UNIVERSITY OF CAPE COAST

APPLICATION OF LINEAR PROGRAMMING IN PROFIT MAXIMIZATION OF ASANDUFF CONSTRUCTION

CLEMENT ESSANDOR AMPONG

2022

UNIVERSITY OF CAPE COAST

APPLICATION OF LINEAR PROGRAMMING IN PROFIT MAXIMIZATION OF ASANDUFF CONSTRUCTION

BY

CLEMENT ESSANDOR AMPONG

A Project Work presented to the Department of Mathematics, School of Physical Sciences, College of Agriculture and Natural Sciences of the University of Cape Coast, in partial fulfilment of the requirements for the award of Bachelor of Science degree in Mathematics

NOVEMBER 2022

DECLARATION

Candidate's Declaration

I hereby declare that the Project Work is the result of my own research and that no portion of it has been submitted in part or whole for another degree in this university or elsewhere.

Candidate's Name: Clement Essandor Ampong

Candidate's Signature: ……………………..……….

Date: ………………………..………

Supervisor's Declaration

I hereby declare that the preparation and presentation of the Project Work were supervised in accordance with the guidelines on supervision of Project Work laid down by the University of Cape Coast.

Supervisor's Name: Henry Amankwah

Supervisor's Signature: ………………………………..

Date: …..……………………………

DEDICATION

I dedicate this Project Work to my uncle, Mr John Ampong, with the outmost love and gratitude.

ACKNOWLEDGEMENTS

I appreciate my supervisor, Dr Henry Amankwah, for his guidance and encouragement that enabled the outcome of this report. His suggestions were incredibly beneficial to me. May God bless him.

I want to express my gratitude to the management and staff of Asanduff Construction for providing the information used in this study.

My deepest gratitude is extended to all my roommates and programme mates. Congratulations, guys.

ABSTRACT

An operation research method called linear programming is frequently used to identify solutions to managerial decision-making issues involving the allocation of limited resources in order to maximize profit and decrease cost. Practically, in all businesses and institutions, optimization has become a routine occurrence. The goal of this Project Work was to apply linear programming for profit maximization in a block corporation. Asanduff Construction was used as our study case. Asanduff Construction manufactures four various sizes of building blocks (8 inches, 6 inches, 5 inches, and 4 inches). These sizes were taken into consideration in the study as decision variables. The production cost, production time, demand employed in the manufacturing, and the quantity of raw material needed for each block size were examined in order to determine the maximum profit using the linear programming technique. The problem was modeled, and solved with the use of EXCEL solver software that used the simplex method to produce the best results. It was observed that three of the four types of building blocks account for the maximum profit of Asanduff Construction. The result shows that 800 units of the 8 inches blocks, 2200 units of the 6 inches blocks, 290 units of the 5 inches blocks, and 0 units of 4 the inches blocks should be produced respectively which will give a daily maximum profit of GHS 5564.00. The daily profits of the company was increased by approximately 27.1% as a result of employing linear programming methods in determining the company's profit maximization.

TABLE OF CONTENTS

CHAPTER THREE: METHODOLOGY

CHAPTER FOUR: RESULTS AND DISCUSSION

CHAPTER FIVE: SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

LIST OF TABLES

LIST OF FIGURES

CHAPTER ONE

INTRODUCTION

In this Project Work, we considered the application of linear programming in profit maximization. The data for this report was collected from Asanduff Construction and analysis of the data was carried out using excel solver.

1.1 Background to the Study

Linear programming (LP) is a very important technique that is adopted in the study of Operations research. Operations research refers to a method of decision-making that uses science to try to decide how to construct and run a system most effectively when there are limited resources (Oyekan, 2015). India is one of the few countries in the world to have implemented operation research. In fact, the Second World War may have been the first time that individuals realized that scarce resources could be distributed effectively (Anderson, Sweeny, & Williams, 1995). During World War II, British military commanders commissioned scientists to investigate military concerns such as radar deployment, bombing and mining operations. Dantzig (1949) coined the phrase “Linear Programming” in 1947 to describe specific optimization situations in which both the constraints and the objective functions are linear. The early uses of LP, like other fields of Operations Research, may be found in military planning operations. Not only in the military operations, but also in business and government, operation research has proven to be effective. Soon after that, LP became widely used in industry, with the food industry proving to be the most fruitful. Operation research is now employed in practically every field.

A mathematical technique for solving optimization problems is linear programming. It is also a popular Mathematical modelling tool for allocating limited resources to known activities with the purpose of achieving the desired goal (Taha, 1977). A Linear Programming problem is one in which the goal is to maximize the value of an objective function subject to certain constraints. These constraints are a collection of requirements that the optimal solution must meet. Any solution that satisfies the objective function and the set of constraints is referred to as an optimum solution. In LP, the objective function and the constraints are linear equations or linear inequalities. The goals of LP may be to reduce cost within the constraints of available resources or to maximize profit, which is the main purpose of this study. According to Akingbade (1996), the term “linear”, denotes proportionality, which means that the parts in a scenario are sufficiently related that when graphed, they look as straight line. While the “programming” denotes a way of problem solving that can be accomplished through an iterative process in which a researcher progresses from one solution to a better one until a final solution is obtained that cannot be improved upon. Mathematics, engineering, transportation, agriculture, military and economics are just a few of the domains where LP can be used. In addition to industry and business, nonprofit sectors including hospitals, libraries, and government can also benefit from Linear Programming. When driving or going from one location to another, we frequently use LP to find the shortest path or route. To describe the problem of concern, Linear Programming employs a mathematical model. As a result, we reduce a complicated set of real-world interactions or problems to basic linear relationships. As linear functions of the decision variable, the objective function and constraints can be defined. The mathematical nature of LP makes it possible to answer important questions about the optimum solutions sensitivity to data changes.

The ultimate goal of every organization is to continue to exist and expand through time, hence profit making is the ultimate goal. This is because an organization's success or expansion depends on its ability to generate revenues on a consistent basis. Production of items at minimal cost and maximum profit that are of the proper standard, quantity and at the right time, especially for sustainability and growth, is the key to creating profits in manufacturing sectors (Oladejo, Abolarinwa, & Salawu, (2019)). As explained by Nonso (2005), the Board of Directors of a profit-seeking organization must deal with a variety of issues, including: the problem of other competitors in the same business, the availability of funds for new capital projects, the reduction of operational cost, high level of output and ultimately the maximization of profit.

Profitability in every organisation is determine by both operational and long-term business decisions. Every manager's primary responsibility is to make decisions about limited resources. These resources may include men, available raw materials, time, and money. It is the obligation of the management to make the best decision possible with these restricted resources in order to earn or maximize profit.

Nowadays, there has been a significant increase in the number of organizations or firms that may have been liquidated as a result of ineffective decision making. The issue is around determining which resources should be allocated in order to obtain the best profit and cost reduction. Considering the fact that different products demand different amount of production resources, a mathematical technique that can identify the appropriate quantity of resources to use in order to maximize profit is required. Managers utilize the Linear

Programming model, according to Wijeratne and Harris (1984), to find the most cost-effective financing arrangement, to schedule the optimal periods to start and end projects, and to select projects with the lowest total net percent cost of capital. Linear Programming is a commonly used mathematical technique for assisting managers with resource allocation planning and decisions-making, as well as providing relatively easy and realistic solutions to these problems (Bierman, Bonini, & Charles, (1973)). The economic literature recognizes the value of Linear Programming, particularly in developing counties with limited resources, where Linear Programming can assist in allocating these limited resources to get the best results.

This study illustrates the practical use of Linear programming techniques in a block manufacturing company to maximize profit, hence the objectives of Linear Programming could be to decrease cost within the constraints of available resources.

1.2 Statement of the Problem

Planning is a critical skill that is required on a variety of occasions in our daily activities, especially when resources are limited. The main objective of planning is usually to get a maximum profit or reduce cost when working with limited resources. One of the most significant aspects that people consider when starting a business is profit. This is because profit is what ensures a company's long-term survival and expansion. An organization will eventually collapse if the amount of resources invested is more costly than the profits it generates. Every organizations goal is to maximize profits while keeping low cost. That is, it is the manager's obligation to make the best decisions possible in order to maximize profit with the limited resource available. There has been a significant increase in the closure of numerous organizations throughout the years, which has resulted in an increase in unemployment. Because of the high rate of unemployment among young people, social vices such as prostitution, armed robbery and drug addiction have increased. These organizations may have closed as a result of poor management decisions. As a result, businesses must design a manufacturing process in which certain production resources are assigned to produce the optimal number of units of each product. Again, most research work on Linear Programming in profit maximization focuses on larger or medium-sized businesses, while the local or small-scale businesses are left to rely on the trial-and-error method of production to reduce cost and maximize profits. To close this gap and give the owner of Asanduff Construction the power to make better decisions, it was necessary to demonstrate the validity of Linear Programming model in practice.

1.3 Purpose of the Study

The major goal of this study is to consider how organisations and businesses employ Linear Programming techniques to help them better manage their limited resources in order to maximize profits. We used the Asanduff Construction as a case study.

1.4 Objectives to the Study

The project sorts to meet the following objectives in other to reach the goal.

1. To formulate a Linear Programming model that ensures maximum profit of the company.
2. To learn about the financial and resources restrictions of the company.
3. To encourage businesses to use Linear Programming technique to maximize profit.
4. To draw attention of businesses that using Linear Programming technique to determine profit maximization would be more beneficial than doing it otherwise.

1.5 Significance of the Study

Investigating into the area of Linear Programming in profit maximization among organizations will be very beneficial in diverse ways. This project's entire motivation is to determine the best way to make decisions utilizing Linear Programming model in order to maximize profits while working with limited resources. Again, the study will provide a thorough understanding and insight into the uses of Linear Programming models in industries, as well as how to implement such models in real-world situations. Finally, findings of the study will serve as a reference material for future researchers or students with similar interest who may perform further research on Linear Programming techniques.

1.6 Organisation of the Study

This study is organised into five chapters. Chapter One presents the general introduction of the study, including background to the study, statement to the problem, purpose of the study, objectives to the study, significance of the study and the organisation of the study. Chapter Two entails literature from different researchers from different countries concerning the Recast. Chapter Three presents the research methodology of the study, collection of data, analysis of the data collected, and presentation of results. Chapter Four focuses on the discussion of the results. Chapter Five presents the summary, conclusions and also presents recommendations for the study.

1.7 Definition of Terms

In this section, we present some definitions that will be useful in this Project Work.

Binding Constraint: A constraint is binding if the left-hand side and the right-hand side of the constraint are equal when the optimal values of the decision variables are substituted into the constraint.

Nonbinding Constraint: A constraint is nonbinding if the left-hand side and the right-hand side of the constraint are unequal when the optimal values of the decision variables are substituted into the constraint.

Basic Solution: suppose that a linear programming is given in the standard form with n decision variables and m constraints, then a basic solution to the LP is where n of the variables are set to zero and the equation is solved for the other m variables. A basic solution exists if the solution is unique.

Basic Variable (BV): these are the variables whose value is obtained from the basic solution.

Non Basic Variable (NBV): these are variables whose values are assumed as zero in a basic solution.

Basic Feasible Solution (bfs): this is any basic solution to an LP in which all the variables are nonnegative.

Slack Variables: to change the linear constraints of a linear programming problem from inequality constraints to equality constraints, additional variables known as slack variables are added.

1.8 Chapter Summary

This chapter was focused on the introduction, background to the study, statement of the problem, purpose of the study and objectives of the study. Also, a short discussion was made on the significance of the study and how the work was organised. Again, basic terminologies that will be used in this Project Work were also presented.

CHAPTER TWO

REVIEW OF LITERATURE

2.0 Introduction

In agriculture, insurance, and many other sectors, but particularly in the business industries, Operational Research methodologies have been used to model and solve a wide range of problems. This chapter seeks to provide relevant literature on Linear Programming, as well as its applications for maximizing profits in various organisations.

2.1 Relevant Review

In the 1940s, the discipline of linear programming was born out of the need to discover answers for challenging planning issues during wartime activity. Most practical planning problems could be flamed mathematically as finding a solution to a set of linear equations or inequalities, which made this achievable. Linear Programming technique is a mathematical device created by the mathematician George Dantzig in 1947 for organizing the many activities of the United State Air Force in relation to the problem of supply to the Force. Dantzig then proposed using this strategy to solve corporate and industrial difficulties. Dantzig also created the "simplex method", a strong mathematical tool for solving linear programming problems (Dantzig, 1993). The method is now widely employed in all fields of management, including aviation, the healthcare system, agriculture, energy planning, and others. Managers who are familiar with Linear Programming rigorous models avoids its use since they do not know how it could be put to use. However, Taha (1997) adds other programming types in his contributions, such as integer, objective, quadratic, convex and stochastic. Taha claims that they are different in terms of the kind of data they can manage and assumptions they make. Finally, Taha shows how the Ozark Poultry Farm used Linear Programming to establish the feed mix in order to maintain a balance ratio that includes calcium, protein, and fiber in the proper proportions. A step-by-step improvement strategy is used in an optimization model to identify the best option out of an infinite number of possibilities. An optimization algorithm outlines the procedures needed to get the optimal solution, which is what management is trying to do.

According to Dwivedi (2011), maximization of output, cost minimization, or resource allocation optimization is only one aspect of a firm's profit maximization, and that Linear Programming is useful in making business decisions because it aids in the measurement of complex economic relations and thus provides an optimal solution to the problem of resource allocation. Dwivedi claims that Linear Programming bridges the gap between abstracts economic theory and managerial decision-making. Dwivedi also emphasized the importance of having three specifications for any linear programming equation: objective function specification, constraint equation specification, and non-negative requirement.

Researchers at the Nigeria Bottling Company, Ilorin facility, employed the Linear Programming method to determine how to produced soft drinks with the greatest profit (Balogun, Jolayemi, & Akingbade, 2012). The corporation developed a linear operating program, and the simplex method was used to achieve the best results. Their findings demonstrated that more Coke 50cl and Fanta Orange 50cl should be produced in order to satisfy their customers, than producing Fanta Orange 50cl and 35cl, Fanta lemon, Sprite, and Schweppes. Additionally, as they typically add to the profit made, more Coke 50cl and Fanta Orange 50cl should be manufactured in order to maximize profit. In a similar study, to identify which bread size contributed most to profit maximization of the Johnsons Nigerian limited bakery division, Oyekan and Temisan (2019) employed the simplex method of Linear Programming. The minimum and maximum cost coefficient of the bread size within which the business could maintain its ideal profit were determined by using sensitivity analysis.

Developing nations like Nigeria have increasingly caught up the trend of using Linear Programming in production planning. This is supported by research conducted by a number of academics, including studies by Kareem and Aderoba (2008) who determined the effectiveness of using Linear Programming model in maintenance and manpower planning using information gathered from a cocoa processing industry in Ondo State, Nigeria. Their research revealed that only four maintenance crew, out of a total of 19, are required to properly complete maintenance tasks in the industry, hence lowering the cost of labour for the cocoa producing company.

Ezema and Amakon (2012) also reported that the issue facing industries worldwide is caused by a lack of production inputs, which leads to low capacity utilization and therefore low outputs. In order to find and reach the ideal product-mix for the Golden Plastic Sector, they employed Linear Programming to profit optimization. The company was initially producing eight pipes, but data analysis and estimation show that only two sizes of the total eight polyvinyl chloride pipes should be produced. This was achieved by formulating the Linear Programming problem for the production of plastic and estimating as such. They also succeeded in determining that 7,136.564 pieces of 20 mm by 5.4 m thick pressure pipe and 114317 should be produced. In order to make a monthly profit of N1,964,537, two pieces of 25 mm by 5.4 m conduct pipe should be produced, along with zero quantities of the remaining size.

In a different study, Susilawati (2002) extended the use of linear programming to the development of dormitories at Petra Christian University in order to determine the number of rooms and area of each facility that could be accommodated while taking into account the restricted space of 4,994.83 square meters and a maximum cash flow of Rp 392,952.00 that is discounted by 17 percent per year for seven years. Using specialized computer software (excel solver) that can solve linear programming models, they were able to calculate the number of area of facilities such as restrooms, cafeterias, dining rooms, sport facilities, and bookshops. The outcome indicates that, aside from the garden, all supporting facilities must be improved.

Byrd and Moore (1978) used a study on an American manufacturing company to identify the ideal product-mix composition, and they viewed raw materials as a crucial restriction. Cost limitation take into account the highest cost that a company's production process can incur. They used linear programming to analyze the product-mix of 29 unidentified goods in their investigation. Under the constraints of capacity, demand, and the availability of raw materials, the goal is to maximize profit. As a result of the study, the management of the company proposed from focusing exclusively on high profit products for manufacturing, eliminating the low profit things from the list. Customers of the company were to be provided with a replacement product in its place.

Felix and Judith (2010) applied Linear Programming model to the distribution of farm resources. They compared the outcome from utilizing the Linear Programming model and the traditional approach of planning and found that the Linear programming model's results were significantly better than those from the traditional method.

According to Igwe, Onyenweaku, and Nwaru (2011), Linear Programming is a useful technique for improving the production planning efficiency, notably for boosting agricultural productivity. When they investigated how to maximize the gross return from semi-commercial agriculture in the Ohatia zone of Abia state, they came to this conclusion. The decision variable for general deterministic model are the number of hectares the farmer dedicated to the production of crop and the combination of crops or livestock capacity produced by the farmer. The general deterministic model is a gross margin maximization model designed to find the best solution.

Again, according to Stephans and Dimitrios (2010), when faced with a practical challenge of tremendous complexity, Linear Programming has given mankind the ability to state general goals and to lay out the path of precise decisions to take in order to "best" attain its aims. They contend that determining the relationships between an objective function, such as maximizing of profit for one or more items, is the first step in a straightforward Linear Programming activities.

In order to increase profit, Igbinehi, Oyebode, and Taofeek-Ibrahim (2015) used a Linear Programming model in a local soap manufacturer that makes three different types of soap: 5 g white soap, 10 g white soap and 10 g colored soap. The data study revealed that while the corporation spends more on colorful soap, they make more money from white soap. In order to maximize profits, the corporation was instructed to manufacture more white soap (5 g and 10 g) than colored soap.

In conclusion, it is required to further investigate and show examples of the usage of the linear programming model in business decision-making processes. A good possibility for such application is the determination of Asanduff Construction's profit maximization. This study will attempt to determine the characteristics of applying linear programming techniques to make management decisions and provide useful solutions to the issues.

2.2 Chapter Summary

This chapter discussed the relevant literature on linear programming. In order to maximize profit in a business and make better management decisions, nearly all studies agree that using linear programming method is preferable to doing it otherwise.

CHAPTER THREE

METHODOLOGY

3.0 Introduction

This chapter describes the different approaches that can be used to solve Linear Programming problem with focus on the approach that will be applied in this Project Work.

3.1 Research Methodology

A Linear Programming Problem (LPP) is a problem that is focused on finding the optimal value for a specific linear function subject to certain constraints. The optimal value may be either maximum or minimum value. The objective function is the function we are attempting to optimize, and the requirement that must be met are called the constraints. There are numerous ways to solve linear programming problem including the graphical method, simplex method, by using software like R, an open solver, etc. The simplex method and the graphical method are the two key methods that are commonly used in solving linear programming problem.

The graphical method is used to optimize the value of two-variable linear problems. Finding the optimal solution is best done using the graphical method when there are only two decision variables. The collection of linear equations or inequalities are subject to constraints in this method. These linear equations or inequalities are then plotted in the $X - Y$ plane. The intersection region will be used to determine the feasible region once all the linear equations or inequalities have been drawn on the $X - Y$ graph. The optimal solution and all possible values for our model are explain by the feasible region. The feasible region for a Linear Programming is the set of all points that satisfies all the LP's constraints and all the LP's sign restrictions. However, the graphical method is limited to problems with only two decision variables. It gets more difficult to visualize the solution space as the number of decision variables and constraints increases. Because of this, it is impossible to successfully use the graphical technique in such circumstances. To overcome this limitation, George Dantzig developed the simplex method, which was already discussed in Chapter Two and is a useful approach for solving Linear Programming Problems. The simplex method can be used to solve problems involving two or more decision variables.

To solve a Linear Programming Problem using the simplex method, the following steps must be followed.

1. Identify and set up the problem. Thus, write the objective function and the inequality constraints to set up the problem.
2. Convert the problem into its standard form. To do this, each "inequality sign" (≤ or ≥) in the constraint is changed into an "equal to sign" (=) by adding slack variables or subtracting excess variables respectively.
3. Set up the initial simplex tableau by using the standard form of LP.
4. Determine the optimal tableau by performing pivoting operations.
5. From the optimal tableau, identify the optimal solution.

Through an iterative procedure, the simplex method eventually reaches the minimum or maximum optimal value for the objective function. In solving a linear programming problem, one of the following four solutions is achieved:

1. Unique solution. This solution satisfies all the LP's constraints with minimum or maximum objective function value.

2. Some LP's have infinite number of solutions. This means that the LP has multiple optimal solutions.
3. Infeasible solution. This means that the LP contains an empty feasible region and hence no optimal solution exists.
4. Some LP's are unbounded. They are points in the feasible region with arbitrary large objective function value.

3.2 Linear Programming Model

Linear Programming models are used to represent Linear Programming problems mathematically. There are three component to a Linear Programming problem. The first is that an objective function exists and the objective function can be either maximized or minimized. The second is a set of linear constraints that describes the technical details of the issues in respect to the available resources. The third is that while negative or zero production does not have a physical counterpart, there are a number of non-negative limitations or restrictions. In general, any Linear Programming model with decision variables for a maximization problem can be expressed in the form:

Maximize $Z = A_1X_1 + A_2X_2 + \ldots + A_nX_n$ (Objective function)

Subject to

$$C_{11}X_1 + C_{12}X_2 + \ldots + C_{1n}X_n \leq B_1$$

$$C_{21}X_1 + C_{22}X_2 + \ldots + C_{2n}X_n \leq B_2$$

$$C_{31}X_1 + C_{32}X_2 + \ldots + C_{3n}X_n \leq B_3$$

$$\ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots$$

$$C_{m1}X_1 + C_{m2}X_2 + \ldots + C_{mn}X_n \leq B_m \quad \text{(Linear constraints)}$$

$$X_1, X_2, \ldots, X_n \geq 0. \qquad \text{(Sign restriction).} \qquad (3.1)$$

From (3.1),

Z is the total profit contribution. X_i represents the decision variables and it shows the number of each type of blocks needed to be produced (for i = 1, 2, …, n). The A_i represent the profit for each unit of product i. The B_j show the total amount or number of available resources j (for j = 1, 2, …, m). The C_{ij} represent the amount of resource j that are respectively used by each unit product i. Similarly, $X_i \geq 0$ show the non-negative restrictions or conditions.

There are various characteristics that set Linear Programming models apart. We can recognize problems that can be solved with LP models and properly construct an LP model by being aware of these characteristics. These characteristics can be separated into components and assumptions. A model's components relates to its structure, whereas assumptions provide the conditions under which a model is valid. Model (3.1) must satisfy the following assumptions in order to be considered valid.

1. It is considered that the amount of raw materials needed for the block production is finite (limited).

2. It is assumed that the characteristics of the components used to produce block are standard and not inferior.
3. It is assumed that the variables used in the model have a linear connection.
4. The quantity of blocks produced is presumed to be equal to the quantity of blocks sold. Since producing goods that are not in demand is impractical.

3.3 Chapter Summary

The methodology of the work was the main topic of this Chapter. The graphical method and the simplex method were the methods discussed in this Chapter. The simplex method is preferred for solving linear programming problems over the graphical method because the simplex method is not restricted by any number of available constraints. The Linear programming model that will be used in this Project Work was also determined and it will be used in Chapter Four to determine Asanduff Constructions maximum profit.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.0 Introduction

In this chapter, we take into account the outcome of the optimal solution for the data collected from Asanduff Construction and explain the findings.

4.1 Data Collection

Data for this work were collected from Asanduff Construction. Asanduff Construction is a company that manufactures high-quality building blocks to meet the need of its customers. An interview was conducted with the administration officer of Asanduff Construction specifically to learn more about the decision-making process used by the company. Through the interview, it was observed that, four (4) different types of blocks (8 inches, 6 inches, 5 inches and 4 inches blocks) are produced by Asanduff Construction. The company currently makes a daily profit of GHS 4220.00 on manufacturing 450 units of the 8 inches blocks, 1000 units of the 6 inches blocks, 1500 units of the 5 inches blocks, and 300 units of the 4 inches blocks type. The block production machine creates four (4) blocks on a palette for 8 inches, six (6) blocks on a palette for 6 inches, eight (8) blocks on a palette for 5 inches, and twelve (12) blocks on a palette for 4 inches blocks.

Again, data were gathered on the unit cost of production for each type of block, the unit selling price of each type of block, the average daily cost price for producing all four types of block, and the daily working hour that is available for both human laborers and the block machines. Additionally, information on the blocks with the highest daily sales were gathered. Tables 1 to Table 4 provide a summary of the information gathered.

Table 1 presents information on the requirements that is needed for each block type to be produced. Data on the machine hour, labor hour and the average production cost required for each block type are recorded.

Table 1: Requirement for each block type

Block type	Machine hour (s)	Labor hour (s)	Average production cost (GHS)
8 inches	0.32	0.41	30
6 inches	0.45	0.55	32
5 inches	0.53	1.15	40
4 inches	1.03	1.90	50

According to the data in Table 1, the 8 inches block type require 0.32 seconds of machine hour, 0.41 seconds of labor hour and an average production cost of GHS 30.00 to produce four (4) units of blocks on a palette. Also, the 6 inches block type require 0.45 seconds of machine hour, 0.55 seconds of labor hour and GHS 32.00 to produce six (6) units of blocks on a palette. Again, the 5 inches block type require 0.53 seconds of machine hour, 1 minute 0.15 seconds of labor hour and GHS 40.00 to produce eight (8) units of blocks on a palette. Finally, the 4 inches block type require 1 minute 0.03 seconds of machine hour, 1 minute 0.90 seconds of labor hour and GHS 50.00 to produce twelve (12) units of blocks on a palette.

Table 2 presents information on the available resources needed to produce each block type. These resources consist of the daily available machine hour, labor hour and cost of production per day.

Table 2: Available resources

Resource	Available
Machine hour (s)	32400
Labor hour (s)	32400
Production cost (GHS)	106,000

The data in Table 2 shows that Asanduff Construction has a daily working capacity of 9 hours (32400 seconds) for both machine and labor forces. Also, a daily production cost of GHS 106,000.00 is available for producing the four types of blocks.

Table 3 presents information on the daily demands and profit that is associated with each block type. Also, Data on the unit cost and unit selling price of each type of block are listed.

Table 3: Production and profit for each block type

Block type	Unit cost price (GHS)	Unit selling price (GHS)	Unit profit (GHS)	Daily Demands
8 inches	7.50	9.50	2.00	800
6 inches	5.33	7.00	1.67	2200
5 inches	5.00	6.00	1.00	3300
4 inches	4.20	4.70	0.50	350

From Table 3, the unit cost price and selling price of the 8 inches block are GHS 7.50 and GHS 9.50 respectively. In order to calculate for the unit profit, we deduct the unit cost price from the unit selling price of each type of block. As a result, the unit profit associated with the 8 inches block is GHS 2.00. Similarly, the unit cost price and selling price of the 6 inches block are GHS 5.33 and GHS 7.00 respectively. It also has a unit profit of GHS 1.67. Again, the unit cost price and selling price of the 5 inches block are GHS 5.00 and GHS 6.00 respectively. It also has a unit profit of GHS 1.00. Finally, the unit cost price and selling price of the 4 inches block are GHS 4.20 and GHS 4.70 respectively. It also has a unit profit of GHS 0.50.

Additionally, the four (4) different types of blocks (8 inches, 6 inches, 5 inches and 4 inches blocks) have a daily demands of 800, 2200, 3300, and 350 units of blocks respectively.

Table 4 presents a summary of the entire data listed in Tables 1 to Table 3. The data consist of the machine hour, labor hour, average production cost, demands and profits associated with each block type needed to be produced.

Table 4: Summary of Table 1 to Table 3

Block type	Machine hour	Labour hour	Average production cost (GHS)	Daily Demands	Profits (GHS)
8 inches	0.41	0.32	30	800	2.00
6 inches	0.55	0.45	32	2200	1.67
5 inches	1.15	0.53	40	3300	1.00
4 inches	1.90	1.03	50	350	0.50
Available	32400	32400	106,000		

The data presented in Table 4 are transform mathematically into the linear programming problem using Model (3.1).

4.2 Analysis of the Data

The number of decision variables for each type of block to be manufactured in the block company is specified as follows.

X_1 represent the number of 8 inches blocks to be produced daily

X_2 represent the number of 6 inches blocks to be produced daily

X_3 represent the number of 5 inches blocks to be produced daily

X_4 represent the number of 4 inches blocks to be produced daily.

Again, let the objective function that is to be maximize be denoted by Z. Then, using model (3.1), the mathematical representation of the problem (data) summarized in Table 4 is given as follows.

Max Z = $2.00X_1 + 1.67X_2 + 1.00X_3 + 0.50X_4$ (objective function)

Subject to

$0.41X_1 + 0.55X_2 + 1.15X_3 + 1.90X_4 \leq 32400$ (machine constraint)

$0.32X_1 + 0.55X_2 + 0.53X_3 + 1.03X_4 \leq 32400$ (labour constraint)

$30.0X_1 + 32.0X_2 + 40.0X_3 + 50.0X_4 \leq 106000$ (cost constraint)

$X_1 \leq 800$ (8 inches block constraint)

$X_2 \leq 2200$ (6 inches block constraint)

$X_3 \leq 3300$ (5 inches block constraint)

$X_4 \leq 350$ (4 inches block constraint)

$X_1, X_2, X_3, X_4 \geq 0$. (Non-negative restrictions) (3.2)

The model (3.2) is converted to the standard form by adding seven slack variables, denoted by S_i (i = 1, 2, 3, 4, 5, 6, 7). As a results, the inequality signs in the model (3.2) constraints aspect were changed to equality signs. A slack variable will take into account any unused raw material at the end of the production process. The standard form of the problem is given as follows.

Max $Z =$ $2X_1 + 1.67X_2 + X_3 + 0.50X_4$ || $Z - 2X_1 - 1.67X_3 - X_3 - 0.50X_4 = 0$

Subject to

$$0.41X_1 + 0.55X_2 + 1.15X_3 + 1.90X_4 + S_1 = 32400$$

$$0.32X_1 + 0.55X_1 + 0.53X_3 + 1.03X_4 + S_2 = 32400$$

$$30.0X_1 + 32.0X_2 + 40.0X_3 + 50.0X_4 + S_3 = 106000$$

$$X_1 + S_4 = 800$$

$$X_2 + S_5 = 2200$$

$$X_3 + S_6 = 3300$$

$$X_4 + S_7 = 350$$

$X_1, X_2, X_3, X_4, S_1, S_2, S_3, S_4, S_5, S_6, S_7 \geq 0$. (Non-negative restrictions) (3.3)

EXCEL built-in solver was used to solve the Linear Programming model (3.3) mentioned above. Excel solver is a software that assists users in choosing the optimal solution to a Linear Programming problem. The decision variable values that satisfy the constraints while maximizing the profit will be discovered using the excel solver. EXCEL solver offers useful information, like sensitivity analysis, answer report and limit report. The models decision variables, objective function and the constraints are placed in the appropriate spreadsheet cells with numbers that the solver can used. In Figure 1, the worksheet's cells C2, D2, E2, and F2 are held in reserve for the decision variables X_1, X_2, X_3, and X_4. These cells will determine the number of each type of block to be produced.

	A	B	C	D	E	F	G	H	I
1	decision variable		x1	x2	x3	x4			
2	value of		0	0	0	0			
3	objective function		2	1.67	1	0.5			
4									
5	profits								
6	0								
7							LHS		RHS
8	machine constraint		0.52	1.33	1.52	2.5	0	≤	32400
9	labour constraint		0.32	0.45	0.53	1.05	0	≤	32400
10	cost constraint		30	32	40	50	0	≤	106000
11	8 inches block constraint		1				0	≤	800
12	6 inches block constraint			1			0	≤	2200
13	5 inches block constraint				1		0	≤	3300
14	4 inches block constraint					1	0	≤	350
15									
16									
17	Non-negative restriction		1				0	≥	0
18	Non-negative restriction			1			0	≥	0
19	Non-negative restriction				1		0	≥	0
20	Non-negative restriction					1	0	≥	0

Figure 1: Presentation of the data in EXCEL worksheet

The profits being maximize is entered in cell A5 and its value is entered in cell A6. The formula for finding the profit in cell A6 is given as.

Formula for cell A6: =SUMPRODUCT(C2:F2,C3:F3)

The available resources needed to produce each unit of block is entered in cell C8:F14. These numbers are the coefficients of the decision variable in the model's constraints equation. Again, the sign restriction constraints are entered in cell C17:F20. The data were analysed using EXCEL solver and the output is presented in Figure 2.

	A	B	C	D	E	F	G	H	I	J	K
1	decision variable		x1	x2	x3	x4					
2	value of		800	2200	290	0					
3	objective function		2	1.67	1	0.5					
4											
5	profits										
6	5564										
7							LHS		RHS		
8	machine constraint		0.52	1.33	1.52	2.5	3782.8	≤	32400		
9	labour constraint		0.32	0.45	0.53	1.05	1399.7	≤	32400		
10	cost constraint		30	32	40	50	106000	≤	106000		
11	8 inches block constraint		1				800	≤	800		
12	6 inches block constraint			1			2200	≤	2200		
13	5 inches block constraint				1		290	≤	3300		
14	4 inches block constraint					1	0	≤	350		
15											
16											
17	Non-negative restriction		1				800	≥	0		
18	Non-negative restriction			1			2200	≥	0		
19	Non-negative restriction				1		290	≥	0		
20	Non-negative restriction					1	0	≥	0		
21											

Figure 2: Solution of simplex method from EXCEL worksheet

4.3 Presentation of Results

The optimal results obtained from EXCEL solver is presented in Table 5.

Table 5: Optimal solution

Variable Name	Value
Profits (GHS)	5564
value of X_1	800
value of X_2	2200
value of X_3	290
value of X_4	0

From Table 5, it can be observed that the optimal solution for the model (3.3) is, X_1= 800, X_2= 2200, X_3= 290, X_4= 0, and the profits being maximizes Z= GHS 5564.00.

4.4 Discussion of Results

Based on the analysis carried out in this project, the result shown in Table 5 require that Asanduff Construction should produce daily, 800 pieces of 8 inches block, 2200 pieces of 6 inches block, 290 pieces of 5 inches block and no pieces of 4 inches block should be produced. This production strategy would results in a daily profit of GHS 5564.00 for Asanduff Construction. These show that just three of the four types of block account for the maximum profit. Therefore, the 8 inches block, 6 inches block, and 5 inches block are the best products the company can sell for the highest profit. In this situation, it is preferable for Asanduff Construction to concentrate on lowering resources costs on producing the 4 inches block, since it does not add much to their profits.

4.5 Shadow price

The shadow price of the i^{th} constraint shows the amount by which the optimal Z-value is improved (increased in a maximization problem and decreased in a minimization problem) if we increased b_i by one unit. The shadow price of each constraints of the EXCEL solver is presented in Table 6.

Table 6: Shadow Price Result

Name	Shadow Price
machine constraint	0
labour constraint	0
cost constraint	0.025
8 inches block constraint	1.25
6 inches block constraint	0.87
5 inches block constraint	0
4 inches block constraint	0

From Table 6, the shadow price of the machine constraint, the labour constraint, the 5 inches block constraint, and the 4 inches block constraint are all GHS 0 respectively. This means that increasing the amount of these constraints by one unit would not increase Asanduff Construction's profit. Also, the shadow price of the cost constraint is GHS 0.025 and means that Asanduff Construction's profit would increase by GHS 0.025 if one more cost constraint were available. Similarly, the shadow price of the 8 inches block constraint is GHS 1.25. This means that increasing the amount of the 8 inches block constraint by one unit would result in an increase in Asanduff Construction's profit by GHS 1.25. Lastly, the shadow price of the 6 inches block constraint is GHS 0.87. This means that increasing the amount of the 6 inches block constraint by one unit would result in an increase in Asanduff Construction's profit by GHS 0.87.

The optimal solution presented in Table 5 shows that the daily amount of profit made by Asanduff Construction has been increased from GHS 4220.00 to GHS 5564.00. This accounts to an increased daily profit of GHS 1144.00 which is approximately 27.1% of the profit made. Similarly, by using the linear Programming model (3.3), the daily number of blocks that the company used to manufacture for the various four types of blocks (8 inches, 6 inches, 5 inches, and 4 inches) have all been modified to 800 units of blocks, 2200 units of blocks, 290 units of blocks, and 0 units of blocks respectively. These results has shown that using Linear Programming technique to determine profit maximization in an organisation is more beneficial than doing it otherwise, as Asanduff Construction's daily profit has been maximized by approximately 27.1%.

4.6 Chapter Summary

From the analysis of the results obtained, it was observed that three of the four types of building blocks account for the maximum profit of Asanduff Construction. The results showed that, with a daily production of 2200 blocks, the 6 inch block generated the highest profits, followed by the 8 inch block with a daily production of 800 blocks, and the 5 inch block generated the least profits with a daily production of 290 blocks. This resulted to an increased daily profit of GHS 1144.00 which is approximately 27.1% of the profits made by the company. The shadow price of the data were also covered and it was noted that increasing the constraints of the cost constraint, the 8 inches block constraint, and the 6 inches block constraint by one units resulted in an increased in profit. However, the remaining constraints did not increase profit for Asanduff Construction.

CHAPTER FIVE

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.0 Overview

This chapter, which serves as the Project Work's last chapter, presents information on the summary, conclusions and recommendations of the Project Work.

5.1 Summary

Applications of Linear Programming in Profit Maximization of Asanduff Construction is the topic of this research work. The major goal of this study is to consider how organisations and businesses employ Linear Programming techniques to help them better manage their limited resources in order to maximize profits. Asanduff Construction manufactures four various sizes of building blocks (8 inches, 6 inches, 5 inches, and 4 inches). These sizes were taken into consideration in the study as decision variables. The production cost, production time, demand or sales employed in the manufacturing, and the quantity of raw material needed for each block size were examined in order to determine the maximum profit using the linear programming technique. The problem was modeled, and solved with the use of excel solver software that used the simplex method to produce the best results. The result shows that 800 unit of 8 inches block, 2200 unit of 6 inches block, 290 unit of 5 inches block, and 0 unit of 4 inches block should be produced respectively which will give a daily maximum profit of GHS 5564.00. The daily profits of the company was increased by approximately 27.1% as a result of employing linear programming methods in determining the company's profit maximization.

5.2 Conclusions

We successfully took into account the various product categories, the quantity of raw materials used, and the cost of manufacturing in Asanduff Construction in this study. The best solution was discovered after formulating the linear programming problem using secondary data on the four types of building block sizes that were collected from the company's administrative department. The outcome showed that, in order to achieve a maximum daily profit of GHC 5564.00, the management of Asanduff Construction should concentrate more on the manufacturing of the 8 inches, 6 inches, and 5 inches building block size. The primary objectives of the study are to highlight the distinctiveness of linear programming modeling as an optimization technique at the business level and to persuade manufacturing organizations to use linear programming to calculate their ideal profit. The results of this Project Work has shown that using Linear Programming technique to determine profit maximization in an organisation is more beneficial than doing it otherwise as Asanduff Construction’s daily profit has been maximized by approximately 27.1%. These observations will enable the block factory to maximize its contribution both now and in the future with these production techniques.

5.3 Recommendations

All production planning challenges can be solved by linear programming models, which increase production capacities, reduce costs, and ultimately increases profits for production industries and businesses.

It is recommended that Asanduff Construction employ the linear programming method in their operations. This is due to the linear programming method’s ability to determine the proper number of which products to manufacture more and which ones to manufacture less with their limited resources.

Additionally, it is recommended for Asanduff Construction to concentrate on lowering resources costs on producing the 4 inches block, since it does not add much to their profits and focus more on producing the required amount of the remaining block sizes.

The observations of the research suggest that in order to boost profitability, production companies should begin utilising mathematical techniques like linear programming to determine profit maximization, as Asanduff Construction's daily profit has been maximized by approximately 27.1%. Managements of various firms are advised to spend more money on mathematics consultants.

REFERENCES

Akingbade, F. (1996). *Basic Operations Research Techniques.* Lagos Nigeria: Panaf Inc.

Anderson, D. Sweeny, D., & Williams, T. (1995). *Linear Programming Application. Quantitative method for business (6th ed.).* West Publishing Company: St. Paul minn.

Balogun, O. S. Jolayemi, E. T. Akingbade, T. J., & Muazu, H. G. (2012). Use of Linear Programming for Optimal Production in Production Line in Coca-Cola Bottling Company, Ilorin. *International Journal of Engineering Research and Application (IJERA)*, 2(5), 2004-2007.

Bierman, J. Bonini, H., & Charles, P. (1973). *Quantitative Analysis for Business Decisions (4th ed.).* Illinois: Richard D. Irwin.

Byrd Jr, J., & Moore, L. T. (1978). *The application of a product mix linear programming model in corporate policy making. Management Science.*

Dantzig, G. (1993). *Computational Algorithm of the Revised Simplex Methods.* RAND Memorandum. RM-1266.

Dantzig, G. B. (1949). Programming of interdependent activities: II Mathematical Model, Econometrica.

Dwivedi, D. N. (2011). *Managerial Economics (1st ed.).* New Delhi: VIKAS Publishing House PVT Limited.

Ezema, B. I., & Amakon, U. (2012). Optimizing profits with the linear programming model: A focus on Golden plastic industry limited, Enugu, Nigeria. *Interdisciplinary Journal of Research in Business*.

Felix, M., & Judith, M. (2010). A Farm Resource Allocation Problem: A Case Study of Small-Scale commercial Farmers in Zimbabwe. *Journal of Sustainable Development in Africa*, 12(2). 315 - 320.

Igbinehi, E. M. Oyebode, A. O., & Taofeek-Ibrahim, F. A. (2015). Application of Linear Programming in manufacturing local soap. IPASJ. *International Journal of Management (IIJM)*.

Igwe, K, C. Onyenweaku, C, E., & Nwaru, J, C. (2011). Application of Linear Programming to semi-commercial arable and fishery enterprise in Abia State, Nigeria. *International Journal of Economics and management science*.

Kareem, B., & Aderoba, A. (2008). Linear Programming Based Effective Maintenance and Manpower Planning Strategy. *International Journal of the Computer, the internet and Management*.

Nonso, A. (2008). *Application of linear programming for Managerial Decision.* unpublished.

Oladejo, N. K. Abolarinwa, A. Salawu, S. O., & Lukman, A. F. (2019). Optimization Principle and Its Application in Optimizing Landmark University Bakery Production Using Linear Production. *International Journal of Civil Engineering and Technology (IJCIET)*, 10(2), 183-190.

Oyekan, E. A., & Temisan, G. O. (2019). Application of linear programming to profit maximization of Johnsons Nigerian Ltd bakery division. *Journal of Advances in Mathematical and Computational Science*, 7(1). 11 - 20.

Oyekan, E. A. (2015). *MTH 310: Operations Research I. Lecture note,*. OSUSTECH (Unpublished).

Stephanos, K., & Dimitrios, A. (2010). Regional tourism development using Linear Programming and vector analysis. *Regional science inquiry Journal*.

Susilawati, C. (2002). Application of Linear Programming for Dormitory Development Plan at Petra Christian University. *http.//petra.ac.id/journals/civil, Indonesia*.

Taha, H. (1977). *Operations Research; An introduction (2nd ed.).* New York: Macmillan Publishing Co. Inc.

Wijeratne, N., & Harris, F. C. (1984). Capital budgeting using a linear programming model. *International Journal of Operations & Production Management*, 4(2), pp.49-64.