improve the efficiency of allocation done by the firms if they understand the method and comply with the rules. The test data obtained from the 3 firms confirm this phenomenon. None of the firms has ever tried it. Most firms actually would have liked to use it because they believe they would do better and be more efficient, but for the complexity of use.

h. The principal reason firms do not use the linear programming method is that the employees are not exposed enough to understand the system. Besides, they are so convinced of the efficacy of their current methods of allocation that the desire to try out a seemingly more complicated but sophisticated process of doing the same thing is not there at all.

I. By inference, it was found out that manyf firms could avoid most unprofitable jobs they engage in and wastages they record if only they use the linear programming method. There is no way mental judgement would have the accuracy and precision of the linear programming method.

4.6 CONCLUSION

In this chapter, the linear programming method had been applied to the allocation problems of printing firms and the analysis have shown that whether the firm's objective is the maximization or the minimization of some function, the method is both effective and efficient enough to achieve that. This strengthens our hypothesis that the application of linear programming will significantly improve the operational and allocational efficiency of printing firms.

Having interpreted the results of the analyses of data in this chapter, the next chapter will be devoted to drawing reasonable conclusions and making useful recommendations towards the solution of the research problem.

CHAPTER FIVE

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1 SUMMARY:

This research work has highlighted the applicability of the linear programming method to the allocation problems of printing firms. It has also shown that the method can be used to appropriately allocate scarce resources in order to achieve optimality, efficiency and improved performance.

The basic assumption of the study is that no printing firm in Nigeria currently uses this method for allocating scarce resources and this accounts for why many of the firms are sub-optimal.

One major hypothesis and two subsidiary hypotheses were tested and the results show that the application of linear programming method to resource allocation will allow printing firms in Nigeria to achieve optimality, greater efficiency of operations and better management.

Sample production data obtained from selected printing firms were used to prove the efficiency of the linear programming method after which the research findings were summarised.

5.2 CONCLUSIONS:

The following conclusions were drawn from the study:

i. The use of linear programming method is relevant to the operations of a printing firm;

ii. The application of the linear programming method will significantly increase the ability of a printing firm to achieve optimality in resource allocation;

iii. The performance of the firms using linear programming for resource allocation will be significantly better than the performance of those using other methods to allocate their own resources;

iv. Many printing firms do not use the method because their employees are either:

   a. Not necessarily illiterate, but have no adequate exposure;
   b. Unwilling to change from the old methods; or
   c. Are not convinced it will make any difference.

v. More academic and industrial exposure will help the employees in the printing industry to learn and appreciate the use of the linear programming method of resource allocation.

5.3 RECOMMENDATIONS:

Based on the conclusions drawn above, the following recommendations are hereby given:

1. Printing firms should adopt the use of the linear programming method for resource allocation because will help them to:
   a) Achieve optimality in the use of scarce resources,
   b) Minimize waste and improve management efficiency,
   c) Decide in advance, what to do and what not to do. That is early determination of the feasibility or otherwise of a project will be made possible.
2. More academic institutions in Nigeria should incorporate Printing Technology in to their curricular so that many more people can be educated and trained well enough to be able to use such mathematical models.
3. The government should get involved in the regulation of the Printing Profession/business by specifying standards of quality and minimum qualifications acceptable for certain key positions in the printing industry.

4. The owners of printing businesses should endeavour to train their staffs and give them enough educational and industrial exposure to enable them embrace and use such mathematical models.

5. An organized body should be set up to monitor, register and control the activities of the printing firms in the country. The body will, in addition, be responsible for the training of professionals and accrediting them in the country. For example **"Nigerian Institute of Printing Technology"** or **"Chartered Institute of Printers, of Nigeria"**.

   Such a body will also organize periodic seminars, workshops and so on with the aim of acquainting members with the current developments in the industry, both at local and international levels.

5.4 LIMITATIONS OF STUDY

A number of factors among which are the under listed limited this study:

a. **The study population:** - ideally, this study should have taken into consideration all the printing firms in the Nigerian polity. However, due to the sheer size of the country, the researcher could not visit all these firms and had to limit his survey and questionnaire administration to only the Kaduna metropolis. Thus the mere use of a sample for drawing inference is itself enough limitation

b. **The list of registered firms:** - the researcher went through difficult times in the hands of the Association of Nigerian Printers before he could obtain the valid list of registered printing organisations in Kaduna Metropolis. Despite the letter presented by the researcher from the school, the Association's Secretariat believed that the information sought by the researcher was meant for some other purpose than the one declared. As a result, the research work could not be completed within the expected period.

c. **Other resource constraints**: - the other factors limiting the research work were time, financial and material constraints. As it would be expected, the researcher tried his best but certainly had no access to **all** the financial and materials required for this research work. In addition, he did not have all the time in the world to do the work since there was a time limit within which all the work must be finished. Therefore, the validity, accuracy, correctness and reliability of the entire work depend heavily on these and the afore-mentioned vitiating factors.

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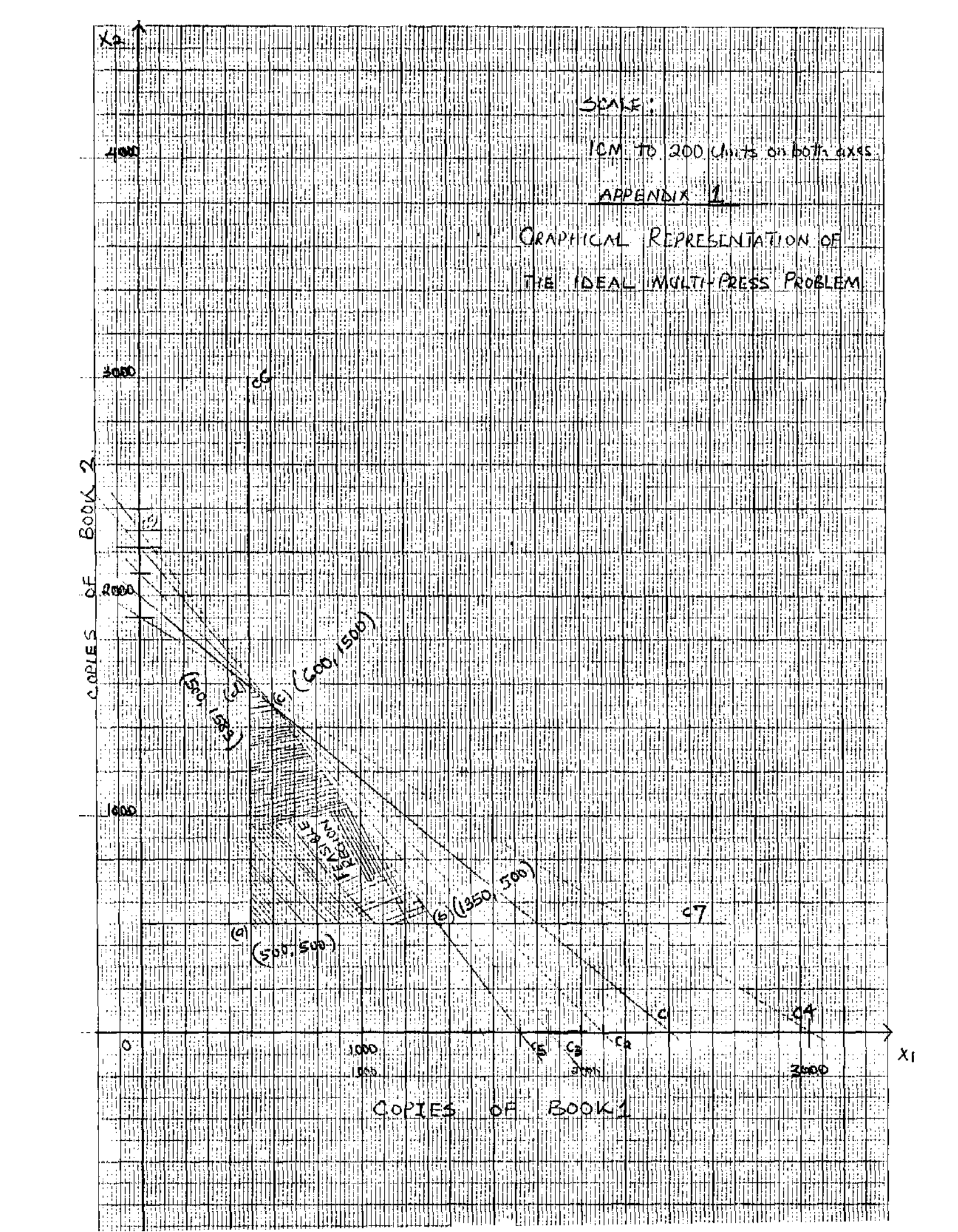
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SCALE:
1CM TO 200 Units on both axes
APPENDIX 1
GRAPHICAL REPRESENTATION OF
THE IDEAL MULTI-PRESS PROBLEM
X_2
X_1
COPIES OF BOOK 2
COPIES OF BOOK 1
3000
2000
1000
0
1000
3000
C_5
C_3
C_6
C_7
C_4
C
(500, 1500)
(600, 1500)
(1350, 500)
(500, 500)
INFEASIBLE
FEASIBLE

APPENDIX 2

RESEARCH QUESTIONNAIRE

Dear Respondent,

Kindly complete the questionnaire and answer the questions contained therein as honestly and objectivity as possible. The information will be confidential and used only for academic purposes.

Thank you.

Please Tick (√)

1. What exactly does your company do?

Printing ☐ Publishing ☐ Both ☐

2. How old is your organization?

0-5 ☐ 5-10 ☐ Over 10 years ☐

3. How many departments/units do you have? Less than 3 ☐

4 ☐ 5 ☐ 6 ☐ More than 6 ☐

4. What is the status of departmental/unit heads?

Supervisors ☐ Managers ☐ General Managers ☐

5. What is the minimum qualification for a unit or department head?

SSCE/GCE/OL/CITY & GUILD ☐ OND/HSC/NCE ☐

HND/DSC/BA ☐ Higher Degrees ☐ No Precise Qualification ☐

6. What methods do you use in allocating your human, material and Financial Resources?

Metal Judgement/Calculation ☐

Budgetary Procedure ☐

Clearly Defined Mathematical model like Linear Programming ☐

Any Other (Specify) ☐

7. Is the method of allocation adequate and effective?

Yes ☐ No ☐

8. What are the factors influencing your methods of resource allocation?

(Please List) as .....

.....

9. Would you say that illiteracy on the part of staff would hinder application of a clearly defined mathematical model for resource allocation?

Yeas ☐ No ☐

10. Have you heard about **Linear Programming**? Yes ☐ No ☐

11. Do you think that Linear Programming is relevant at all to you company's operations?

Very Relevant ☐

Relevant ☐

Not Very Relevant ☐

Not Relevant at all ☐

12. Have you ever tried using it to allocate your resources? Yes ☐ No ☐

13. Would you prefer it to present method of allocation? Yes ☐ No ☐

14. Do you think this mathematical model will be more effective and efficient than your current method of allocation? YES ☐ NO ☐

15. Do you think that your organization will perform better if it uses **Linear Programming?** Yes ☐ No. ☐

16. Do you think that firms using **Linear Programming** will perform better than those using mental judgement calculations?

Big Difference ☐

Small Difference ☐

No Difference ☐

17. do you think more training exposure will stimulate the staff interest in such a method **Linear Programming** for resource allocation? Yes ☐ No ☐

18. Any other comments if any?

APPENDIX 3

LIST OF PRINTING FIRMS VISITED IN KADUNA METROPOLIS

S /NO	NAME OF PRINTING FIRM	ADDRESS OF PRINTING FIRM
1	A J Y Press & Company	NH 10, Ibibio Road, P.O.Box 7075. Kaduna
2	A.M.B. Ventures (Nig) Limited	V.V.14 Nassarawa Road P.O. Box 10297, Kaduna Tel: 062-240402
3	A.O. Mark & Co.	6.Cameroun Road, off Gwari Road Kaduna
4	Adaga Graphic Press Limited	D4 Gwari/Cameroun Road, Kaduna.
5	Ade Clear Types Press Ltd	RF 5/7 Jos Road Kaduna P.O.Box 3695 Kaduna Tel: 062-241854
6	Ade Royal Arts (Nig) Enterprises	BZ76 Damask Rd S/Crescent Kaduna Tel: 062-234179
7	Adenic Nigeria Limited	U.V.5, Keffi Road, Kaduna P.O.Box 7742, Kaduna Tel. 062-240918, 247093. Fax: 062-246646.
8	Adewale printing works Ltd.,	AN 13, junction Road Keffi Road. P.O. Box 9267, Kaduna.
9	Advance concepts	NB19 Muri Road by Shopping Complex, Kaduna
10	Akanji Ade printers	NJ. 14, Gwari Road, P.O. Box 921, Kaduna (South), Tel: 062-244951, 211664
11	Akeje Rasmo Professional Printers	A12 Nupe Road P.O.Box 8563 Kaduna, Tel: 062-240513.
12	Al – Shura Press Limited	12 Mambilla Road, Malali, Kaduna
13	Allsorts Network Limited	N.H, 14 Ibibio / Lokoja Road, Kaduna 0803-7865758, 062-243665, 230633
14	Alpha Digital Press Limited	(A Division of Alpha Technologies Ltd.) NC 12 Muri Road P.O. Box 10793, Kaduna, Tel: 062-231911, 090-806013
15	Amen Press Limited	AU.20, Kano/Calabar Street Kaduna
16	AN-NUR-Graphics	RR10 Nasarawa Road, by Lagos Street, Kaduna. Tel: 062-241296
17	Arewa Printers Limited	4, Cameroun / Gwari Road Kaduna
18	Atman Limited	C 17 Rimi Road, Kaduna Costain by Constitution Road P. O. Box 1000 Kaduna Tel: 062-245601,210553,233105.
19	Atolabi Isiaka & Co. Limited Kaduna	J.14 Gubuchi Road, (Near Tudun Wada Roundabout) off Poly Road, P.O.Box 8997 Kaduna. Tel: 062-412203
20	Ayokunle Printers Ltd	NA 19, Gwari/Muri Road Kaduna.

21	Balu Nigeria Limited	34, Ali Akilu Road Tel:062-217588
22	Bamed Engineering Services	58 Yoruba Road, Kaduna RF 5&7, Jos Road Kaduna Tel: 062-216381, 241854
23	Baraka Press and Publishers Limited	Ahmadu Bellow Way, Opposite Arewa Chinese Restaurant, Kaduna.
24	Bowofola Nigeria Printers Limited	UU 4 Kazaure Road, Kaduna.
25	Coapalprints & Int,L Services Ltd.	Kaduna office: NC11.Lagos Street/Muri Road Kaduna Tel: 062-210184.
26	Dekachi Graphics Supply	N.N.9, Lokoja Road, P.O.Box Kaduna Tel: 062-210261
27	Ebenezer Graphics Printers	NC.2 Jamaa Road P.O. Box 2901 Kaduna Tel: 062-215397
28	Espee Printing & Advertising	F.60 Ruwan Godiya Close, Ungwa Sarki Kaduna P.O. Box 3566 Kaduna Tel:062-210263
29	Felipet (Nigeria) Limited	AN 20, Lagos Street, P.O.Box 8815, Kaduna Tel: 062-240485
30	Festade Printing & Publishing Co.	1st Floor 20, Lagos /Keffi Road, Kaduna. Tel:062-240185
31	Glemco Glitter Printers	No3, Gwari Road, Kaduna P.O.Box 2898 Kaduna Tel: 062-240686, 242135
32	Goldpeak Printers	N.A. 12 Gwari Road by Cameroun Rod off Junction Road P.O. Box 5409, Kaduna 240472
33	Hakins Nigeria Limited	K.18 Ibadan Street Box 1871 Kaduna Tel: 062-214542
34	Hazab Printers Limited	NH3 Muri Road, Kaduna Tel: 062-218219
35	Highlite Productions (Nig) Ltd.	A.J 11 Yoruba Road Kaduna P.O.Box 717, Kaduna Nigeria Tel: 062-240686, 242135
36	ICS Press	UU11, Keffi Road by Lagos Street P.O. Box 2744 Kaduna
37	Ideal Multi Press Limited	BZ 68 Abuja Road, Kaduna.
38	Imam Press Limited	XX13, Adamawa / Ibadan Street Kaduna. Tel: 062-212225
39	J.J Graphic Printers	ND7, Abubakar Kigo Road P.O.Box 4156, Kaduna Tel: 062-232121
40	Kaduna State Government Press	Yakubu Gowon, Opposite National Archives Office Kaduna
41	Karl Prints Nigeria Limted	Ground Floor, Royal Electronics Building, Junction Road, Kaduna. Tel. 062-240143
42	Kazoga (Nig) Ltd	N.B 415, Jemaa Road, P.O.Box 7993, Kaduna Tel.: 248732 Fax: 248590
43	Klemko Glitter Prints	Suite 23 Gwari Road New Shopping Complex off junction/Cameroun Road Kaduna Tel: 062-240875,310133 Res.

44	Kusi Prints Limited	No.3 Gwari Road. P.O.Box 2898 Kaduna Tel:240875
45	Labari Communications	N.J.18 Gwari Road, Kaduna Tel: 062-218175
46	Leo Wealth Graphics	NH. 1, Muri/Yauri Road, Kaduna Tel:062-241005
47	Mach' Graphics Press Ltd	NA.16, Gwari Road Kaduna
48	Majesty Prints	NA.16, Muri Road Kaduna
49	Majiyebo Int;L Printers Ltd.,	NA 21, Gwari Road, Kaduna P.O. Box 3293 Kaduna Tel: 062-216420,236234
50	Mansiho Limited	N.B.12, Muri Road Kaduna Tel: 062-241920
51	Mediads Associates	2, Dendo Road Kaduna Tel: 062-242457
52	Mers Ventures	NB16 Muri /Lagos Street Kaduna Tel:062-240313
53	Mogba Tech. Graphics Press	AK 36A, Wushishi Road, Oriakpkata Kaduna Tel: 062-216275
54	Mulaco Press Limited	6 Block 17, Makera Road, Kaduna South. Tel: 062-233974, Res. 062-232632
55	NASARA Press Limited	AJ 26 Zaria Road, (West) P.O.Box, Kaduna Tel: 062-241478, 246861.
56	Nation House Press Limited	Light Industrial Zone, Nnamdi Azikiwe Road, Trikania, Kaduna.
57	Nigerian Army 1st Division Printing Press	Ali Akilu Road, Oppsite Former UTC Stores, Kaduna.
58	Nora Graphics	37/38, Lokoja Road, Shopping Complex Kaduna Tel: 062-240601
59	Obadaki Printing Press	26 – 28 Kinshasa Road, Angwan Rimi, Kaduna
60	Ojimick Investment Limited	N.A 17 Gwari Road Kaduna Tel: 062-240596
61	Oju Printing Press	V.V. 15, Nassarawa Road by Hospital City Special P.O. Box 8857 Kaduna Tel:062-217864, 240402
62	Perfect Prints	U.U.11, Lagos Street/Keffi Road Kaduna Tel: 062-211899
63	Primeraft Nig. Limited	NH4 Ibiblo Road, Opp. One Nigeria Hotel Kaduna Tel: 062-232538
64	Printlink Nigeria Limited	S.84, Nassarawa Road Kaduna Tel: 062-241713,240402
65	Salient Ventures Limited	NC10 Abubarkar Kigo Road Kaduna P.O. Box 9009 Kaduna Tel: 062-247692, 802256
66	Samayo Press Limited	A4 Katsina / Independence Way, Kaduna

67	Sebolarc Printing Press	AK 27 Wushishi Road By Ori Apata Kaduna P.O. Box 3880 Tel: 062-247692,802256
68	Shukurah Printers Limited	AH 6A, Gamagira Road Tudun Wada P.O. Box 7663, Kaduna Tel: 062-410354 E-mail shukuraprinters@yahoo.com
69	Slimline Communication Limited	NO.14 Muri Road Kaduna
70	Success Systems (Graphic Printers)	9, Yakubu Gowon way, P.O.Box 7600, Kaduna Tel:062-230501
71	The Regent Printing & Publishing Ltd.	Dabson Link/Argungu Road, off Katsina Road, Kaduna. Tel: 062-24241756,239587241607. Fax:062-239587
72	Thunder bold Business Services	Investment House (3rd Floor) 27, Ali Akilu Road P.O. Box 2057. Kaduna
73	TJ Graphics & Printers Limited	B2 Kazaure Road, Kaduna.
74	Truprints Production Limited	ND10, Lokoja Road, Kaduna Tel: 062-236402 Res.
75	Waato Press & Publishers Limited	1, Bida Road, P.O. Box 703 Kaduna
76	Welsak Nigeria Limited	B7, 74, Sardauna Crescent, Abuja Road, P.O. Box 4641 Kaduna Tel: 062-237279,247207
77	White House Press Limited	NA 12 Gwari / Cameroon Road, Kaduna.
78	Wura Graphics Prints	OO9, Warri Street/Kano Road Opposite Tati Hotel Kaduna
79	Yelu Graphic Printers	Y5 Adamawa Road Kaduna
80	Yomijet Nigeria Limited	ZZ 19, Ibadan/Daura Road Kaduna Tel: 062-241288, 241129, 247126.
81	Young Lekus Nigeria Limited	NB 16, Muri Road, Kaduna
82	Zacch Graphics Printers (Multi-colour Printers)	NB8, Muri Road, Kaduna Tel:062-216420
83	ZAKARA Press & Publishers	15C, Sultan Close off Sultan Road Kaduna Tel:062-238736,240100
84	Zion Productions (Printers) Limited	CC, 11 Abeokuta / Kabba Road, Opposite Kale Visions, Kaduna Tel:062-242016
85	Zomo Press Limited	NM3, Lokoja Road, P.O.Box 9002 Kaduna Tel: 062-240100