

**THE APPLICATION OF LINEAR PROGRAMMING IN PROFIT  
MAXIMIZATION IN A MANUFACTURING INDUSTRY: A CASE STUDY OF  
NADIA BAKERY COMPANY LIMITED, BENIN CITY**

**BY**

**Charles Tochukwu OKWOR  
SSC2008475**

**DEPARTMENT OF ECONOMICS  
FACULTY OF SOCIAL SCIENCES  
UNIVERSITY OF BENIN  
BENIN CITY**

**MARCH, 2025**

**THE APPLICATION OF LINEAR PROGRAMMING IN PROFIT  
MAXIMIZATION IN A MANUFACTURING INDUSTRY: A CASE STUDY OF  
NADIA BAKERY COMPANY LIMITED, BENIN CITY**

**BY**

**Charles Tochukwu OKWOR  
SSC2008475**

**A PROJECT SUBMITTED TO THE DEPARTMENT OF ECONOMICS,  
FACULTY OF SOCIAL SCIENCES, UNIVERSITY OF BENIN, BENIN CITY. IN  
PARTIAL FULFILMENT OF THE REQUIREMENT FOR THE AWARD OF  
BACHELOR OF SCIENCE (B.Sc.) DEGREE IN ECONOMICS UNIVERSITY OF  
BENIN, BENIN CITY**

**MARCH, 2025**

## CERTIFICATION

This is to certify that this project work “The Application of Linear Programming For Profit Optimization In Manufacturing Firms: A Case Study Of Nadia Bakery Company, Benin City” was carried out by **Charles Tochukwu OKWOR** with matriculation number **SSC2008475** in the Department of Economics, Faculty of Social Sciences, University of Benin.

---

**Dr. O. James**  
**Project Supervisor**

---

**Date**

---

**Dr. S. O Igbinedion**  
**Project Coordinator**

---

**Date**

---

**Dr. Nosakhare Arodoye**  
**Head of Department**

---

**Date**

## **DEDICATION**

This project work is dedicated to my parents Mr. and Mrs. Fidelis Okwor and Okwor Charles Tochukwu for their unwavering support towards my academic journey. I express my deepest gratitude to my parents for their endless encouragement and for instilling in me the values of perseverance and dedication. I also dedicate this work to my mentors and teachers, whose guidance, intellectual rigor, and passion for knowledge have significantly shaped my academic and personal development. Their insightful advice and continuous support have been instrumental in overcoming the many challenges encountered during this research. Finally, I wish to honour the thoughts of those who inspired me with their curiosity and commitment to education, and who believed in the power of learning to transform lives.

## **ACKNOWLEDGEMENTS**

My sincere appreciation goes firstly to God Almighty for his loyal love towards me and in my pursuit of academic excellence. I would also like to express my sincere gratitude to my Project Supervisor, Dr. O. James, for his expertise and invaluable corrections that shaped this project into what it is today. My appreciation extends also to the Head of Department Dr. Nosakhare, and other lecturers and staff of the Department of Economics, most especially to Dr. Success, Dr. Uju, Dr. Mogbolu, Dr. Sowemimo. I am also grateful for Nadia Bakery Company Benin City, for giving me the necessary information to carry out this study. The researcher would like to thank the graduating class of 2023/2024 of the Department of Economics, with friends including; Bright, Marshall, Ese, Yohanna, Cosmos, Seigha, Martins, David, Esther, Omotayo divine, Jerry, Marvelous, Willy, Manu and many more whom I have come across in this unwavering journey of academic excellence. I would also like to thank my entire family for their unwavering support during this spurious times etc.

## TABLE OF CONTENTS

<b>Title Page</b>	<b>i</b>
<b>Certification</b>	<b>ii</b>
<b>Dedication</b>	<b>iii</b>
<b>Acknowledgements</b>	<b>iv</b>
<b>Table of Contents</b>	<b>v</b>
<b>List of Tables</b>	<b>vii</b>
<b>Abstract</b>	<b>viii</b>
<b>CHAPTER ONE: INTRODUCTION</b>	
1.1 Background to the Study	1
1.2 Statement of the Problem	7
1.3 Research Questions	9
1.4 Objectives of the Study	9
1.5 Hypothesis of the Study	10
1.6 Significance of the Study	10
1.7 Scope of the Study	11
1.8 Limitations of the Study	12
<b>CHAPTER TWO: LITERATURE REVIEW</b>	
2.0 Introduction	13
2.1 Conceptual Literature	14
2.2 Theoretical Literature	23

2.3	Empirical Literature	27
2.4	Nigerian Food Industry and The Manufacturing Sector	42
<b>CHAPTER THREE: METHODOLOGY</b>		
3.1	Theoretical Framework	54
3.2	Model Specification	57
3.3	Source of Data	58
<b>CHAPTER FOUR: DATA PRESENTATION AND ANALYSIS</b>		
4.1	Presentation of Data	59
4.1.1	Materials and Methods	59
4.2	Data Analysis	61
<b>CHAPTER FIVE: SUMMARY, CONCLUSION AND RECOMMENDATION</b>		
5.1	Summary of Findings	65
5.2	Recommendations	66
5.3	Conclusion	67
<b>REFERENCES</b>		<b>70</b>
<b>APPENDIX</b>		<b>74</b>

## LIST OF TABLES

<b>Table 4. 1:</b>	Quantity of Raw materials in stock and needed to produce the products	59
<b>Table 4.2:</b>	The table shows the products under review and the profit per unit of each Product	60
<b>Table 4.3</b>	Presentation of Optimal Solution	61
<b>Table 4.4</b>	Sensitivity Results from the Analysis	62

## **ABSTRACT**

This paper demonstrates the use of linear programming methods as applicable in the manufacturing industry. Primary data was used for this study and were collected from the Quality Control of Nadia Bakery Company, Benin City, Nigeria, on the three types of bakery products which includes Family size bread, Sardine bread and Banana bread. Information on profit of the already produced products as well as quantity of each of the raw material held in stock per month for the production of each of the products were available in the records of the company. The analysis was carried out with an optimization software GAMS (General Algebraic Modeling System. Based on the profit of the products, the maximum profit that would accrue to the company given the optimal product mix was determined. The results showed that the company would attain optimal daily profit level of about #309,045 if she concentrates mainly on the unit production of Family sized bread 3.26, Sardine bread 1.89 units, Banana bread of 1.88 units.

. The research recommends that the company should produce within this optimal mix, review allocations of raw materials as they were many non-binding constraints and employ more resource on the binding constraints to improve the optimal value.

**KEYWORDS:** Linear Programming, Optimal Value, GAMS, Profit Maximization

## **CHAPTER ONE**

### **INTRODUCTION**

#### **1.1 BACKGROUND TO THE STUDY**

Linear programming was used implicitly by Fourier in the early 1800s, but it was first formalized and applied to problems in economics in the 1930s by Leonid Kantorovich. Linear programming is a method of optimising operations with some constraints. The main objective of linear programming is to maximize or minimize the numerical value. It consists of linear functions which are subjected to the constraints in the form of linear equations or in the form of inequalities. Linear programming is considered an important technique that is used to find the optimum resource utilisation. The term “linear programming” consists of two words as linear and programming. The word “linear” defines the relationship between multiple variables with degree one. The word “programming” defines the process of selecting the best solution from various alternatives. Linear Programming is a generalization of Linear Algebra. It is capable of handling a variety of problems, ranging from finding schedules for airlines or movies in a theater to distributing oil from refineries to markets. The reason for this great versatility is the ease at which constraints can be incorporated into the model. Linear Programming is used to successfully model numerous real world situations, ranging from scheduling airline routes to shipping oil from refineries to cities to finding inexpensive diets capable of meeting the minimum daily requirements. In many of these problems, the number of variables and

constraints are so large that it is not enough to merely to know there is solution; we need some way of finding it (or at least a close approximation to it) in a reasonable amount of time. We describe the types of problems Linear Programming can handle and show how we can solve them using the simplex method. We discuss generalizations to Binary Integer Linear Programming (with an example of a manager of an activity hall), and conclude with an analysis of versatility of Linear Programming and the types of problems and constraints which can be handled linearly, as well as some brief comments about its generalizations (to handle situations with quadratic constraints).

Linear programming is a technique in algebra that uses linear equations to determine how to arrive at the optimal situation (maximum or minimum) as an answer to a mathematical problem, assuming the finiteness of resources and the quantifiable nature of the end optimization goal. The manufacturing industry refers to the economic sector that involves the transformation of raw materials into finished goods through a combination of labor, machinery, tools, and chemical processes, essentially creating products on a large scale to meet consumer demand, with a focus on efficiency and quality control across various stages of production; encompassing design, material sourcing, fabrication, assembly, testing, and distribution.

The bakery industry encompasses the production, distribution, and sale of baked goods like bread, pastries, cookies, cakes, and pies, primarily made from flour, sugar, yeast, and other ingredients, ranging from small artisanal shops to large-scale industrial

manufacturers, with a focus on quality, taste, and innovation, often catering to diverse dietary needs and market trends; key aspects include the manufacturing process, ingredient sourcing, equipment technology, retail strategies, and industry events like the International Baking Industry Exposition (IBIE) which showcase the latest advancements in baking technology and practices. A bakery is an establishment that produces and sells flour-based baked goods made in an oven such as bread, cookies, cakes, doughnuts, bagels, pastries, and pies. Some retail bakeries are also categorized as cafés, serving coffee and tea to customers who wish to consume the baked goods on the premises. In some countries, a distinction is made between bakeries, which primarily sell breads, and pâtisseries, which primarily sell sweet baked goods.

Baked goods have been around for thousands of years. The art of baking was very popular during the Roman Empire. It was highly famous art as Roman citizens loved baked goods and demanded them frequently for important occasions such as feasts and weddings. Because of the fame of the art of baking, around 300 BC, baking was introduced as an occupation and respectable profession for Romans. Bakers began to prepare bread at home in an oven, using grist mills to grind grain into flour for their breads. The demand for baked goods persisted, and the first bakers' guild was established in 168 BC in Rome. The desire for baked goods promoted baking throughout Europe and expanded into eastern parts of Asia. Bakers started baking bread and other goods at home and selling them on the streets.

This trend became common, and soon, baked products were sold in streets of Rome, Germany, London, and more. A system of delivering baked goods to households arose as the demand increased significantly. This prompted baker to establish places where people could purchase baked goods. The first open-air market for baked goods was established in Paris, and since then bakeries have become a common place to purchase delicious goods and to socialize. On July 7, 1928, a bakery in Chillicothe, Missouri introduced sliced bread using the automatic bread-slicing machine, invented by Otto Frederick Rohwedder. While the bread initially failed to sell, due to its "sloppy" aesthetic, and the fact it went stale faster, it later became popular. In World War II bread slicing machines were effectively banned, as the metal in them was required for wartime use. When they were requisitioned, creating 100 tons of metal alloy, the decision proved very unpopular with housewives. Bread is a staple food prepared from a dough of flour (usually wheat) and water, usually by baking. Throughout recorded history and around the world, it has been an important part of many cultures' diets. It is one of the oldest human-made foods, having been of significance since the dawn of agriculture, and plays an essential role in both religious rituals and secular culture. Bread may be leavened by naturally occurring microbes (e.g. sourdough), chemicals (e.g. baking soda), industrially produced yeast, or high-pressure aeration, which creates the gas bubbles that fluff up bread. In many countries, commercial bread often contains additives to improve flavor, texture, color, shelf life, nutrition, and ease of production.

Characteristics of Linear Programming

The following are the five characteristics of the linear programming problem:

- Constraints – The limitations should be expressed in the mathematical form, regarding the resource.
- Objective Function – In a problem, the objective function should be specified in a quantitative way.
- Linearity – The relationship between two or more variables in the function must be linear. It means that the degree of the variable is one.
- Finiteness – There should be finite and infinite input and output numbers. In case, if the function has infinite factors, the optimal solution is not feasible.
- Non-negativity – The variable value should be positive or zero. It should not be a negative value.
- Decision Variables – The decision variable will decide the output. It gives the ultimate solution of the problem. For any problem, the first step is to identify the decision variables.

## **MANUFACTURING SECTOR**

Manufacturing is the creation of finished goods through the use of tools, human labor, machinery, and chemical processing. Manufacturing allows businesses to sell finished products at a higher cost than the value of the raw materials used. Large-scale manufacturing allows for goods to be mass-produced using assembly line processes and advanced technologies as core assets. Efficient manufacturing techniques enable

manufacturers to take advantage of economies of scale, producing more units at a lower cost. Manufacturing is an integral and huge part of the economy. It involves processing and refining raw materials, such as ore, wood, and foodstuffs, into finished products, such as metal goods, furniture, and processed foods.

Manufacturing, any industry that makes products from raw materials by the use of manual labour or machinery and that is usually carried out systematically with a division of labour. (See industry.) In a more limited sense, manufacturing denotes the fabrication or assembly of components into finished products on a fairly large scale. Among the most important manufacturing industries are those that produce aircraft, automobiles, chemicals, clothing, computers, consumer electronics, electrical equipment, furniture, heavy machinery, refined petroleum products, ships, steel, and tools and dies. Manufacturing industries are those that produce goods of some sort through a combination of human labor, automated equipment, chemical processing, tooling, and similar systems. What is a manufacturing sector?

### **Contribution of Industry to National Economy**

The share of manufacturing sector in the GDP (Gross Domestic Product) has been stagnant at 17% over the last two decades. The total contribution of industry to the GDP is 27% out of which 10% comes from mining, quarrying, electricity, and gas.

The manufacturing sector has been growing at the rate of 7% since the last decade. Since 2003, the growth rate has been 9 to 10% per annum. The desired growth rate over the next decade is 12%.

Finally, a bakery is an establishment that produces and sells flour-based baked goods made in an oven such as bread, cookies, cakes, doughnuts, bagels, pastries, and pies. Some retail bakeries are also categorized as cafés, serving coffee and tea to customers who wish to consume the baked goods on the premises. In some countries, a distinction is made between bakeries, which primarily sell breads, and pâtisseries, which primarily sell sweet baked goods.

## **1.2 STATEMENT OF THE PROBLEM**

David Onwuchekwa (2024) When studying the product mix of paint manufacturing firms in Port Harcourt using linear programming techniques, several challenges and issues may arise that could problematize the study. Some of these challenges include: Complexity of Production Processes: Paint manufacturing involves multiple ingredients and processes that can make it difficult to accurately model and optimize using linear programming techniques. Market Dynamics: The demand for different types of paints can fluctuate based on market trends, consumer preferences, and economic conditions, making it challenging to

predict and optimize product mixes. Resource Constraints: Paint manufacturing firms may face constraints such as limited raw materials, production capacity, or budgetary restrictions that can impact their ability to optimize productives effectively (Oyedele, 2016).

Oluba (2018) in this study, the question of how to produce and efficiency of the resource use is our utmost concern. Thus in a manufacturing company, the problems usually encountered are:

- Inability to efficiently combine the resources available to make the most output. How then can we ascertain if this is the best we can get i.e if we are efficient?
- The inability to know the actual profit contribution of a given product.
- In addition to these, a survey for this study at Aka Paint Nigeria Limited showed that There is lack of skill in determining the best mix of products to optimize the objective of the firm. There is also a lack of skill in determining how changing cost of production and demand for goods can affect profit of the factory.

Therefore, in summary, there is a problem of inadequate production planning for optimal benefits.

David Ebiegberi Amanawa (2022), the majority of production managers in Nigeria's bread-baking businesses base their decisions on the overall input required throughout the manufacturing process. The rate at which production companies (especially feed mill producing companies) liquidate in Nigeria is alarming, which can be traced to

wastage of production resources, high level of idleness on the production floor, and the inability of the production companies to maximize the meaningful profit that will enable these companies to meet up with the expectations of its stakeholders (Solaja et al., 2019). Making decisions based on limited resources is a major problem factor that brought the application of the linear programming model.

### **1.3 RESEARCH QUESTION**

- How is the company currently making decision on the allocation resources for the production of it's products to maximize it's sales and profit?
- Whether the company uses qualitative decisions or employs mathematical/ statistical models or both?
- Whether the current method adopted in making decision is effective or not?

Whether the resources available are sufficient for production of the products to satisfy the demands of the customers?

### **1.4 OBJECTIVE OF THE STUDY**

The main objectives/reasons for the application of linear programming in a bakery industry include:

- To investigate how Linear Programming can be used to optimize resource use in bakeries for higher profits.

- To show how bakeries can use Linear Programming as a tool for decision-making, guiding choices that improve overall profitability.
- To know about the constraints of the company regarding costs, resources.

### **1.5 HYPOTHESIS OF THE STUDY**

To provide a framework for empirical testing and analysis, the study proposes the following hypothesis. These hypotheses are formulated based on the research questions and objectives, aiming to explore the relationship between the application of linear programming and profit maximization in a bakery industry in Nigeria. The following null hypothesis were formulated:

- Linear Programming doesn't play a crucial role in resource optimization in manufacturing industries in Nigeria.
- There's no significant relationship between Linear Programming and effective decision-making, and profit optimization in bakery industries in Nigeria.
- Linear programming isn't effective in identifying the constraints of the company, regarding costs and resources.

### **1.6 SIGNIFICANCE OF THE STUDY**

This study holds significant importance as it emphasizes on the importance of the use of linear programming in bakery industries in Nigeria. It helps to understand the best

way of making decisions using quantitative models in order to determine its optimal product mixes that can maximize its profits subject to the scarce resources it has. The study will provide a deep understanding and insight of the applications of linear programming models in industries and how to apply such models in practical and real world experience. The use of linear programming in industries hasn't really been popularized as such. The aim of this study is to popularize the benefits of the use of this approach in industries to optimize profit, while making efficient use of scarce resources. It can also be used to show the optimal allocation of resources for product mix. The application of linear programming in a firm would improve overall efficiency. It allows manufacturers to analyze different scenarios and their potential outcomes, helping them to make informed decisions about production planning, resource allocation, and investment strategies. Linear programming can be used for long term strategic planning, such as capacity planning facility location, and supply chain management. Linear programming can help optimize production schedules, minimizing production time and maximizing output. In essence, it can help manufacturers become more competitive in the market.

## **1.7 SCOPE OF THE STUDY**

The scope of this study establishes the parameters within which the research will be conducted, ensuring a comprehensive and well-defined examination of the impact of the application of linear programming on the profit maximization in a Bakery Industry in Nigeria. It encompasses the various aspects of production, resource management, and

strategic decision making. It encompasses determining the optimal production quantities for different products to maximize profit while considering constraints like raw material availability, and labour hours.

Efficiently distributing resources across different production processes to minimize costs and maximize output. Streamlining the flow of materials from suppliers to production facilities and finished goods to customers, considering Nigeria's infrastructural challenges.

## **1.8 LIMITATIONS TO THE STUDY**

There are certain limitations to the application of linear programming in a bakery/manufacturing industry in Nigeria. Many bakeries in Nigeria, especially smaller ones, may have inconsistent or incomplete records of ingredient costs, production data, and sales figures. This can make it difficult to gather the accurate and reliable data needed for linear programming. The Nigerian bakery market can be informal and dynamic, with fluctuating prices, seasonal demand variations, and

Unpredictable customer preferences. This can make it challenging to obtain reliable data for forecasting and model building. Linear programming models often involve simplifications of real-world situations. For example, they may assume linear relationships between variables, which may not always hold true in practice.

Bakery staff may be resistant to adopting new methods and technologies, making it challenging to implement the recommendations of the linear programming model.

## **CHAPTER TWO**

### **LITERATURE REVIEW**

#### **2.0 INTRODUCTION**

This chapter presents a comprehensive review of existing literature relevant to the study, encompassing conceptual, theoretical, and empirical perspectives and analysis. The conceptual literature review clarifies key concepts and their relationships, while the theoretical literature review examines foundational theories underpinning the research. The empirical literature review analyzes previous studies and their findings, providing a basis for comparison and identifying research trends. A summary of the reviewed literature synthesizes the main points and current state of knowledge in the field. Finally, the chapter identifies gaps in the existing literature, highlighting areas where further research is needed and positioning the current study to address these knowledge deficits, thereby establishing its significance and potential contributions to the field. Linear programming model (LP) is a technique used in managing resource for optimal production. It is a mathematical (algebraic) technique in which relationships between resources and outputs in a system are

described by a set of algebraic (linear) equations. Since resources are scarce, output will be constraint. In other words, output in the technique is determined by limited resources.

## **2.1 CONCEPTUAL LITERATURE**

### **LINEAR PROGRAMMING**

Linear programming is a strategy to ensure or optimize a certain quantity. The ability to produce products with the best quality and lowest possible cost is an aspect that determines the company's resilience in market competition. According to Kumar, linear programming is a technique for allocating production resources

optimally to get the best results. Linear programming techniques are widely used to determine optimal resource utilization. Moreover, linear programming is

the best method to determine the optimal solution by fulfilling a specific objective function limited by various constraints and restrictions. The results of solving linear

problems are only two, namely, maximum or minimum. The characteristics of the issues that can be solved using the techniques in the linear program are as follows:

- A feasible decision variable, meaning that the variable's value makes sense.

- It has a function, the relationship between the decision variables to be minimized or maximized.
- There is at least one constraint function.
- The objective function and the constraint function are linear functions, or the variable has the power of one.
- The domain is clearly defined. In general, the value of the decision variable must be positive  $x \geq 0$ . Linear programming problems can be expressed in a standard function form to be optimized or minimized.

$$Z = C_1X_1 + C_2X_2 + C_3X_3 + \dots + C_nX_n$$

by taking into account the constraints

$$a_1X_1 + a_2X_2 + a_3X_3 + \dots + a_nX_n (\leq, =, \geq)$$

Information:

$X$  = decision variable;

$b$  = The number of types of activities that use these resources;

$a$  = number of resources used to produce each unit of activity;

$Z$  = Value of objective function;

$C$  = The coefficient of the objective function of the decision variable.

Linear programming model (LP) is a technique use in managing resource for optimal production. It is a mathematical (algebraic) technique in which relationships between resources and outputs in a system are described by a set of algebraic (linear) equations. Since resources are scarce, output will be constraint. In other words, output in

the technique is determined by limited resources. Notably, the resource and output equations are often connected by another equation called an “objective function” which describes the desired outcome in mathematical terms (Hurley, Trafford, Dooley & Anderson, 2013). However, to obtain optimum solution in the equation, a set of mathematical procedure is observed in form of matrix inversion, which progresses following step-by-step process in achieving optimality. Bagshaw (2017) views linear programming as a linear and optimal mathematical procedure used in solving problems in determining quantities of resources that needs to be used or produced, which will either maximize benefit or minimizes cost. In other words, LP is about making maximum benefit or minimum loss out of limited resources in daily life. The model plays an important role in enhancing managerial decision and has shown to be capable of solving problem like production planning, allocation of resources, inventory control and advertisement (Sohi et al., 2013). Mac’ Odo (1997) views linear programming as a model applied in optimum allocation of limited resources to competing alternative uses, under assumptions of certainty, linearity, fixed technology, constant profit or cost per-unit and divisibility. Notably, the model plays important role in enhancing managerial decision capable of solving issues relating to product-mix, assignment of personnel and machines, investment portfolio selection, plant location, transportation schedule and so on. Managements’ often aimed at making decisions in either minimizing cost or maximizing benefits, given a set of scarce resources such as manpower, money, materials, skills, time, facility and so on. As opined by Aadharshana (2019), the process of either minimizing or maximizing is often

referred to as optimization or mathematical programming. The optimization process can be utilized in solving problem using either the graphical approach or the Simplex method depending on the variables involved. Notably, the model is applied virtually in all manufacturing or productive activities as well as some service-related businesses in allocating scarce resources and determining production quantities, as it enables industries as well as businesses find optimal solutions to economic and production decisions. Though, linear programming model is applicable across manufacturing or production as well as some service-related activities around the world, notably, Nakhanu, Toili and Nyongesa (2015) traced its earliest application to the twentieth century (1930), when Leonid Kantorovich (a Soviet mathematician) and Wasily Leontief (an American economist) first used it in manufacturing schedules and in economics. Kantorovich, developed the model in planning expenditures and returns, for the purpose of reducing cost incurred by the army (USSR) during the Second World War. Similarly, Dantzig between 1946 and 1967 developed the simplex approach used in optimal allocation of resources. The approach developed by Dantzig was used by the U.S Air Force in 1947 in planning problems. Though, linear programming was developed during the early part of the twentieth century, it is still widely in use in today's business organizations in solving multiplicity of issues relating to resources allocation.

Dwivedi (2008) averred that linear programming is highly useful in making business decision, as it aid firms in evaluating complex economic relations, which further provides an optimum solution to the problem of resource allocation. Notably,

management makes decision concerning abstract economic theories in practical terms utilizing linear programming techniques, thus, as opined by Dwivedi (2008), it links the gap between abstract economic theories and decision made by management. As opined by Hillier and Lieberman, cited in Osagie and Icheme (2018), viewed linear programming problem as any problem whose mathematical model fits the very general format for the linear programming model.

Mac'Odo (1997) view the objective function as a decision on the result needed or required which may involve the maximizing of a desired outcome (contribution, utility, revenue just to mention but few) or the minimizing of negative outcomes (cost, time, distance and so on). The objective function could be stated thus: Optimize  $F = a_1x_1 + a_2x_2 + a_3x_3 + \dots + a_nx_n$ . The function consists of coefficients and the decision variables. Expatiating further,  $a_1, a_2, a_3 \dots a_n$  are seen as the objective function coefficients while  $x_1, x_2, x_3 \dots x_n$  are said to be the decision variables. Contrarily, the constraints are seen as limitations that influence or govern the realization of the stated objectives. As opined by Mac'Odo (1997), constraints are in dual part which could either be functional or structural (that is, inequality statement or input requirements within the limits of the available resources as well as obligations) and the non-negativity or quantity constraint. It is stated thus:

subject to

$$b_{11}X_1 + b_{12}X_2 + \dots + b_{1n}X_n < k_1$$

$$b_{21}X_1 + b_{22}X_2 + \dots + b_{2n}X_n < k_2$$

$$b_{m1}X_1 + b_{m2}X_2 + \dots + b_{mn}X_n < k_m$$

$$X_1, X_2, X_3 \dots X_n > 0$$

However, the constraints in minimization problem is often denoted with 'greater than or equal to' sign ( $\geq$ ) while maximization problems show constraints of 'less than or equal to' sign ( $\leq$ ). The goal is to determine the quantities of resources that needs to be produced or utilized which will maximize benefits to the organization or contrarily minimize cost incurred by organizations.

### **Conditions for The Use of Linear Programming Model in**

#### **Problem Solving.**

Though linear programming is considerably applied in solving problems facing organizations in terms of quantities of resources that need to used or produce and often supports managerial decision, the model is not applicable in all conditions. However, as opined by Mac'Odo (1997), certain conditions must be met before applying LP model in solving problems. These conditions are:

- The problem must be capable of being stated in numeric terms.
- All factors involved in the problem must have linear relationship.
- The problem must permit a choice(s) between alternative course of action.
- There must be one or more restrictions on the factors involved (restrictions on resources or characteristics).

### **Assumptions of Linear programming model**

As stated by Martinich (1997), linear programming makes certain assumptions – Proportionality, additivity, divisibility and certainty. In addition, there are the assumptions of optimality, non-negativity.

- The assumption of Proportionality implies that the contribution of individual variables in the objective function is proportional to their value. In other words, if the value of a variable is doubled, the contribution of that variable to the objective function and each constraint in which the variable appears, doubles. The contribution per unit of the variable is constant, thus, satisfies the assumption of proportionality.
- The assumption of Additivity implies that the total value of the objective function and each constraint function is obtained by adding up the individual contributions from each variable.
- Divisibility – This implies that the decision variables can take on any real numerical values within a specified range. In other words, the variables are not restricted to integer value, it can be formulated to take on any real numerical value within the confines of the specified constraints.
- The assumption of Certainty implies that the parameter values in the model are known with certainty. In other words, the optimal solution achieved is ideal for the specific problem formulated. If the values of parameter are erroneous, the resulting solution becomes of little importance.

- Non-negativity. This implies that all decision variables must take on values equal to or greater than zero. In other words, in linear programming negative values of physical quantities are an impossible situation.

## **Methods of solving a Linear Programming Model**

Generally, there are two main approach or methods used in solving problems in linear programming. These include the graphical approach and the simplex approach or tableau.

### **Graphical method**

The Graphical method or approach is often applied in visualizing basic concepts utilized in the linear programming problem. This approach is often use when

there are only two decision variables in the LP problem, though as opined by Kannan, Dinakaran and Lavanya (2004), it can also be applied in solving for LP problems involving three decision variables but becomes rigorous when manually used. However, applying the graphical approach on problem having two decision variables involves plotting the constraints on a graph and identifying the region that satisfies all of the constraints. In other words, the areas in the graph that accommodates all the constraints is seen as feasible region.

## Simplex Method

The simplex method is used in linear programming, starting from a feasible basis solution to another possible basis solution by doing it repeatedly (iteratively) to reach an optimum solution. Many methods are used to solve linear programming problems, the simplex method is the most powerful method. The Simplex method was developed in 1946 by George Dantzig. Before calculating, the objective function and the constraint function must be converted into standard form. The common form of the constraint function in the simplex method is to provide additional variables. Adding slack variable for the constraint function with the symbol  $\leq$ , minus the surplus variable adding the artificial variable for the constraint function with the character  $\geq$ , and adding an artificial variable for the constraint function with a symbol  $=$ . The calculation steps to optimize the objective function with the simplex method are as follows:

- Form a mathematical model into a standard form by adding a slack variable to the constraint and objective functions to obtain the basic variable. Then create a simplex table based on the existing data;
- Determine the critical column or Entering Variable (EV), which is the column with the highest negative value;
- Determine the key row or Leaving Variable (LV) by comparing the price of the right side with the coefficient value on the variable selected as the basis, which is the chosen minimum. The intersection between LV and EV is called the pivot element;

- Perform Gaussian elimination by making the pivot element one by dividing the critical row by the pivot element. Each component of the key column is changed to zero and changes the values contained in other than the critical row by the old row – (key column coefficient  $\times$  new key row value);
- Repeating the same way until getting the optimal solution, namely when there is no negative value in row Z.

## **2.2 THEORETICAL LITERATURE**

There are contrastive views of researchers about relevance of LP modelling to various managerial decisions. These views are indulged over a long time that improved the LP technique applicability in solving business decision making problems. The economic literature recognizes the importance of linear programming

particularly for the better planning of developing countries that usually have scarce resources where linear programming assist in apportioning these truncated resources in obtaining optimal solution.

Evidencing from the history, LP technique is a mathematical tool that was enrooted by George Dantzig, a mathematician, in 1947 for rationalizing logistics for U.S. Air Force. Later, he argued to use this technique to solve business problems. He also developed simplex method that was improved version of linear programming (Dantzig, 1993). In case of allocation problems, there are plenty of activities that are required to be done, being various alternative ways of doing them, with limited resources to be allocated among these activities, then management has to confront with the dilemma of how effectively integrate these resources and activities to maximize output. This problem is termed as optimization problem and can be construed with mathematical programming. Charles & Cooper (1963) termed LP modelling as a single objective optimization approach as it exerts to bring out single objective of either maximization (profit or contribution) or minimization (cost or time). Similarly, Gupta and Hira (2009) argue that LP modelling wiolds to optimize a linear function termed as objective function contingent on aggregation of linear equations known as constraint functions.

Economic theories which explain the application/which linear programming hinges on include:

- i. **General Equilibrium Theory:** The General equilibrium theory tells us that in all the markets of an economy, supply and demand interact actively, resulting in price equilibrium. The markets in an economy are all interconnected, and as such, supply and demand decisions in one market will affect the supply and demand decisions in another.

In macroeconomics, General Equilibrium Theory explains how supply and demand interact dynamically, culminating in an equilibrium of prices in an economy with many markets. The theory assumes a gap between actual and equilibrium prices and identifies the circumstances under which the equilibrium price achieves stability.

The theory was first developed by the French economist Leon Walras in the late 19th century. It stands in contrast with partial equilibrium theory, or Marshallian partial equilibrium, which only analyzes specific markets or sectors. Walras developed the general equilibrium theory to solve a much-debated problem in economics. Up to that point, most economic analyses only demonstrated partial equilibrium that is, the price at which supply equals demand and markets clear in individual markets. It was not yet shown that equilibrium could exist for all markets at the same time in aggregate. General equilibrium theory tried to show how and why all free markets tend toward equilibrium in the long run. The important fact was that markets didn't necessarily reach equilibrium, only that they tended toward it.

Linear Programming has connections to general equilibrium theory, which seeks to model the simultaneous equilibrium of markets in an economy.

While general equilibrium models can be complex, linear programming provides tools for analyzing specific aspects of market interactions and resource allocation.

- ii. **Input Output Analysis:** Input-output analysis is a type of economic model that describes the interdependent relationships between industrial sectors within an economy. It shows how the outputs of one sector flow into another sector as inputs.

Wassily Leontief, who was a Soviet-American economist, developed the input-output analysis method, earning him the Nobel Prize in Economics in 1973. Input-output models can be regarded as special cases of linear programming problems. Linear programming is the most useful practical tool in helping us to make the best use of scarce resources when faced with complex decision problems. Linear programming is used to solve input output models, determining the optimal production levels for each sector to meet final demand.

- iii. **Production Theory:** linear programming is heavily used in production theory to model the relationship between (labour, capital, raw materials) and outputs (finished goods ). The production theory, in economics, explains the principles by which a business firm decides how much of each commodity that it sells (its “outputs” or “products”) it will produce, and how much of each kind of labour, raw material, fixed capital good, etc., that it employs (its “inputs” or “factors of production”) it will use. The theory involves some of the most fundamental principles of economics. These include the relationship between the prices of commodities and the prices (or wages or rents) of the productive factors used to produce them and also the relationships between the prices of commodities and productive factors, on the one hand, and the quantities of these commodities and productive factors that are produced or used, on the other.
- iv. **Duality Theory:** The duality theory or the duality principle is the principle that optimization problems may be viewed from either of two perspectives, the primal problem or the dual problem. If the primal is a minimization problem then the dual is a

maximization problem (and vice versa). Duality theory, by virtue of the importance of its applications, is one of the central directions in optimal control theory. In mathematics and economics, duality theory is interpreted in the form of prices; in mechanics, potential energy and complementary energy are in a dual relationship—the displacement field and the stress field are solutions to the primary and dual problems, respectively.

In linear programming, duality theory provides a link between the primal problem (e.g. maximizing profit) and the dual problem (e.g. minimizing costs).

### **2.3 EMPIRICAL LITERATURE**

Empirical literature helps other investigators understand precisely what was done and what was found in a particular research study to the extent that they could replicate the study to determine whether the findings are reproduced when repeated. An empirical literature review is more commonly called a systematic literature review and it examines past empirical studies to answer a particular research question. The following are reviews from the application of linear programming by different individuals of different nations showing methodology, findings and conclusion:

Oluwafemi, Samson Balogun (2013), made use of the application of linear programming in a manufacturing company in feed masters, located in kwara state in Nigeria. They applied the simplex method, and they realized certain findings, that based on the data collected 3 products should be produced, 25kg layers mash, 25kg of grower mash, 25kg of broiler finisher mash. They came to a conclusion thus; based on the analysis carried out in this research and the result shown, 25kg of chick mash, 25kg of layer mash, 25kg of grower mash etc should be produced to satisfy the customers.

Ruby Chanda, Vanishnee pabalkar, and Sudeepa Gupta (2022), from India on the application of linear programming on product mix for profit maximization and cost optimization. They made use of face to face interviews. Based on their findings, the examination distinguishes the current asset usage level and the benefit of every period of the apparel producing organizations, utilizing (LP) procedure. They came to a conclusion that there was 54% increase post L.P. compared to the product wise resource utilization.

Siddharth Ghuge, Tanishaa Gupta, Harsh Sharma (2024), applied enhancing profitability and product mix optimization through linear programming problem on the Indian garment industry. The methodology applied is linear programming techniques in Microsoft excel to optimize production process and minimize costs, via simplex method. Findings showed that the company should on an average produce 14,096 suits, 14,190 blazers, 70,000 trousers, 42,472 shirts etc. The maximum profit to be earned is Rs. 717918,005.61.

Ezra P.N., A.V. Oladugba, F. O. Ohanuba (2020), Nigeria on the application of L.P. on the profit maximization of Nigerian bottling company. applied the simplex algorithm using Tora software, sensitivity analysis. Findings recommend that the Nigerian bottling company should focus on producing products that maximize their profits. It was discovered that dubic malt, origin bitter sachet and spirit contributed maximally to the company's profit.

Ahmed A. Mawgoud, Mohammed Hamed N. Taha (2022) Egypt employed L.p. methodology to optimize decision making for ready mixed cement products, a case study on Egypt's new administrative capitals. They applied the use of linear programming. Their findings included the fact that doubling the CCRS can sometimes be a material waste if other resources were consumed. Based on the final conclusion, the problem was solved using 2 linear programming methods.

In 2016, Nigeria, the application of L.P. in profit maximization was applied (a case study of crunches fried chicken). The trial and error method was applied.

Adenike Olubiyi, Michael Olayemi, Opeyimika in (2021) Nigeria employed the use of L.P. to profit maximization in water production. The methods used were linear programming (minimizing or maximizing), sensitivity analysis. Findings included the fact that the L.P. method was proven the only way the company production problem can be addressed. In conclusion Viclibo ventures should produce the three sizes of water (sachet bag of water, 50cl pack of water, 75cl pack of water) in order to satisfy customers.

Nazrul islam, Afsana yeasmin M.M. (2022) Bangladesh applied L.P. for profit maximization: A case study of a cookies factory in Bangladesh. The simplex algorithm; maximization & minimization method was applied. Conclusion made was that L.P. is the best strategy for business to improve financial performance.

Vishwa Nath Maurya, Ram Bilas (2015) in Ethiopia applied a linear programming model for profit optimization; a case study of Ethiopian chemical company. The method of data collection, method of data analysis was applied. As regarding findings it's clear that model based decision is important for it's accuracy and objectivity. In conclusion L.P. is applied for profit maximization in all companies.

Abdeimniem Taha, Maryoud Elna (2019) in Sudan applied L.P. optimization of the productivity and income of small scale farmers in Azum locality of central Darfur state, Sudan. Linear programming; minimization and maximization was applied. It was found out that investment of potato, onion etc, was highly profitable.

In conclusion, groundnut, millet, cowpea are mostly cultivated by small farmers.

Eriky Rian Oliveira, Izabela Viana, Jose Cinval Lopes Fillas (2024) in Brazil applied the use of linear programming to optimize processes at a flour factory in Northeast Brazil. He applied the method of operation analysis, sensitivity analysis, branch and bound method. As regards to findings the factory produces optimally utilizing available inputs,

while maintaining lowest cost. In conclusion the profit for flour R\$190, profit for starch R\$3.72.

Peter K. Anderson, Ram Bilas Misra, Kamlesh Kumar Shukla (2016) in Ethiopia, employed the use of linear programming model for profit optimization, a case study of Ethiopian chemical company. Methodology applied included the use of L.P., M.S. excel solver, simplex algorithm. Findings included that even though the company has an annual record of it's production and sales volumes, it's not employing any quantitative model to forecast sales. Conclusion includes that the L.P. model can be used for other companies for it's profit maximization.

Yahya, Lucey, Andrade, Muhammad Bilal, miss Sehrish Khan(2016) in pakistan on the application of linear programming for profit maximization:a case study of paints company, Pakistan. The simplex method was applied as well as OLS model, Markov analysis, time series analysis. Findings incude other companies should utilize this technique to optimize their financial performance. In conclusion the results of simplex method show that the company can earn maximum contribution by producing only gallon.

Ezekiel, Abiodun Oyekan, Gabriel O. Temisan (2019) in Nigeria, applied L.P. to profit maximization (a case study of Johnsons Nig. Ltd). The simplex method was applied as well as sensitivity analysis. Findings include, if there happens to be a sufficiently large reduction in the objective coefficient of the large kings bread. In conclusion Linear programming is best for profit optimization.

Rorim Panday, Mira Anggana (2023) in Indonesia on profit maximization and production of macsa cake and bakery shops with linear programming. Simplex method as well as research method, POM-QM software was applied. Findings include the maximum profit that can be obtained at the Maesa cake and bakery branch legend bakery is IDR 270,000 by selling 5 units of Banana, Bolu and 50 units of banana bolen. In conclusion the POM-QM software can perform calculations quickly and accurate results.

Paulus Wisnu Anggoro, Baju Bawono (2023) in Indonesia, on the application of linear programming for the optimal profit of PT. Naruna using the simplex method. The simplex method was applied. Findings included that the L.P. technique shows that the composition of the glass types that must be produced is 0.63 or 1 glass of the first type. In conclusion Naruna will get maximum profit when producing type 1 less than type 3 less than type 2 glass.

Ozokeraha, Kehinde Paul (2020) in Nigeria on the application of linear programming in profit maximization at Glad tidings foods, Benin city, Edo state, Nigeria. The trial and error method was applied, along with the L.P. echeleon rule was applied. In conclusion the chicken production sector tends to give more leverage to the company in terms of higher profit maximization.

Oyiborhoro, Ovibije, Akwarigbe (2024) in Nigeria on the application of L.P. for profit maximization at Toprano bakery. Linear programming; minimization and maximization method was applied. In conclusion Toprano bakery should focus more on the

production application of L.P. for profit maximization of medium bread, & produce less of other products.

Usman et al. (2020) attempted a research into the The Optimization Problem of Product Mix and Linear Programming Applications. Using primary data collected from Amo Byng Nigeria Limited and a quantitative decision-making tool called linear programming can be used for the optimization problem of product mix, The findings of the study shows that, the profit of the company can be improved by 9.1% (from 26,520,300 naira per month to 29.192 million per month). by applying linear programming models if customer orders have to be satisfied. The profit of the company can be improved by 9.1% if the linear programming formulation does not need to consider customer order.

Solaja et al (2019) in their research Application of linear programming techniques in production planning used primary data gotten from the agricultural industry. The findings from their study reveals improved profit through streamlining of the product range and cutting off the less productive products.

Solaja, O. A., et al (2019) in their work Application of linear programming in production planning research into the application of linear programming in the agricultural industry. With the use of primary data and processing this data with the help of Management Scientist Version 5.0. The result of this study shows that with the available resources, the company can improve their profit by producing 433 bags of Layer Mash and drop the production of other three products in order to attain maximum profit of N89,808 which is

80% increment when compare to current operating profit the company gets when production planning is made with heuristic techniques. The study suggests the company may adopt the outcome of the linear programming techniques in production planning to improve monthly profit. This study has shown that linear programming techniques is a powerful tool that can be of help to manager in decision making and allocation of limited resources and indicate operations and profit improvement.

Ogbeide et al. (2018) researched into Product Mix Optimization in the Manufacturing Industry using the Linear Programming Approach using Guinness Nigeria Limited as their case study, it was discovered that, given the amount of materials available, the company should produce all the products in order to satisfy its customers but more of *Satzenbrau* should be produced in order to attain maximum profit because they contribute most to the profit earned. It is therefore recommended that any product having an adverse effect or contributing losses to the profit margin of the company can be stopped and the company can focus on those that can generate more profit.

Oladejo et al. (2018) in their research work “Application of Linear Programming for Optimum Production Planning in Maidabino Investment Nigeria Limited, Katsina, Katsina State”. The result from their work showed that Maidabino Investment Nigeria (MIN) limited should produce 750 units of 330ml yoghurts and 1,080 units of 750ml of bottle water in order to obtain optimal production cost of one hundred and sixty-five thousand six hundred naira (₦165,600) given the level of available resources and the

content of each product per unit of the raw materials. It was also shown that for each extra ₦70 and ₦120 spent on treated water and citric acid for production of 750ml of bottle water and 330ml of yoghurt, overall production cost would fall by ₦1.33 and ₦25 respectively. This is because the resources are binding constraints, fully utilized and have non-zero shadow prices. In addition, any attempt to produce a unit of 1000ml of juice or/and 250ml of ice-cream would raise production cost by ₦260 and ₦250 respectively. For these reasons, it is concluded that production of 330ml yoghurts and 750ml of bottle give MIN limited a great advantages to survive and grow vigorously in the industry.

Akpan and Iwok (2016) worked on the “Application of Linear Programming for Optimal Use of Raw Materials in Bakery” using the primary data they got from Goretta Bakery, the results from their study revealed that The analysis was carried out and the result showed that 962 units of small loaf, 38 units of big loaf and 0 unit of giant loaf should be produced respectively in order to make a profit of N20385. From the analysis, it was observed that small loaf, followed by big loaf contribute objectively to the profit. They also recommended that Goretta bakery limited should produce the three sizes of bread (big loaf, giant loaf and small loaf) in order to satisfy her customers. Also, more of small loaf and big loaf should be produce in order to attain maximum profit, because they contribute mostly to the profit earned by the company.

Umar et al. (2015) in their work on “Profit Maximization in a Product optimization Company Using Linear Programming Approach to Resource Allocation”

using primary data and R statistical package using library “lpSolve”. The results showed that the company would attain optimal monthly profit level of about ₦524,369 if she concentrates mainly on the unit sales of her foam product, ignoring other forms sales packages.

Iheagwara et al. (2014) attempted a research work on Application of Linear Programming Problem on Niger Mills Company PLC Calabar. Obtaining primary data from the company and formulating the linear programming model in mathematical terms and solved by the available computer soft wares (Excel Solver and TORA) for solving Linear Programming problems. The solution obtained reveals that 576 (50kg) bags of flour, non presently for Semovita and wheat offals should be produced daily, in order for the company to achieve a maximum daily profit of N161, 280.00. Sensitivity analysis was also conducted to review the following; changing the objective function coefficient for a variable, forcing a variable which is currently zero to be non-zero, and changing the right-hand side of a constraint. The sensitivity analysis revealed that for Semovita (variable X2), the objective function needs to change by 60.00000091 (increase since we are maximizing) before it becomes non-zero. In order words, referring back to our original situation in this research work, the profit per unit on semovita would need to increase by 60.00000091 before it would be profitable to produce any of semovita products. Similarly, the profit per unit on W/offals would need to increase by 45.0000002 before it would be profitable to produce any of W/offals products. Their study recommended 1) Niger Mills Company Calabar should produce 576 (50kg) bags of flour per day, and stop presently to produce semovita and

wheat offals, because of their non-optimality, to enable the company maximize profit. 2) Finally, it is also recommended that a statistical unit be created in the company so that qualified statisticians can be engaged to direct the collection, compilation and subsequent storage of statistical data on the product produced/sold by the company. Because, sometimes important data are not kept, and this will affect the result of any statistical studies conducted on the data as well as invalidate the recommendations of such studies.

Balogun et al. (2013) researched the “Application Of Linear Programming In A Manufacturing Company In Feed Masters, Kulende, Kwara State”. The data from this study was gotten from primary sources from Feed Masters, Kulende, Kwara State. Using simplex method to analyze the data, the result shows that two particular feeds should be produced even when the company should satisfy demands of the other - not - so profitable items in the surrounding of the company.

Uzochukwu and Benedict (2012) worked on Optimizing Profit with the Linear Programming Model: A Focus on Golden Plastic Industry Limited, Enugu, Nigeria. The primary data used for the research was gotten through interactions with Golden Plastic Industry Limited. The study showed that only two of the raw materials –tio 2 and labour time- were surplus, while the other six-resin, calcium carbonate, stabilizer, cast, carbon black and blend-were scarce in relation to the formulated model. The shadow prices of the raw materials obtained showed their unit contribution to the objective function (profits) and suggests to management the prices at which they should either be bought or sold.

Waheed et al. (2012) their study examined the “Profit Maximization in a Product Mix Company Using Linear Programming”. Using primary data gotten from KAMZO Industry Limited (a manufacturing industry), the analysis was carried out with R statistical package using library “lpSolve”. The results showed that the company would attain optimal monthly profit level of about N271,296 if she concentrates mainly on the unit sales (one tablet per pack) of her medicated soap product, ignoring other forms of sales packages. By this, her sales turn-over per month would be about 18,900 soap tablets.

Fagoyinbo et al. (2011) examined the “Maximization Of Profit In Manufacturing Industries Using Linear Programming Techniques: Geepee Nigeria Limited”. Primary data was sourced for and analyzed using simplex method for Linear Programming Model. Based on the model formulated, and the analysis carried out that the amount of polyethylene and ox oxyacetylene yacetylene used in the production of different sizes of plastic material produced with the allotted time attached to each product; Combo Tanks (of height 2,600mm, containing 4,600 litres i.e. 10,200 gallons of liquid) assures a profit margin of three hundred dollars if the quantity produced stood at 5 within the specified period of time. The management of GEEPEEE NIGERIA LIMITED should give more attention to the production of the product (Combo) than other products because it seems to give the highest profit. In the same vein, critical examination should be carried out on other products on their contribution to the growth or success of the company, if their profit margin is very low, then their production can be ignored. Finally, any product having an

adverse effect or contributing losses to the profit margin of the company can be stopped and the company invest more on the production of Combo to generate more profit.

Sujai B. (2024) in his work “Practical Application of Linear programming technique in textile spinning industry” examined the application of linear programmin in the manufacturing process using the textile spinning industry as a case study. Data was sourced using primary means and analyzed using simplex method for linear programming model. The findings from his study is in order to achieve maximum profit they can produce 66.66% Karded yarn and 33.33% combed yarn (2666 kgs of karded yarn and 1333.6 Kgs of combed yarn) so that average selling price of the product will be 150 Rs / Kg yet achieving Min 88% overall yarn realization. Suppose if they are ready to compromise the yarn realization further by 5% i.e. 82% then by going through the same process we will reach Optimal Solution:  $p = 162.5$ ;  $x = 0.25$ ,  $y = 0.75$  In this case the maximum profit can be achieved by producing 25% Karded yarn and 75% combed yarn (1000 kgs of karded yarn and 3000 Kgs of combed yarn) so that average selling price of the product will be 162.5 Rs / Kg at 83% overall yarn realization.

Marek, K. (2020) examined the “Application Of Linear Programming In Supply Chain Management In The Foundry” Primary data was sourced for to be used in his analysis and was analyzed using Octave MATLAB. The findings resulted to the lowest costs of planned production and delivery will occur when the M1 company supplies raw materials for the N3 and N4 foundries, the M2 company for the N3 foundries, and the M3 company

provides alloying additives for the N2 foundry. In addition, M2 and M3 companies should use N5 for export to utilize their production capacity. In turn, if the companies did not decide to produce their production surplus to the warehouse, then the optimal distribution of deliveries, assuming minimal production costs.

Akshar et al. (2019) examined the Application of Linear programming (Simplex Method) in Kraftwork company for Manufacturing an Optimal product mix. Using primary data the final result showed that the company should produce 200 skirts, 45 tops, 200 dresses and 100 pants per day to maximize profit.

Isaiah et al. (2019) attempted a research on “Energy Optimization Model Using Linear Programming for Process Industry: A Case Study of Textile Manufacturing Plant in Kenya”. The results from their findings In this research, if monthly demand of product P1 increases to 401 kg the objective function value would increase by Ksh 50 (the dual price) to Ksh 2,813,080 per month. Also, if monthly demand of product P2 increases to 601 kg the objective function value would increase by Ksh 84 (the dual price) to Ksh 2,813,114 per month. Similarly, if monthly demand of product P3 increases to 20,001 kg the objective function value would increase by Ksh 137 (the dual price) to Ksh 2,813,167 per month. Additional hour of production time will not affect the objective function value since the dual price corresponding to production time is zero.

Diksha et al. (2018) worked on A Linear Programming Approach To Maximize Profit And Minimize Wastage In A Hospital Products Manufacturing Firm- Global

Services Ltd. The analysis made use of primary data that was sourced from Global Service Ltd. Using linear programming we found a total profit objective function, subject to constraint functions and non-negative functions and arrived at an optimal solution which brings in a profit of Rs.1131800, i.e. 18.507% higher than the original profit. For optimal profit, the number of units produced for O.T gown, Dr scrub, baby set should be 4000, 5000 and 500 respectively.

Marek and Krzysztof (2018) in their analysis “Applications of linear programming to optimize the cost-benefit criterion in production processes”, used the primary data and linear programming model for analysis. The study reveals improved profit through streamlining of the product range and cutting off the less productive products.

Eric, J. (2018) researched the Application of linear programming techniques in production planning. His worked focus on the agricultural industry, taking primary data and analyzing it using Management Scientist Version 5.0. The study reveals improved profit through streamlining of the product range and cutting off the less productive products.

Glauca and Giovanna (2017) attempted a work on Production Planning Of A Manufacturing Industry Using Linear Programming. His study focused on the manufacturing industry and primary data was sourced through it. The study reveals improved profit through streamlining of the product range and cutting off the less productive products.

Muhammad et al. (2016) worked on the Application of Linear Programming for Profit Maximization: A Case of Paints Company, Pakistan. The study made use of primary data which was analyzed using linear programming. Their findings showed that the company can earn maximum contribution by only investing its resources (raw material) in the production of gallon and producing 444 units of it thus generating contribution Rs. 162038.

Wahid (2016) made an analysis on the “Implementation Of Modern Garment Planning Tools & Techniques In Garment Industry Of Bangladesh” focusing on the manufacturing industry, primary data was sourced for and used for analysis using linear programming model. The study reveals improved profit through streamlining of the product range and cutting off the less productive products.

Eshetie et al. (2016) worked on Case Study on Profit Planning of Textile Industry Using Linear Programming Approach. Their study focusing on the textile industry used primary data for analysis. As a result, the linear programming model was developed which maximizes profit from around 44.46 million ETB to 53.77 million ETB. This was achieved by applying proper product mix strategy as production of 0.25 unit of yarn, 0.25 unit of fabric, 0.76 unit of CM, 8.5 units of knit garment, and 0.25 unit of woven garment product.

Usman et al. (2015) The Optimization Problem of Product Mix and Linear Programming Applications, a Revise Simplex Approach. A quantitative decision-making tool called linear programming was be used for the optimization problem of product mix. The

findings of the study shows that, the profit of the company can be improved by 9.1% (from 26,520,300 naira per month to 29.192 million per month). by applying linear programming models if customer orders have to be satisfied. The profit of the company can be improved by 9.1% if the linear programming formulation does not need to consider customer order

## **2.4 NIGERIAN FOOD INDUSTRY AND THE MANUFACTURING SECTOR**

The manufacturing industries in Nigeria is an economic sector that brings approximately 10 percent of total GDP (Gross Domestic Product) each year. Manufacturing activity is concentrated in large cities like Lagos, Port Harcourt, and Ibadan, in the south of the country. Millions of people are involved in producing household goods, consumer products, automobiles, agriculture, mining, cement and building materials etc. The Nigerian manufacturing sector is dominated by the production of cement and building materials, food and beverages, tobacco, chemicals and fertilizers, wood, and textiles. Out of all only 3 subsectors (food & beverage, cement, and textile) account for 77% of manufacturing output generating the greatest value. Also, breweries and flour mills contribute well in the manufacturing sector.

Aghogho Udi February 26, 2024, The contribution of the manufacturing sector to Nigeria's GDP in the fourth quarter of 2023 dropped from 8.40%, as recorded in the corresponding period of the previous year, to 8.23%, according to the GDP report for Q4 published by the NBS. On a quarter-on-quarter basis, the sector's contribution to GDP dropped by 0.19%, from 8.42% to the current figure. The manufacturing sector's Q4 2023

Real GDP growth stood at a 1.38% year-on-year increase, representing a slight decline from 2022 but an improvement from the previous quarter. Quarter-on-quarter growth stood at 9.54%. The Manufacturing sector experienced a notable increase in Nominal GDP growth in the fourth quarter of 2023, reaching 38.06% on a year-on-year basis. This marked a significant leap of 29.20 percentage points from the 8.86% growth observed in the same period of 2022, and a modest improvement of 1.47 percentage points over the previous quarter's growth rate of 36.59%. Additionally, the sector saw a quarter-on-quarter growth of 7.70% during the final quarter of the year. Looking at the sector's performance throughout 2023, there was a remarkable annual growth rate of 30.93%, a stark contrast to the 6.93% growth rate in 2022. The Manufacturing sector's contribution to the Nominal GDP in Q4 2023 was 16.04%, which represents an increase from the 13.49% contribution during the same quarter in 2022, though it slightly declined from the 16.18% recorded in the third quarter of 2023. This data underscores the Manufacturing sector's significant and growing impact on the overall economy. The Manufacturing sector encompasses industries involved in cement production, beverages, oil refining, food processing, tobacco, textiles, rubber processing, footwear manufacturing, paper production, and the creation of chemicals and pharmaceuticals. The decline in the Manufacturing sector's contribution to the real GDP this quarter was anticipated, given the challenging macroeconomic conditions it faced. Elevated energy costs, significant exchange rate fluctuations, increased interest rates, and the rising cost of raw material imports forced many companies to scale back production and endure narrower profit margins. Moreover, manufacturers have consistently

urged the Federal Government to tackle persistent issues such as multiple taxation, the current monetary policy stance, and the energy sector's inefficiencies.

Oyaniran, 2020 the agricultural sector accounted for 23.4 percent of GDP in 2021 (World Bank, 2021). Crop production dominates the agricultural sector, accounting for 87.6 percent of output, followed by livestock (8.1 percent), fisheries (3.2 percent) and forestry (1.1 percent). In 2018, the Central Bank of Nigeria (CBN) Governor noted that Nigerians spend an average of 73% of their income on food and beverages products, however given the choice, a vast majority of Nigerian consumers will opt for food and beverages products made outside of the country. Nevertheless, in the last five years, more indigenous brands are coming up or expanding, to meet the needs of the Nigerian consumers who prefer local flavors. According to IMF and PwC estimates, Nigeria has the potential to be the fastest growing large African economy, with a projected annual GDP growth rate of 4.2% in the period 2016-2050. This will push it up the GDP rankings to become the 14th largest economy in the world by 2050. In terms of population, Nigeria will be the 3rd largest in the world by that time -larger than the United States of America. Spending on food In Nigeria was estimated at almost USD 44 billion in 2017, with an average food spend per person per year around USD 220: low-income consumers dominate. Growth in spending on food and beverage will see a bump over 2020, as consumers re-prioritise their spending patterns toward essentials due to Covid-19-induced lockdowns. The country's growing population and urbanisation present opportunities for the industry as a whole, including for Flemish exporters. This report intends to give a high-level

overview of both the developments in the industry, as well as trends and opportunities that may arise out of them. Despite the contribution to the economy, Nigeria's agricultural sector faces many challenges which impact on its productivity. These include; poor land tenure system, low level of irrigation farming, climate change and land degradation. Others are low technology, high production cost and poor distribution of inputs, limited financing, high post-harvest losses and poor access to markets. These challenges have stifled agricultural productivity affecting the sector's contribution to the country's GDP as well as increased food imports due population rise hence declining levels of food sufficiency. For instance, between 2016 and 2019 Nigeria's cumulative agricultural imports stood at N3.35 trillion, four times higher than the agricultural export of N803 billion within the same period. The Government has implemented several initiatives and programmes to address the situation including the Agriculture Promotion Policy (APP), Nigeria–Africa Trade and Investment Promotion Programme, Presidential Economic Diversification Initiative, Economic and Export Promotion Incentives and the Zero Reject Initiative, Reducing Emission from Deforestation and Forest Degradation (REDD+); Nigeria Erosion and Watershed Management Project (NEWMAP); Action Against Desertification (AAD) Programme, among others. All these efforts aim to increase agricultural productivity in order to provide sufficient quantities of food to meet domestic demand as well as an abundance of commodity crops for export in the international market. Besides, they aim at reversing forest loss and degradation; promoting sustainable management of natural resources; rehabilitation of degraded lands and reducing erosion and climate vulnerability.

The Association of Fast Food and Confectioners of Nigerian (AFFCON), an umbrella body of Quick Service Restaurants (QSR) has revealed that the Nigerian food industry is estimated to worth over a trillion Naira, with the Fast Food segment gulping over N250 billion, and this number is still expected to rise in the future. Euro monitor, a leading research firm also stated that the Nigerian food industry is one of the best-performing industries in country despite the economy downturn and huge decline in consumer spending power over the years. The industry has grown so well and consumers are still making the switch from unpackaged and unbranded products to packaged products as they become more aware.

Another segment they said worth examining is the Carbonated Soft Drink (CSD) segment, which undoubtedly has become the most competitive and aggressive in the food industry as a whole. This is as a result of changes in consumer's lifestyle and their demand for quality, durability and convenience, which saw the transition from the use of glass bottles for beverages to highly versatile PETs and Tetrapak designs.

#### **2.4.1 THE BAKERY INDUSTRY**

Nigeria is a net importer of food and major agricultural products. Bread, semolina, pasta and other wheat flour-based products are staples in Nigeria and the demand for the

products has continued to increase. Currently, the shares of wheat flour for bread and others, are estimated at 60 percent, respectively. Nigeria's wheat consumption is mostly filled by local production augmented by imports valued at about \$1.5 billion in 2017 and \$1.7 billion in 2018. Local wheat production remained inadequate and domestic supplies of substitute staples within Nigeria and neighboring countries have not kept pace with demand. USDA forecasts Nigeria's wheat consumption in MY 2019/20 at 5.26 million metric tons (MT).

USDA forecasts Nigeria's wheat production in marketing year (MY) 2019/20 (July-June) to reach 60,000 metric tons (MT), unchanged from the production figure for marketing year 2018/19. The area harvested to remain at 60,000 hectares, with yields holding steady at one metric ton per hectare, according to USDA Foreign Agricultural Service (FAS) report published in May. After four years of growth, the Nigerian bread and bakery market decreased by -7.8% to \$25.8B in 2015. The market value increased at an average annual rate of +1.1% from 2007 to 2015; the trend pattern remained relatively stable, with somewhat noticeable fluctuations being observed throughout the analyzed period. The pace of growth appeared the most rapid in 2008 when the market value increased by 10% year-to-year. Over the period under review, the market attained the maximum level at \$28B in 2014, and then fell in the following year. In value terms, bread and bakery production reached \$26.3B in 2015 estimated in export prices. The total output value increased at an average annual rate of +3.9% from 2007 to 2015; the trend pattern indicated some noticeable fluctuations being recorded throughout the analyzed period. The growth pace

was the most rapid in 2014 when the production volume increased by 38% against the previous year. Over the period under review, production hit record highs in 2015 and is likely to continue growth in the immediate term. In 2015, consumption of bread and bakery increased by 1.3% to 9.4M tonnes, rising for the fifth consecutive year after two years of decline. Overall, consumption saw a relatively flat trend pattern. The most prominent rate of growth was recorded in 2012 when the consumption volume increased by 2.4% year-to-year. Over the period under review, consumption attained the peak volume in 2015 and is likely to see gradual growth in the near future. The value of the bread and bakery market in Nigeria declined to \$25.8B in 2015, which is down by -7.8% against the previous year. This figure reflects the total revenues of producers and importers (excluding logistics costs, retail marketing costs, and retailers' margins, which will be included in the final consumer price). The market value increased at an average annual rate of +1.1% from 2007 to 2015; the trend pattern remained relatively stable, with somewhat noticeable fluctuations in certain years. The most prominent rate of growth was recorded in 2008 with an increase of 10% year-to-year. Over the period under review, the market reached the peak level at \$28B in 2014, and then fell in the following year.

Fresh bread and miscellaneous bakery (8.5M tonnes) constituted the product with the largest volume of consumption, accounting for 91% of total volume. Moreover, fresh bread and miscellaneous bakery exceeded the figures recorded for the second-largest type, gingerbread, sweet biscuits and waffles (689K tonnes), more than tenfold. From 2007 to 2015, the average annual growth rate of the volume of consumption of fresh bread and

miscellaneous bakery was relatively modest. With regard to the other consumed products, the following average annual rates of growth were recorded: gingerbread, sweet biscuits and waffles (+0.8% per year) and crispbread and rusks (+2.0% per year). In value terms, fresh bread and miscellaneous bakery (\$23.1B) led the market, alone. The second position in the ranking was occupied by gingerbread, sweet biscuits and waffles (\$2.1B). From 2007 to 2015, the average annual rate of growth in terms of the market volume of fresh bread and miscellaneous bakery stood at +3.2%. With regard to the other consumed products, the following average annual rates of growth were recorded: gingerbread, sweet biscuits and waffles (+2.8% per year) and crispbread and rusks (+6.3% per year). Although annual bread consumption per capita (10.5kg) is small in relation to South Africa (40.2kg), for example, given the size of the population (almost 192 million), it translates to a market size of 7.2 million loaves per day or \$2bn annually. Wheat consumption grew by 4.5% per annum between 2009-2014 and 62% of this goes towards bread production. Similar dynamics hold for pastries with current consumption at 22 million units per day.

Sugar bread is Nigeria's No. 1 bakery product. All Nigerians love this sweet sandwich bread, whatever their social class or ethnic origin. Consumers expect top quality at rock-bottom prices — a major challenge to both artisan and industrial bakeries. No other food in Nigeria enjoys such wide popularity as sugar bread. The white pan loaf made from wheat flour finds its way onto the table at every meal. Filled as a succulent club sandwich, crisp out of the sandwich toaster, or fried as sweet French toast, the silky-soft slices have a multitude of uses and have long since overtaken traditional staple foods like “Garri,” a

cooked cassava porridge. A special feature of Nigerian sandwich bread is its sweetish taste, the origin of its name. Besides flour, salt (1.5% to 2%), fresh yeast (3% to 6%) and baking enzymes, the sugar bread recipe contains 7% to 12% sugar.

Adekoyeni Oludare Olumuyiwa<sup>1</sup> Abdulhamid Ellawule(2020), Bread is a staple fermented confectionery produced by baking dough recipes largely based on or containing significant quantities of wheat or other cereal flour which are blended with other ingredients. The bread making process has undergone dramatic development over the ages, from traditional baking which involves bread production using wheat flour, yeast (*Saccharomyces cerevisiae*), salt, and water followed by a series of processes such as mixing, kneading, proofing, shaping and baking to commercial industrial production on a large-scale basis that involves the use of enzymes and additives to improve qualities of bread. Several varieties of bread are available in Nigerian market wheat-meal bread, multigrain and kibbled bread, rye bread and fruit bread. The wheat-meal bread comprises whole wheat and white bread usually referred to as sandwich or sugar bread. The white bread is made with wheat flour from which the bran and germ layers have been removed. The bread business in Nigeria is dominated by the white bread while the whole bread is sparingly demanded by people with health challenges. It constitutes one of the most important sources of nutrients such as carbohydrate, protein, fibre, vitamins and minerals in the diets of many people worldwide. The consumption of bread in Nigeria is

on a steady increase because it is convenient and ready-to-eat food. The desire for more nutritious baked goods is creating a new form of products in the specialized baked goods market. Bread is the most staple bakery food eaten by both the low and high social classes in Nigeria. It is relatively cheap, affordable and easy to find in the streets. It is widely consumed across the country by almost all citizens, ethnics, and religious groups.

According to Ohimain Malomo, et al. Odedeji and Adeleke the consumption of bread has increased considerably in Nigeria due to population increase and urbanization, and the changing preference for convenience foods. Nigerian population of 198 million and which is expected to be the third most populous country in the world by 2050. The country has an estimated national population growth rate of 5.7 per cent per annum and an average economic growth rate of 3.5 per cent per annum in the past five years. In 2016, the value growth of bread in Nigeria was put at 12 per cent while other baked products were 11 per cent. It is evident that investment in bread business is increasing. However, the investors require certain eminent information that would assist in the business projection for profitability. Economic feasibility assessment of a proposed business involves a cost/benefits analysis of the project, helping organizations determine the viability, cost, and benefits associated with the project before financial resources are allocated. It also serves as an independent project assessment and enhances project credibility—helping decision-makers determine the positive economic benefits to the organization that the proposed project will provide. It takes into account both quantitative and qualitative factors for analysis of the value for money for a particular project or investment opportunity.

Therefore, it is imperative to carry out such research before embarking on any business as entrepreneurs.

The manufacturing process fits into the production process of any type of bread with adjustment on the

processing operation. Other baked products passed through similar processing unit operations. Straight dough

method was used for the bread production as described by Ijah, et al. With some adjustment based on the

laboratory scale production. The bread-making process is mainly based on 3 steps: dough formation, fermentation and baking. The first step in preparation for mixing is assembling and weighing the ingredients. Some ingredients require special preparation. The yeast, whether compressed or dry must be suspended in water according to the manufacturer's instructions. This is usually written on the packaging material. The Baking formula was 60.80% heat flour, 21.90 % water, 9.70 % sugar, 3.70 % skim milk powder, 1.22 % salt, 4.87 % fat, 3.7 % preservative, 0.5 % improver, and 1.22 % yeast. All ingredients are mixed in a Kenwood mixer (Model A 907D) for 10 min. The purpose of mixing the dough is to distribute the yeast cells throughout the dough, distribute food for them yeast, and to form and develop the gluten. Gluten is formed when the two proteins of the flour, gliadin and glutenin come in contact with water. The time required to develop the gluten depends

on the strength of the flour and the speed of the machine. The dough was fermented in bowls, covered with wet clean muslin cloth for 55 min at a warm temperature. To ensure alcoholic fermentation which is most desirable, a temperature range between 25.5 -27.5 °C was maintained during the processing. The dough was punched, scaled to 0.9 g dough pieces, proofed in a proofing cabinet at 30°C for 90 min and 85% relative humidity, and baked at 250°C for 30 min. The intense baking heat dries out the part exposed to the air and causes a crust to form. The golden-brown colour of the crust is the result of chemical changes in the starch, sugar and milk known as a browning reaction (Maillard reaction) also known as caramelisation. The baked bread samples are then depanned, cooled at ambient temperature and packaged in a polyethene bag.

Linear programming can help optimize production schedules by finding the best combination of products to produce, given constraints such as production capacity, raw material availability, and demand requirements. This can lead to maximizing profit or minimizing costs. Linear programming can assist in developing a production plan that meets demand forecasts while minimizing inventory holding costs and production costs. It can help determine the optimal production quantities for each product over a specific time horizon. Linear programming can be used to analyze different production scenarios and assess their impact on profitability and resource utilization.

## **CHAPTER THREE**

### **METHODOLOGY**

### 3.1 THEORETICAL FRAMEWORK

Theoretical frameworks are structured representations, concepts, or variables that explain the application of linear programming in a manufacturing industry in order to solve a problem. One of the most important (and difficult) theorems in linear programming is the General Representation Theorem. This theorem not only provides a way to represent any point in a polyhedral set, but its proof also lays the groundwork for understanding the Simplex method, a basic tool for solving linear programs. The General Representation Theorem: Let  $X = \{x : Ax \leq b, x \geq 0\}$  be a nonempty polyhedral set. Then the set of extreme points is not empty and is finite, say  $\{x_1, x_2, \dots, x_k\}$ . Furthermore, the set of extreme directions is empty if and only if  $X$  is bounded. If  $X$  is not bounded, then the set of extreme directions is nonempty and is finite, say  $\{d_1, d_2, \dots, d_l\}$ . Moreover,  $x \in X$  if and only if it can be represented as a convex combination of  $x_1, x_2, \dots, x_k$  plus a nonnegative linear combination of  $d_1, d_2, \dots, d_l$ .

The theoretical framework of linear programming is built upon a foundation of mathematical and optimization principles.

- **Linearity:** The fundamental assumption is that all relationships between variables are linear. This means the objective function and constraints are expressed as linear equations or inequalities.
- **Optimization:** The goal is to find the optimal solution (maximum or minimum) of an objective function subject to a set of linear constraints.

- Feasible region: the set of all possible solutions that satisfy the constraints defines the feasible region. In linear programming, this region is a convex polytope.
- Convexity: the feasible region is a convex set, meaning that any line segment connecting two points within the region also lies entirely within the region.

### **Key components:**

- Objective function: a linear function that represents the quantity to be optimized (e.g., profit, cost).
- Constraints: linear inequalities or equalities that define the limitations or requirements of the problem.
- Decision variables: variables that represent the quantities to be determined.

### **Mathematical foundation:**

- Linear algebra: linear equations, inequalities, vectors, and matrices are used to represent and manipulate linear programming problems.
- Optimization theory: concepts from optimization theory such as optimality conditions and duality, are applied to linear programming.

### **Key theories and methods:**

- Simplex method: an iterative algorithm that moves from one corner point of the feasible region to another, improving the objective function at each step. The simplex

method is used in linear programming, starting from a feasible basis solution to another possible basis solution by doing it repeatedly (iteratively) to reach an optimum solution. Many methods are used to solve linear programming problems, the simplex method is the most powerful method. The Simplex method was developed in 1946 by George Dantzig. Before calculating, the objective function and the constraint function must be converted into standard form. The common form of the constraint function in the simplex method is to provide additional variables. Adding slack variable for the constraint function with the symbol  $\leq$ , minus the surplus variable adding the artificial variable for the constraint function with the character  $\geq$ , and adding an artificial variable for the constraint function with a symbol  $=$ .

- Duality theory: establishes a relationship between a primal linear programming problem and its dual problem, providing valuable insights into the economic interpretation of solutions.
- Sensitivity analysis: examines how changes in the parameters of a linear programming problem affect the optimal solution.
- The Graphical method or approach is often applied in visualizing basic concepts utilized in the linear programming problem. This approach is often use when there are only two decision variables in the LP problem, though as opined by Kannan, Dinakaran and Lavanya (2004), it can also be applied in solving for LP problems involving three decision variables but becomes rigorous when manually used. However, applying the graphical approach on problem having two decision variables involves plotting the

constraints on a graph and identifying the region that satisfies all of the constraints. In other words, the areas in the graph that accommodates all the constraints is seen as feasible region.

### 3.2 MODEL SPECIFICATION

In linear programming, this is the process of translating a real world problem into a mathematical representation that can be solved using linear programming techniques. It involves defining the objective function, variables, and constraints that accurately capture the essence of the problem.

The objective of the study is to maximize profit. A Linear Programming Problem (LPP) has the generic form maximize/minimize the objective function:

$$Z = c_1x_1 + c_2x_2 + c_3x_3 + \dots + c_nx_n \text{-----} (1)$$

subject to the constraints:

$$a_{11}x_1 + a_{12}x_2 + a_{13}x_3 + \dots + a_{1n}x_n \leq, b_1 \text{ (flour)}$$

$$a_{21}x_1 + a_{22}x_2 + a_{23}x_3 + \dots + a_{2n}x_n \leq, b_2 \text{ (sugar)}$$

$$a_{31}x_1 + a_{32}x_2 + a_{33}x_3 + \dots + a_{3n}x_n \leq, b_3 \text{ (milk)}$$

$$a_{41}x_1 + a_{42}x_2 + a_{43}x_3 + \dots + a_{4n}x_n \leq, b_4 \text{ (butter)}$$

$$a_{51}x_1 + a_{52}x_2 + a_{53}x_3 + \dots + a_{5n}x_n \leq, b_5 \text{ (salt)}$$

$$am_1x_1+am_2x_2+am_3x_3 + \dots + am_nx_n \leq, bm$$

And the non-negative restrictions  $x_j \geq 0, j = 1, 2, \dots, n$  there can be no negative products.

### **3.3 SOURCE OF DATA**

Data for the study was obtained from the company's record book, explanations and further information was gotten from the production manager in some aspect of the data given. Data was obtained on the quantity of each raw material used per month as well as work hours.

## **CHAPTER FOUR**

### **DATA PRESENTATION AND ANALYSIS**

## 4.1 PRESENTATION OF DATA

### 4.1.1 Materials and Methods

Data for the study was obtained from the company's managerial system, clarification and explanation were obtained through an officer in that unit. Data was obtained on the quantity of each raw material used per day on the production of a single unit, as well as mix of these basic raw materials.

**Table 4.1: Quantity of raw materials in stock and needed to produce the products.**

RAW MATERIALS	PRODUCTS			AVAILABLE RESOURCES
	Family size bread	Sardine bread	Banana bread	
Flour	70	90	60	2300g
Sugar	120	860	150	2300g
Milk	90	120	250	3200g
Butter	210	130	250	1400g
Salt	130	250	350	3300g
Labor time	24	28	55	1500hours
Machine time	55	32.5	31.5	300hours

**Sou**  
**ree:**  
*Rese*  
*arch*  
*ers*  
*Fiel*  
*d*  
*wor*  
*k*  
**Tab**  
**le**

**4.2: The table shows the products under review and the profit per unit of each product**

Products	Profit(N)
Family size bread	40,000
Sardine bread	60,000
Banana bread	40,000

**Source:** *Research fieldwork*

In formulating the model properly, we have;

Maximize Z (N profit):

$$40,000(\text{family size bread}) + 60,000(\text{sardine bread}) + 40,000(\text{banana bread})$$

Subject to:

$$70x_1 + 90x_2 + 60x_3 \leq 2300(\text{flour})$$

$$120x_1 + 860x_2 + 150x_3 \leq 2300(\text{sugar})$$

$$90x_1 + 120x_2 + 250x_3 \leq 3200(\text{milk})$$

$$210x_1 + 130x_2 + 250x_3 \leq 1400(\text{butter})$$

$$130x_1 + 250x_2 + 350x_3 \leq 3300 \text{(salt)}$$

$$24x_1 + 28x_2 + 55x_3 \leq 1500 \text{(labor time)}$$

$$55x_1 + 32.5x_2 + 31.5x_3 \leq 300 \text{(machine time)}$$

$x_1, x_2, x_3 > 0$  ( non-negativity constraint) this is an assumption that no product produced can be negative.

## 4.2 DATA ANALYSIS

**Table 4.3 presentation of optimal solution**

	LOWER	LEVEL	UPPER	MARGINAL
Family-Sized-Bread	-	3.2621	+INF	
Sardine-Bread	-	1.8920	+INF	
Banana-Bread	-	1.8760	+INF	
VAR z	-INF	<b>319,045.2822</b>	+INF	

**Source:** *Researchers analysis from GAMS software*

From the result of data analysis, it was found out that for the organization to operate optimally in the background of inherent constraints, it must produce 3.2621 units of family

size bread, approximately 2 units of sardine bread and approximately 2 units of banana bread for optimal production. This optimal product mix would yield a maximum objective (profit) of ₦319,045.2822 daily for the case study company.

**Table 4.4 Sensitivity results from the analysis**

	<b>LOWER</b>	<b>LEVEL</b>	<b>UPPER</b>	<b>MARGINAL</b>	<b>UNUSED CAPACITY</b>
Flour	-INF	511.1889	2300.0000	.	1788.8111
Sugar	-INF	2300.0000	2300.0000	45.3089	0
Milk	-INF	989.6275	3200.0000	.	2210.3725
Butter	-INF	1400.0000	1400.0000	103.3594	0
Salt	-INF	1553.6739	3300.0000	.	1746.3261
Labor time	-INF	234.4461	1500.0000	.	1265.5539
Machine time	-INF	300.0000	300.0000	233.7720	0

**Source:** Researchers Analysis

This analysis presents the results of the GAMS linear programming model, which was designed to determine the optimal production levels of different bread types in a bakery while ensuring efficient use of raw materials. The objective of the model was to maximize total profit while adhering to constraints on available ingredients and production capacity. The table above also present unused capacities (raw materials) on the constraints that are non-binding, these constraints includes flour, milk, salt, labor time of #1788.8111, #2210.3725, #1746.3261, and #1265.5539 respectively. The non-binding constraints have no impact on the optimal value, thus an increase in their capacities would not affect the optimal value.

Based on the solution, the bakery should produce the following quantities of each bread type:

<b>Bread Type</b>	<b>Optimal Production Quantity</b>
Family-Sized Bread	3.26 units
Sardine Bread	1.89 units
Banana Bread	1.88 units

These production levels maximize profit while ensuring that resource constraints are not exceeded. Notably, Coconut Bread and Honey Bread are not included in the optimal production plan, indicating that they are either not profitable or that their production would

exceed resource availability. The results show how efficiently the bakery is using its available raw materials and production resources.

<b>Resource</b>	<b>Optimal Usage</b>	<b>Maximum Available</b>	<b>Binding?</b>
Flour	511.19	2,300	No
Sugar	2,300.00	2,300	<b>Yes</b>
Milk	989.63	3,200	No
Butter	1,400.00	1,400	<b>Yes</b>
Salt	1,553.67	3,300	No
Labor Time	234.45	1,500	No
Machine Hour	300.00	300	<b>Yes</b>

- Sugar, Butter, and Machine Hours are fully utilized (binding constraints). These resources are the most restrictive in the production process, meaning that increasing their availability could allow for higher production and greater profitability.
- Flour, Milk, Salt, and Labor Time are underutilized, meaning that the bakery has some flexibility in these areas. This suggests that the primary limitations are not due to labor or general ingredient shortages, but rather specific critical inputs.

## **CHAPTER FIVE**

### **SUMMARY, CONCLUSION AND RECOMMENDATION**

#### **5.1 SUMMARY OF FINDINGS**

This research is based on the application of linear programming techniques i.e simplex method on profit maximization for Nadia Bakery Company. The appropriateness of the use of linear programming methods of profit maximization has been demonstrated in this work. This is evident from the results obtained from the profit maximization type of the linear programming model fitted to the data collected on Nadia Bakery company limited. The summary of findings from this work are as follows:

- i. The model successfully found an optimal production strategy, yielding a maximum profit of ₦319,045.28. The solution status confirms that the optimization was successfully completed, meaning that the recommended production levels represent the most efficient use of available resources.
- ii. Based on the solution, the bakery should produce the following quantities of each bread type:

Bread Type	Optimal Production Quantity
Family-Sized Bread	3.26 units
Sardine Bread	1.89 units
Banana Bread	1.88 units

These production levels maximize profit while ensuring that resource constraints are not exceeded. Notably, Coconut Bread and Honey Bread are not included in the optimal production plan, indicating that they are either not profitable or that their production would exceed resource availability.

- iii. Flour, Milk, Salt, and Labor Time are underutilized, meaning that the bakery has some flexibility in these areas. This suggests that the primary limitations are not due to labor or general ingredient shortages, but rather specific critical inputs.

## 5.2 RECOMMENDATION

Based on the findings from this study, the researcher would recommend the following:

1. Nadia Bakery Company Limited should adopt the application of linear programming model in its production decision making process.
2. More machinery should be employed as the firm lacks the machine power to fully utilize its resources
3. The company should consider other factors that affect consumer demand before production activities is being made, as demand contributes majorly to profit margins.
4. The company should review the materials made available for the constraints that are non-binding as this will reduce wastage of raw materials.
5. The company should review the materials made available for the constraints that are binding as this will result to an increase in the optimal value.

### **5.3 CONCLUSION**

The Linear programming model provides a clear and actionable strategy for optimizing bread production in the bakery. By following the recommended production levels and addressing critical constraints, the bakery can maximize profit while making efficient use of resources. The insights from the shadow prices suggest that investing in machine capacity and securing additional sugar and butter would significantly improve profitability. Moving forward, further refinements to the model such as incorporating cost structures, market demand constraints, or seasonal variations in ingredient availability could provide even more precise recommendations for sustained growth and profitability.

However, for a firm to compete effectively in the competitive business environment and achieve set goals in term of profitability, high sales volume and large market share, it must continuously develop products and product lines to satisfy the need of constantly changing desires and needs of customers.

The Nigeria Bakery Product Market is anticipated to witness significant growth in the coming years, propelled by ongoing urbanization and changing dietary habits. Emerging trends include the increasing demand for health-oriented bakery products, such as gluten-free and whole grain options. Technological advancements, such as automation in production lines, will likely enhance efficiency and product quality. Nevertheless, the market must navigate challenges related to economic fluctuations and raw material sourcing, influencing future pricing strategies and competitkive dynamics. In the Nigeria bakery product market, cakes and pastries are emerging as the fastest-growing segment. This trend is driven by a flourishing celebration culture and an increasing consumer inclination towards indulgent treats. The demand for innovative flavours and visually appealing designs, influenced by social media and food trends, is propelling sales in this category. Additionally, the rise of artisanal bakers and gourmet offerings is capturing the interest of consumers seeking unique experiences, further enhancing the growth of caes and pastries in the market. When it comes to distribution channels, online retailing stands out as the fastest-growing segment in Nigeria's bakery product market. The growing accessibility of the internet and mobile devices has led to a surge in e-commerce, allowing consumers to conveniently purchase bakery items from the comfort of their homes. This shift is

especially pronounced among younger demographics who favour the flexibility and variety offered by online shopping. As retailers enhance their digital presence and logistics capabilities, online retailing is expected to continue its rapid expansion in the bakery sector. The bread business in Nigeria can be very profitable because bread is in high demand and affordable. A small bakery that sells 500 loaves of bread per day at ₦200 each could make a net profit of ₦1.5 million per month. A medium-sized bakery that sells 1000 loaves of bread per day at ₦250 each could make a net profit of ₦4.5 million per month. A large-scale bakery that sells 5000 loaves of bread per day at ₦300 each could make a net profit of ₦31.5 million per month. Production costs: The cost of production is a key factor in determining profitability

The right equipment, such as mixers, ovens, and bread slicers, can help a bakery be more efficient and profitable. The size of the bakery, from small to large scale, can affect profitability. Bread is in high demand in Nigeria, and the demand is expected to continue to rise. Being able to consistently supply bread to buyers is key to profitability. A well-thought-out business plan can help with budgeting, marketing, and other aspects of running a successful bakery

## REFERENCES

- Akpan, N. P. & Iwok, I. A. (2016). Application of linear programming for optimal use of raw material in Bakery, *International Journal of Mathematics & Statistic Invention* 4, (8), 51-57
- Akpan, N. P. and Iwok, I. A. (2016). Application of linear programming for optimal use of raw material in Bakery, *International Journal of Mathematics and Statistic Invention* 4(8): 51-57
- Akpan, P. C. (2010). *Basic principles of management*. University Press PLC.
- Akshar, G., Anirudh, S. & Anoushka, G. (2019) Application of Linear programming (Simplex Method) in Kraftwork company for Manufacturing an Optimal product mix
- Akshar, G., Anirudh, S. & Anoushka, G. (2019) Application of Linear programming (Simplex Method) in Kraftwork company for Manufacturing an Optimal product mix
- Balogun, O.S. Jolayemi, E.T. Akingbade, T.J. & Muazu, H.G. (2012). Use of linear programming for optimal production in a production line in Coca-Cola bottling company, *International Journal of Engineering Research & application* Vol. 2.

- Balogun, O.S. Jolayemi, E.T. Akingbade, T.J. & Muazu, H.G. (2012). Use of linear programming for optimal production in a production line in Coca-Cola bottling company, *International Journal of Engineering Research & application* Vol. 2.
- Balogun, O.S., Jolayemi, E.T., Akingbade, T.J., and Muazu, H.G., 2012. Use of Linear programming For Optimal Production In A Production Line In Coca –Cola Bottling Company, Ilorin. *International Journal of Engineering Research and Applications*, 2 (5), Pp. 2004-2007.
- Benedict, I. E. & Uzochukwu, A. (2012). Optimizing profit with the linear programming model: A focus on golden plastic industry limited, Enugu, Nigeria. *Interdisciplinary Journal of Research in Business*, 2(2), 37–49.
- Birge, J. R., & Louveaux, F. (2011). *Introduction to stochastic programming* (2nd ed.). Springer.
- Clinton E. & Isaiah F. (2013) Application of linear programming in production planning
- Connie, S., Desire L. L. & Andre, P. (2001) Application Of Linear Programming For Dormitory Development Plan At Petra Christian University
- Dantzig, G. B. (1947). Maximization of a linear function of variables subject to linear inequalities. In T. C. Koopmans (Ed.), *Activity analysis of production and allocation* (pp. 339-347). Wiley.
- Dantzig, G. B. (1963). *Linear programming and extensions*. Princeton University Press.
- Dantzig, G. B., & Thapa, M. N. (2006). *Linear programming 1: introduction*. Springer Science & Business Media. [9] Lewis, C. (2008). *Linear Programming: Theory & Applications*. Whitman College Mathematics Department.
- Diksha G., Disha, S. & Divya, S. (2018) A Linear Programming Approach To Maximize Profit & Minimize Wastage In A Hospital Products Manufacturing Firm- Global Services Ltd
- Dragičević, S., & Bojić, M. (2009). Application of linear programming in energy management. *Serbian Journal of Management*, 4(2), 227-238.
- Eric, J. (2018) Application of linear programming techniques in production planning
- Eshetie K., Ashish T. Niguss H., & Aregawi, G. (2016) Case Study on Profit Planning of Textile Industry Using Linear Programming Approach

- Fagoyinbo, I. S., & Ajibode, I. A. (2010). Application of linear programming techniques in the effective use of resources for staff training. *Journal of Emerging Trends in Engineering & Applied Sciences (JETEAS)*, 1(2), 127-132
- Gass, S. I. (2004). Linear programming. *Encyclopedia of Statistical Sciences*,
- Glaucia, M. B., & Giovanna, P. S. 2017 Production Planning Of A Manufacturing Industry Using Linear Programming
- Glover, F., & Kochenberger, G. A. (2006). *Handbook of metaheuristics*. Springer.
- Haider, Z., Fareed, R., Tariq, M.B., Ud din, S.U.N., and Khan, M.S., 2016. Application of Linear Programming for Profit Maximization: A Case of Paints Company, Pakistan. *International Journal of Management Sciences and Business Research*, 5 (12), Pp. 144-151.
- Hasanbeigi, A. (2010). Energy-efficiency improvement opportunities for the textile industry. . Steve Shoe Production Centre, Enugu, Nigeria. *International Journal of Research Granthaalayah*, 6(9), 123-136
- Herbst, A., Toro, F., Reitze, F., & Jochem, E. (2012). Introduction to energy systems modelling. *Swiss journal of economics & statistics*, 148(2), 111-135.
- Hillier, F. S., & Lieberman, G. J. (2014). *Introduction to operations research* (10th ed.). McGraw-Hill.
- Iheagwara, A. I., Opara, J., Esemokumo, P. A., Lebechi, J. I. (2014) Application of Linear Programming Problem on Niger Mills Company PLC Calabar. *International Journal of Innovation & Research in Educational Sciences* Volume 1, Issue 2, ISSN (Online): 2349–5219
- Isaiah, K., Paul, M. & Augustine, M. 2019 Energy Optimization Model Using Linear Programming for Process Industry: A Case Study of Textile Manufacturing Plant in Kenya
- Issam, M. S. (2006). Linear programming approach to optimize strategic investment in the construction workforce. *Journal of Construction Engineering and Management* © ASCE, 132(11), 1158-1166.
- Jorion, P. (2006). *Value at risk: The new benchmark for managing financial risk* (3rd ed.). McGraw-Hill.

- Kamien, M. I., & Schwartz, N. L. (2012). *Dynamic optimization: The calculus of variations and optimal control in economics and management* (2nd ed.). Dover Publications.
- Lewis, C. (2008). *Linear Programming: Theory & Applications*. Whitman College Mathematics Department.
- Marek, K. & Krzysztof, M. (2018) Applications of linear programming to optimize the cost-benefit criterion in production processes
- Maurya, V.N., Misra, R.B., Anderson, P.K., and Shukla, K.K. (2015): Profit Optimization using Linear Programming Model: A Case Study of Ethiopian Chemical Company. *American Journal of Biological and Environmental Statistics*. Vol.1, No.2, pp.51-57. doi:10.11648/j.ajbes.20150102.12
- Osagie, G. N., & Icheme, M. O. (2018). Optimization of resources with the aid of linear programming model in
- Singh, R.K., Varma, S.P., and Kumar, A., 2013. Application of Linear Programming techniques in Personnel Management. *IOSR Journal of Mathematics (IOSR-JM)*, 8 (1), Pp. 45-48.
- Umar, M., Oluwafemi, S., Rafiyatu, H., 2015. Profit Maximization in a Product Mix Company Using Linear Programming Approach to Resource Allocation. *International Journal of Sciences: Basic and Applied Research*, 24 (4), Pp. 46-52
- Uzochukwu A. & Benedict I. E. (2012) Optimizing Profit with the Linear Programming Model: A Focus on Golden Plastic Industry Limited, Enugu, Nigeria *Interdisciplinary Journal of Research in Business*, 2(2), 37–49.
- Varian, H. R. (1992). *Microeconomic analysis* (3rd ed.). W.W. Norton & Company. Nash, Equilibrium points in n-person games, *Proceedings of the National Academy of Sciences of the United States of America*, 36 (1):48–49. (1950)
- Waheed B. Y., Muhammed, K., Samuel, O., & Adekunle, E. A. (2012). Profit maximization in a product mix company using linear programming. *European Journal of Business & management* Vol. 4, No. 17
- Wahid, M. K. (2016) Implementation Of Modern Garment Planning Tools & Techniques In Garment Industry Of Bangladesh

- Zangiabadi, M., Maleki, H.R., 2007. A Method for Solving Linear Programming Problems with Fuzzy Parameters Based on Multi-objective Linear Programming Technique. *Asia Pacific Journal of Operational Research*, 24 (04), Pp. 557-573.
- Zhang, G., Lu, J., & Gao, Y. (2015). Optimization Models. In *Multi-Level Decision Making* (pp. 25-46). Springer, Berlin, Heidelberg.

## APPENDIX

### GAMS Code

#### Sets

I row indices /Flour,Sugar,Milk,Butter,Salt,LabourTime,MachineHour/

J column indices /Family-Sized-Bread,Sardine-Bread,Banana-Bread/;

*\*objective function variable and problem variables*

**Variables** z, x(J); **positive variable** x;

#### Parameter

c(J) coefficient vector of objective

/Family-Sized-Bread 40000,

Sardine-Bread 60000,

Banana-Bread 40000/

b(I) right-hand side vector of constraints

/Flour 2300

Sugar 2300

Milk 3200

Butter 1400

Salt 3300

LabourTime 1500

MachineHour 300/;

**Table** A(I,J) coefficient matrix

## Family-Sized-Bread Sardine-Bread Banana-Bread

**Flour** 70 90 60

**Sugar** 120 860 150

**Milk** 90 120 250

**Butter** 210 130 250

**Salt** 130 250 350

**LabourTime** 24 28 55

**MachineHour** 55 32.5 31.5;

*\*Equation declaration*

### Equations

obj the objective function

constr(I) the i-th constraint;

*\*Definition of objective and constraints*

obj.. z=E=Sum(J,c(J)\*x(J)); constr(I)..Sum(J,A(I,J)\*x(J)) =L=b(I);

*\*Naming your model*

**Model** TestLp2 /ALL/;

*\*solve the model*

**Solve** TestLp2 **UsingLP**Maximizing z;

### GAMS SOLVE SUMMARY

GAMS 49.2.0 9b2b0844 Mar 5, 2025 WEX-WEI x86 64bit/MS Windows -

03/09/25 19:10:05 Page 1

General Algebraic Modeling System

Compilation

1 Sets

2 I row indices /Flour, Sugar, Milk, Butter, Salt, Labor Time, Machine Hour/

3 J column indices /Family-Sized-Bread, Sardine-Bread, Banana-Bread/;

4 \*objective function variable and problem variables

5 Variables z, x(J); positive variable x;

6 Parameter

7 c(J) coefficient vector of objective

8 /Family-Sized-Bread 40000,

9 Sardine-Bread 60000,

10 Banana-Bread 40000/

11 b(I) right-hand side vector of constraints

12 /Flour 2300

13 Sugar 2300

14 Milk 3200

```

15 Butter      1400
16 Salt        3300
17 Labor Time  1500
18 Machine Hour 300/;
19 Table A(I,J) coefficient matrix
20           Family-Sized-Bread  Sardine-Bread  Banana-Bread
21 Flour       70                90          60
22 Sugar       120               860         150
23 Milk        90                120         250
24 Butter      210               130         250
25 Salt        130               250         350
26 Labor Time  24                28          55
27 Machine Hour 55               32.5        31.5;
28 *Equation declaration
29 Equations
30 obj the objective function
31 constr(I) the i-th constraint;
32 *Definition of objective and constraints
33 obj.. z=E=Sum(J,c(J)*x(J)); constr(I)..Sum(J,A(I,J)*x(J)) =L=b(I);
34 *Naming your model
35 Model TestLp2 /ALL/;
36 *solve the model
37 Solve TestLp2 Using LP Maximizing z;

```

```

COMPILATION TIME = 0.016 SECONDS 3 MB 49.2.0 9b2b0844 WEX-WEI
GAMS 49.2.0 9b2b0844 Mar 5, 2025 WEX-WEI x86 64bit/MS Windows -
03/09/25 19:10:05 Page 2
General Algebraic Modeling System
Equation Listing SOLVE TestLp2 Using LP From line 37

```

---- obj =E= the objective function

obj.. z - 40000\*x(Family-Sized-Bread) - 60000\*x(Sardine-Bread) - 40000\*x(Banana-Bread) =E= 0 ; (LHS = 0)

---- constr =L= the i-th constraint

constr(Flour).. 70\*x(Family-Sized-Bread) + 90\*x(Sardine-Bread) + 60\*x(Banana-Bread)  
=L= 2300 ; (LHS = 0)

constr(Sugar).. 120\*x(Family-Sized-Bread) + 860\*x(Sardine-Bread) + 150\*x(Banana-Bread)  
=L= 2300 ; (LHS = 0)

constr(Milk).. 90\*x(Family-Sized-Bread) + 120\*x(Sardine-Bread) + 250\*x(Banana-Bread)  
=L= 3200 ; (LHS = 0)

REMAINING 4 ENTRIES SKIPPED

GAMS 49.2.0 9b2b0844 Mar 5, 2025 WEX-WEI x86 64bit/MS Windows -  
03/09/25 19:10:05 Page 3  
General Algebraic Modeling System  
Column Listing SOLVE TestLp2 Using LP From line 37

---- z

z  
1 (.LO, .L, .UP, .M = -INF, 0, +INF, 0)  
obj

---- x

x(Family-Sized-Bread)  
(.LO, .L, .UP, .M = 0, 0, +INF, 0)  
-40000 obj  
70 constr(Flour)  
120 constr(Sugar)  
90 constr(Milk)  
210 constr(Butter)  
130 constr(Salt)  
24 constr(LabourTime)  
55 constr(MachineHour)

x(Sardine-Bread)  
(.LO, .L, .UP, .M = 0, 0, +INF, 0)  
-60000 obj  
90 constr(Flour)

860 constr(Sugar)  
 120 constr(Milk)  
 130 constr(Butter)  
 250 constr(Salt)  
 28 constr(LabourTime)  
 32.5 constr(MachineHour)

x(Banana-Bread)  
 (.LO, .L, .UP, .M = 0, 0, +INF, 0)  
 -40000 obj  
 60 constr(Flour)  
 150 constr(Sugar)  
 250 constr(Milk)  
 250 constr(Butter)  
 350 constr(Salt)  
 55 constr(LabourTime)  
 31.5 constr(MachineHour)

GAMS 49.2.0 9b2b0844 Mar 5, 2025 WEX-WEI x86 64bit/MS Windows -  
 03/09/25 19:10:05 Page 4  
 General Algebraic Modeling System  
 Range Statistics SOLVE TestLp2 Using LP From line 37

RANGE STATISTICS (ABSOLUTE NON-ZERO FINITE VALUES)

RHS [min, max] : [ 3.000E+02, 3.300E+03] - Zero values observed as well  
 Bound [min, max] : [ NA, NA] - Zero values observed as well  
 Matrix [min, max] : [ 1.000E+00, 6.000E+04]

GAMS 49.2.0 9b2b0844 Mar 5, 2025 WEX-WEI x86 64bit/MS Windows -  
 03/09/25 19:10:05 Page 5  
 General Algebraic Modeling System  
 Model Statistics SOLVE TestLp2 Using LP From line 37

MODEL STATISTICS

BLOCKS OF EQUATIONS	2	SINGLE EQUATIONS	8
BLOCKS OF VARIABLES	2	SINGLE VARIABLES	4
NON ZERO ELEMENTS	25		

GENERATION TIME = 0.000 SECONDS 4 MB 49.2.0 9b2b0844 WEX-WEI  
GAMS 49.2.0 9b2b0844 Mar 5, 2025 WEX-WEI x86 64bit/MS Windows -  
03/09/25 19:10:05 Page 6

General Algebraic Modeling System  
Solution Report SOLVE TestLp2 Using LP From line 37  
S O L V E S U M M A R Y

MODEL TestLp2 OBJECTIVE z  
TYPE LP DIRECTION MAXIMIZE  
SOLVER CPLEX FROM LINE 37

\*\*\*\* SOLVER STATUS 1 Normal Completion  
\*\*\*\* MODEL STATUS 1 Optimal  
\*\*\*\* OBJECTIVE VALUE 319045.2822

RESOURCE USAGE, LIMIT 0.000 10000000000.000  
ITERATION COUNT, LIMIT 4 2147483647

\*\*\* This solver runs with a demo license. No commercial use.

--- GMO setup time: 0.00s  
--- GMO memory 0.50 Mb (peak 0.50 Mb)  
--- Dictionary memory 0.00 Mb  
--- Cplex 22.1.2.0 link memory 0.00 Mb (peak 0.00 Mb)  
--- Starting Cplex

--- LP status (1): optimal.  
--- Cplex Time: 0.00sec (det. 0.01 ticks)

Optimal solution found  
Objective: 319045.282177

	LOWER	LEVEL	UPPER	MARGINAL
---- EQU obj	.	.	.	1.0000

obj the objective function

---- EQU constr the i-th constraint

	LOWER	LEVEL	UPPER	MARGINAL
Flour	-INF	511.1889	2300.0000	.
Sugar	-INF	2300.0000	2300.0000	45.3089
Milk	-INF	989.6275	3200.0000	.
Butter	-INF	1400.0000	1400.0000	103.3594
Salt	-INF	1553.6739	3300.0000	.
LabourTime	-INF	234.4461	1500.0000	.
MachineHour	-INF	300.0000	300.0000	233.7720

	LOWER	LEVEL	UPPER	MARGINAL
---- VAR z	-INF	319045.2822	+INF	.

---- VAR x

	LOWER	LEVEL	UPPER	MARGINAL
Family-Sized-Bread	.	3.2621	+INF	.
Sardine-Bread	.	1.8920	+INF	.
Banana-Bread	.	1.8760	+INF	.

\*\*\*\* REPORT SUMMARY :    0   NONOPT  
                          0   INFEASIBLE  
                          0   UNBOUNDED

EXECUTION TIME    =    0.047 SECONDS    4 MB 49.2.0 9b2b0844 WEX-WEI

USER: GAMS Demo, for EULA and demo limitations see G250131/0001CB-GEN  
<https://www.gams.com/latest/docs/UG%5FLicense.html>    DC0000

\*\*\*\* FILE SUMMARY

Input    C:\Users\DELL\Desktop\Gams data 2.gms  
Output   C:\Users\DELL\Desktop\Gams data 2.lst

## APPENDIX II

# UNIVERSITY OF BENIN, BENIN CITY, NIGERIA

## DEPARTMENT OF ECONOMICS

### FACULTY OF SOCIAL SCIENCES



*Our Ref:*

*Your Ref:*

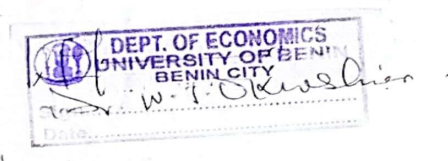
P.M.B 1154  
Tel: 41365  
Fax: 602306  
Cables & Telegrams: Uniben Benin  
Telephone: 08160650999  
E-mail: economics@uniben.edu

Date: .....

28<sup>th</sup> February, 2025.

Nadia Bakery Company,  
Main gate, Benin City,  
Edo State.

Through:  
The Project Supervisor,  
08028383093  
Department of Economics,  
Faculty of Social Sciences  
University of Benin.



Sir,

**REQUEST FOR PERMISSION TO USE NADIA BAKERY COMPANY AS A CASE STUDY**

## **Questionnaire: Profit Optimization Data Collection**

### **Section 1: Company and Product information**

#### **1. Company**

**name** \_\_\_\_\_

**2. Industry :** \_\_\_\_\_

### **Section 2: Product Name and Resource Consumption**

- **Raw Material consists of raw materials and the unit of raw materials required to produce a single tray**

<b>S/N</b>	<b>Product</b>	<b>Unit of Production</b>	<b>Raw Material (1)</b>	<b>Raw Materials (2)</b>	<b>Raw Material (3)</b>	<b>Raw Material (4)</b>	<b>Machine Time in Minutes</b>	<b>Labour Time in Minutes</b>
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								

3. Please list any other resources used in the production process and their units of measurement:

---

---



---



---



---



---



---



---



---

**Section 3: Resource Availability/Constraints**

<b>Resource</b>	<b>Maximum Availability (UNITS/Time Period, Specify Time Period, e.g. per week, per month)</b>
Raw Material 1	
Raw Material 2	
Raw Material 3	
Raw Material 4	
Machine Time/hours	
Labor time	

Other resources(specify)	

**2. Are there any other constraints on production, such as minimum production quantities, contractual obligations, or storage limitations? If so, please describe them:**

---



---



---



---

**Section 4: Profitability and Demand**

For each product listed in Section 1, please provide the following information:

<b>S/N</b>	<b>Product Name</b>	<b>Profit per Unit (N)</b>	<b>Estimated Maximum Demand  (Units/Time Period- Specify Time Period)(optional)</b>
1			
2			
3			
4			
5			

6			
7			
8			
9			
10			

2. Are there any price fluctuations or seasonal variations in demand that should be considered?

---

—

**Section 5: Additional information (optional)**

3. Any other relevant information you think will be relevant for this study?

---

Thank you for your participation

Note:

All data should refer to the same time frame or period(e.g. daily, weekly, monthly, annually).

Be very clear about the units of measurement for all resources, quantities and profits.

Raw	PRODUCTS					Available
Materials	Family size bread	Sardine bread	Coconut bread	Honey bread	Banana bread	Resources ( g or kg)

FLOUR						
SUGAR						
MILK						
BUTTER						
SALT						

NOTE: For the above how much in grams or kilograms is used to bake 1 tray of bread  
answer should be in kilograms or grams