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# THE APPLICATION OF LINEAR PROGRAMMING FOR THE OPTIMAL PROFIT OF PT. NARUNA USING THE SIMPLEX METHOD

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**Abstract:**
PT. Naruna is a ceramics factory located in Salatiga, Indonesia. In PT. Naruna ceramics, all products are handmade with contemporary designs and have a high artistic value in shape and color. Getting profit is the company's primary goal, but many companies still need to learn the maximum profit that can be obtained by optimizing their resources, one of which is PT. Naruna. PT. Naruna produces goods based on intuition. As a result, a lot of goods are piled up in warehouses. Meanwhile, with the development of the times, new trends and images will appear more attractive so that consumer tastes and motifs from ceramics will change. In addition, ceramic products that have gone through the combustion process cannot be recycled and must be burned. This research focuses on the production of glasses with three different types according to price. The aim of this paper is to optimize profits by determining the composition of the number of products produced. We used linear programming with a simplex method to solve our problem in PT. Naruna. Linear programming is the most appropriate method for solving problems that exist in PT. Naruna, namely by paying attention to the objective and constraint functions. The objective function is to maximize profit, so it takes the form of a linear equation with the variable X1 being the first type of glass, X2 being the second type of glass, and X3 being the third type of glass. The constraint functions used include the number of products, the number of workers, the amount of clay, and the time for production. The results show that PT. Naruna can achieve maximum profit when producing glass type 1 less than type 3 less than type 2.

**Key words:** *optimation, profit, simplex method, linear programming*

## INTRODUCTION

PT. Naruna is located in Salatiga, Central Java, Indonesia. The ceramic business has been around since October 2019, but at the age of about three years, Naruna has managed to get a very high turnover and several awards. Naruna's products include cups, glasses, plates, bowls, cutting boards, and spoons. All Naruna products are handmade with designs that follow trends and are guaranteed safe because the products have gone through a high-burning process. The uniqueness of Naruna products is from the shape, motif, and color. Determination of product motifs and shapes must go through a research process so that characters can stand out and become the hallmark of PT. Naruna. The coloring process does not use ordinary paint but the colors used by PT. Naruna is a color that comes from a mixture of natural rocks. One type of color results from a variety of 12 natural stones with a specific dose. The uniqueness of PT. Naruna make they product demands interested by many people. Moreover, PT. Naruna has exported its products to several countries, such as India, Dubai, England, Qatar, Belgium, and Spain.

The main problem for PT. Naruna entrepreneurs are to determine the optimal amount to generate maximum profit. So far, the number of goods produced came from intuition without regard to the available resources. The focus of this research is on glass products of three different types. This study aims to optimize profits by determining the composition of the number of products produced. Many ways to solve this problem, one of which is linear programming using the simplex method. This research is an application of linear programming and elementary linear algebra in calculating iterations.

A linear program is a mathematical model to determine the optimal combination of products to maximize benefits or minimize costs [1, 2]. According to Ezema and Amakom [3] the problems faced by industries worldwide result from a lack of production inputs so that capacity is low and, ultimately, the output is also standard. According to Fagoyinbo and Ilesanmi [4] making the right decisions is a determining factor of success and failure experienced by individuals or organizations in business planning. Linear programming is an essential tool in energy management by converting non-linearity properties into a linear form using Taylor series expansion which can apply optimization methods to produce energy with minimum costs [5]. Linear programming plays an essential role in aggregate production planning [6]. Linear programming is considered a significant evolutionary development of general-purpose capabilities and establishes a decision path to solve a problem [7]. In operations research and management science, program completion models are often used to solve specific resource-use issues [8]. A linear program has three essential things: the objective function, decision variable, and constraint [9]. In addition, in the effort to efficiently each production component, there must be obstacles that arise from the limited capacity of production factors such as raw materials, equipment, and labor [10]. The simplex method is one of the techniques for determining the optimal solution used in linear programming [11]. The simplex method solves problems based on the Gauss Jordan elimination technique by solving according to Howard Anton's book [12] and its application to the simplex method linear program [13]. The decision of the solution with several stages to get the optimal solution is called iteration [14]. The simplex method is used to determine the optimal solution by examining the extreme points one by one utilizing repeated calculations called iterations using tables [15].

## LITERATURE REVIEW

### Linear Programming

Linear programming is a strategy to ensure or optimize a certain quantity [16, 17]. 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 [18, 19]. According to Kumar [19], 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 [20]. Moreover, linear programming is the best method to determine the optimal solution by fulfilling a specific objective function limited by various constraints and restrictions [21]. The results of solving linear problems are only two, namely, maximum or minimum [14]. The characteristics of the issues that can be solved using the techniques in the linear program are as follows.

a. A feasible decision variable, meaning that the variable's value makes sense.
b. Has a function, the relationship between the decision variables to be minimized or maximized.
c. There is at least one constraint function.
d. The objective function and the constraint function are linear functions, or the variable has the power of one.
e. The domain is clearly defined. In general, the value of the decision variable must be positive x ≥ 0.

Linear programming problems can be expressed in a standard function form to be optimized or minimized.

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

by taking into account the constraints

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

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.

### 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 [22]. 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 [14]. 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 ≤, minus the surplus variable adding the artificial variable for the constraint function with the character ≥, and adding an artificial variable for the constraint function with a symbol = [25]. The calculation steps to optimize the objective function with the simplex method are as follows [14].

a. 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;
b. Determine the critical column or Entering Variable (EV), which is the column with the highest negative value;
c. 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;
d. 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 × new key row value);
e. Repeating the same way until getting the optimal solution, namely when there is no negative value in row Z.

## RESEARCH METHOD

### Method of Collecting Data

According to Rumetna [14], there are two ways to collect data. The first is observing the process of making ceramic crafts directly at PT. Naruna. The second is by interviewing Mr. Oka, one of the leaders of PT. Naruna. From observations and interviews, data were obtained on the number of products produced, the price of each type of product, the number of employees, the amount of clay, and the time for production.

### Method of Analysis Data

Analyze existing data using the simplex method in the following way [26]:

a. Determine the mathematical model of the objective function;
b. Determine the mathematical model of the constraint function;
c. Changing the mathematical model of the objective function into standard form by adding a slack variable (with a coefficient of 0), a surplus variable (with a coefficient of 0), and an artificial variable (with a coefficient of -M);
d. Change the mathematical model of the constraint function into standard form with the following rules: add a slack variable for the constraint function with a symbol less than equal to (≤), subtract it from a surplus variable and add it to an artificial variable for the constraint function with a sign (≥), add an artificial variable for function delimiter with sign (=);
e. create a simplex table based on existing data and then iterate until it gets optimal results by:
    1) Determine the critical column or Entering Variable (EV), which is the column with the highest negative value;
    2) Determine the critical 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;
    3) Perform Gaussian elimination by making the pivot element one by dividing the critical row by the pivot element. Then, each component of the key column is converted to zero and changes the values contained in other than the critical row by the old row – (key column coefficient × new key row value). The iteration process ends when getting the optimal solution, namely when all elements of the $Z$ row ≥ 0.

## RESULTS AND DISCUSSION

The focus of this research is to optimize profits on the production of three types of glass at PT. Naruna. The objective and constraint functions can be formed from the available data, namely the price of glass, the number of products, the amount of clay, the number of workers, and production time, as shown in Table 1. The price of three types of glass in a row is Rp120.000,00, Rp115.000,00, and Rp88.000,00. 500 kg clay can produce 100 glasses of type 1, which six workers do in no more than 63 hours. 500 kg clay can be made into 70 glasses of type 2, done by six workers in no more than 126 hours. 358kg clay can be made into 75 glasses of type 3, done by six workers in no more than 81 hours. Each combustion process will produce 400 ready-to-sell products. PT. Naruna spent 19000 kg of clay to produce various types of ceramic crafts. The total number of workers in the production site of PT. Naruna is 34 workers.

***Table 1***
***Glass Production Data at PT. Naruna and The Amount of Resources Used***

| | Price | Number of product | Amount of clay | workers | Time production |
|---|---|---|---|---|---|
| Glass 1 | Rp120.000,00 | 100 | 500 kg | 6 | 63 jam |
| Glass 2 | Rp115.000,00 | 70 | 500 kg | 6 | 126 jam |
| Glass 3 | Rp88.000,00 | 75 | 358 kg | 6 | 81 jam |
| | | 400 | 19000 kg | 34 | |

*Notes: This data was obtained from surveys and interviews directly to PT. Naruna by the author.*

Based on the existing data, it can be formed a mathematical model of the objective function and the constraint function.

Objective function is:

$$Z = 120X_1 + 115X_2 + 88X_3$$

Constraint function is:

$$100X_1 + 70X_2 + 75X_3 \le 400$$
$$500X_1 + 500X_2 + 358X_3 \le 19000$$
$$6X_1 + 6X_2 + 6X_3 \le 34$$
$$100X_1 \le 63$$
$$70X_2 \le 126$$
$$75X_3 \le 81$$

where:
$X_1$ = Glasses type 1,
$X_2$ = Glasses type 2,
$X_3$ = Glasses type 3.

The mathematical model of the objective function and the constraint function will be converted into standard form and then create the simplex Table.

a. Standard form of objective function:

$$Z - 120X_1 - 115X_2 - 88X_3 + 0S_1 + 0S_2 + 0S_3 + 0S_4 + 0S_5 + 0S_6 = 0$$

b. Standard form of constrain function:

$$100X_1 + 70X_2 + 75X_3 + S_1 = 400$$
$$500X_1 + 500X_2 + 358X_3 + S_2 = 19000$$
$$6X_1 + 6X_2 + 6X_3 + S_3 = 34$$
$$100X_1 + S_4 = 63$$
$$70X_2 + S_5 = 126$$
$$75X_3 + S_6 = 81$$

The value of the pivot element, as shown in Table 2, is 100. Next, do the iterations using Gaussian elimination until the optimal solution is obtained, as shown in Tables 3, 4, and 5. split the critical row by the pivot element.

*Table 2*
***Simplex Table for Initial Iteration***

| BV | Z | $X_1$ | $X_2$ | $X_3$ | $S_1$ | $S_2$ | $S_3$ | $S_4$ | $S_5$ | $S_6$ | BSF | BSF/$X_1$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Z** | 1 | -120 | -115 | -88 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| $S_1$ | 0 | 100 | 70 | 75 | 1 | 0 | 0 | 0 | 0 | 0 | 400 | **4** |
| $S_2$ | 0 | 500 | 500 | 358 | 0 | 1 | 0 | 0 | 0 | 0 | 19000 | **38** |
| $S_3$ | 0 | 6 | 6 | 6 | 0 | 0 | 1 | 0 | 0 | 0 | 34 | **5.67** |
| $S_4$ | 0 | 100 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 63 | **0.63** |
| $S_5$ | 0 | 0 | 70 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 126 | |
| $S_6$ | 0 | 0 | 0 | 75 | 0 | 0 | 0 | 0 | 0 | 1 | 81 | |

Then, every component of the critical column other than the pivot element is changed to 0 in the following way: old row – (key column coefficient × new key row value).

*Table 3*
***Simplex Table for The first Iteration***

| BV | Z | $X_1$ | $X_2$ | $X_3$ | $S_1$ | $S_2$ | $S_3$ | $S_4$ | $S_5$ | $S_6$ | BSF | BSF/$X_2$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Z** | 1 | 0 | -115 | -88 | 0 | 0 | 0 | $\frac{6}{5}$ | 0 | 0 | $\frac{378}{5}$ | |
| $S_1$ | 0 | 0 | 70 | 75 | 1 | 0 | 0 | -1 | 0 | 0 | 337 | **4.8** |
| $S_2$ | 0 | 0 | 500 | 358 | 0 | 1 | 0 | -5 | 0 | 0 | 18685 | **37.4** |
| $S_3$ | 0 | 0 | 6 | 6 | 0 | 0 | 1 | $-\frac{3}{50}$ | 0 | 0 | $\frac{1511}{50}$ | **5.04** |
| $X_1$ | 0 | 1 | 0 | 0 | 0 | 0 | 0 | $\frac{1}{100}$ | 0 | 0 | $\frac{63}{100}$ | |
| $S_5$ | 0 | 0 | 70 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 126 | **1.8** |
| $S_6$ | 0 | 0 | 0 | 75 | 0 | 0 | 0 | 0 | 0 | 1 | 81 | |

*Table 4*
***Simplex Table for The Second Iteration***

| BV | Z | $X_1$ | $X_2$ | $X_3$ | $S_1$ | $S_2$ | $S_3$ | $S_4$ | $S_5$ | $S_6$ | BSF | BSF/$X_3$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Z** | 1 | 0 | 0 | -88 | 0 | 0 | 0 | $\frac{6}{5}$ | $\frac{23}{14}$ | 0 | $\frac{1413}{5}$ | |
| $S_1$ | 0 | 0 | 0 | 75 | 1 | 0 | 0 | -1 | -1 | 0 | 211 | **2.81** |
| $S_2$ | 0 | 0 | 0 | 358 | 0 | 1 | 0 | -5 | $-\frac{50}{7}$ | 0 | 17785 | **49.68** |
| $S_3$ | 0 | 0 | 0 | 6 | 0 | 0 | 1 | $-\frac{3}{50}$ | $-\frac{3}{35}$ | 0 | $\frac{971}{50}$ | **3.24** |
| $X_1$ | 0 | 1 | 0 | 0 | 0 | 0 | 0 | $\frac{1}{100}$ | 0 | 0 | $\frac{63}{100}$ | |
| $X_2$ | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | $\frac{1}{70}$ | 0 | $\frac{9}{5}$ | |
| $S_6$ | 0 | 0 | 0 | 75 | 0 | 0 | 0 | 0 | 0 | 1 | 81 | **1.08** |

*Table 5*
***Simplex Table for The Third Iteration***

| BV | Z | $X_1$ | $X_2$ | $X_3$ | $S_1$ | $S_2$ | $S_3$ | $S_4$ | $S_5$ | $S_6$ | BSF |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Z | 1 | 0 | 0 | 0 | 0 | 0 | 0 | $\frac{6}{5}$ | $\frac{23}{14}$ | $\frac{88}{75}$ | $\frac{9441}{25}$ |
| $S_1$ | 0 | 0 | 0 | 0 | 1 | 0 | 0 | -1 | -1 | -1 | 130 |
| $S_2$ | 0 | 0 | 0 | 0 | 0 | 1 | 0 | -5 | $-\frac{50}{7}$ | $-\frac{358}{75}$ | $\frac{434959}{25}$ |
| $S_3$ | 0 | 0 | 0 | 0 | 0 | 0 | 1 | $-\frac{3}{50}$ | $-\frac{3}{35}$ | $-\frac{2}{25}$ | $\frac{647}{50}$ |
| $X_1$ | 0 | 1 | 0 | 0 | 0 | 0 | 0 | $\frac{1}{100}$ | 0 | 0 | $\frac{63}{100}$ |
| $X_2$ | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | $\frac{1}{70}$ | 0 | $\frac{9}{5}$ |
| $X_3$ | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | $\frac{1}{75}$ | $\frac{27}{25}$ |

The third iteration in Table 5 shows that all elements in row *Z* are positive, so the solution obtained is optimal, namely $Z = \frac{1413}{5}$, $X_1 = \frac{63}{100} = 0.63$, $X_2 = \frac{9}{5} = 1.8$, and $X_3 = \frac{27}{25} = 1.08$. From the result, PT. Naruna will get an optimal profit of Rp377.640,00 when producing one glass of the first type, two glasses of the second type, and one glass of the third type every hour. So, PT. Naruna will obtain optimal profit when the number of production glass type 1 less then type 3 less then type 2.

## CONCLUSION

PT. Naruna Ceramics, Indonesia, produces some tableware which unique characteristic shapes, patterns, and colors. PT. Naruna has a problem determining product composition to get maximum profit and optimize the use of available resources. This research focuses on three types of glass most in demand by customers. The data used in this study are the results of interviews with the owner of PT. Naruna and direct observation at PT. Naruna. The solution to this problem is applying a linear program using the simplex method. This method is suitable for solving optimization problems using the objective and constraint functions. To maximize profits, the objective function in this study is the price of each type of glass, while the constraint functions are the amount of production, the number of workers, the amount of clay, and the time for production.

Chapter 1 The results of iterations using the simplex method linear programming technique show that the composition of the glass types that must be produced is 0.63 or 1 glass of the first type, 1.8 or 2 glasses of the second type, and 1.08 or 1 glass of the third type every hour. Based on these results, PT. Naruna will get maximum profit when producing type 1 less then type 3 less then type 2 glass.


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