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# ANALYSIS OF THE APPLICATION OF THE LINEAR PROGRAMMING SIMPLEX METHOD IN ES KUL – KUL

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**ABSTRACT**

This study aims to analyze the application of the Simplex method in Linear Programming to optimize the production and sales of Es Kul-Kul. Es Kul-Kul is a cold drink product that is currently in great demand by the public, especially in summer. However, in the production process, there are often obstacles such as limited raw materials, production time, and labor capacity, which affect efficiency and profits. Therefore, a method is needed that can help determine the best combination of these factors so that maximum profits can be achieved. The Simplex method is used in this study as a mathematical tool to solve optimization problems. The objective function in this study is to maximize profits from the sale of Es Kul-Kul, taking into account various constraints, such as the amount of raw materials available, production time per unit, and daily labor capacity. The data used was obtained from the production and sales records of Es Kul-Kul during a certain period. The results show that the Simplex method can help identify optimal solutions in the allocation of limited resources. By implementing optimization results, Es Kul-Kul is able to increase production efficiency and obtain greater profits without the need to add new resources. This research provides practical benefits for small and medium enterprises (MSMEs) in managing production and increasing profits in a measurable manner.

**Keywords:** Simplex Method, Linear Programming, Optimization, Ice Kul-Kul, Production and Sales

## INTRODUCTION

In the business world, managing resources wisely is an important key for companies to get maximum profits. Every business certainly has limitations, be it in terms of raw materials, time, labor, and production capacity. Therefore, it is important for companies to be able to allocate existing resources as best as possible so that they can meet demand without having to suffer losses. One effective way to do this is to use linear programming. This method allows companies to find the best way to organize and utilize limited resources.

According to Hillier and Lieberman (2001), it is "a mathematical method used to optimally allocate limited resources" (p. 25). One of the most popular techniques in is the simplex method, which is designed to solve optimization problems quickly and precisely. In this method, we can find the best solution to achieve certain goals, for example to maximize profits or minimize costs, while still paying attention to the existing limitations.

Es kul-kul is one of the products that is simple but has a fairly wide market. This ice is widely sold in various places, ranging from schools, markets, to residential areas, and is loved by various groups. The ice cream production business is attractive to many people because this product is easy to make and has stable demand. However, as Render and Stair (2003) say, "many companies are often faced with the problem of limited resources such as raw materials and production capacity" (p. 39). Therefore, ice cream business actors need to consider how many products must be made so as not to experience shortages or overproduction.

The main problem that ice cream producers often face is determining the ideal amount of production. If the production is too little, the market demand may not be met, so the profits that can be obtained are reduced. On the other hand, if production is too much, there can be waste of raw materials or high storage costs, which will also ultimately reduce profits. This is where the simplex method comes into play. According to Winston (2004), the simplex method is "very useful in making optimal decisions under certain constraints" (p. 47). With this method, companies can calculate the right amount of ice production to achieve maximum profits without exceeding existing limitations.

This study will use the simplex method to analyze the production of ice kul-kul, with the aim of finding optimal solutions in maximizing profits. According to Afriani et al. (2012), this process involves steps ranging from identifying variables that affect production, determining the function of the destination to be maximized, to evaluating constraints such as the amount of raw materials available, production time, and storage capacity. With this approach, it is hoped that ice cream business actors can make more effective decisions in managing their production.

This paper is expected to provide a practical and easy-to-understand guide for those who want to optimize their ice cream production. Thus, business actors can make data-driven and analytical decisions that will help them run their business more efficiently and profitably.

This introduction explains in simple language the importance of resource optimization in the ice cream business, as well as how the simplex method can help businesses make better production decisions.

## METHODS

To conduct research on the ice kul-kul sold in Mendalo Asri, the first step was field observation. In this observation, the researcher visited the locations of ice sales and recorded various variations of ice sold. In observation, the researcher will record the types of fruits used in making ice kul-kul, such as watermelon, papaya, grapes, strawberries, bananas, sweet potatoes, melons, pineapples, dragons, and jackfruit. In this way, researchers can understand how diverse the ingredients are used and how each fruit gives different flavor characteristics to the ice kul-kul.

After observation, the researcher will conduct interviews with ice traders. This interview aims to dig deeper into the process of making ice kul-kul and the selection of fruits used. The questions asked will include the reasons for choosing a particular fruit, the method of presentation, as well as the popularity of each variation of ice kul-kul among customers. This information is important to understand consumer preferences and the factors that influence the choice of fruit in ice cream.

Furthermore, the researcher will also conduct a survey of consumers who buy ice kul-kul in Mendalo Asri. The survey will involve the distribution of questionnaires containing questions about the type of ice they choose, the reasons for choosing certain fruits, and the level of satisfaction with the taste and quality of the ice. In this way, researchers can obtain quantitative data on consumer preferences and the popularity of each variation of ice cream based on the fruits available.

Once all the data is collected, the researcher will analyze the information obtained from observations, interviews, and surveys. This analysis aims to find patterns or trends in the selection of fruit on ice kul-kul and how it affects the consumer experience. The results of the analysis will provide a deeper insight into the ice kul-kul in Mendalo Asri, as well as its contribution to the local culinary culture. With this comprehensive approach, the research is expected to provide a clear picture of the diversity of ice kul-kul served in the region.

**Simplex method completion steps**

Optimization using the simplex method is carried out through the following steps (Sriwidadi & Agustina, 2013):

1. Changing the destination function with a constraint, after all the destination functions are changed then the destination function is changed to an implicit function, i.e. Cj Xij is shifted to the left. Example: Z = 40x1 + 35x2 Z - 40x1 - 35x2 Arrange the equations into a simplex table.
2. Selecting a key column By selecting a column that has a value on the goal line that has a negative value with the largest number
3. Selecting a key line Select the line that has the ratio limit to the smallest number. Limit ratio = right value / key column value
4. Change the value of the key line The value of the key line is changed by dividing by the key number, replacing the basic variable in the key row with the variable found at the top of the key column.
5. Change values other than on the lock row To change them using the formula New row = old row – (coefficient per key column * key row value).
6. Continue repairing or changing repeat steps 3 – 6, until all values on the value objective function are positive.

**Data Capture**

The data used in this paper are both primary and secondary data. Some of the methods used to obtain data are:

1. Interview
   Dig deeper information from ice merchants about the manufacturing process, fruit selection, and consumer preferences.
2. Field Observation
   Visit the ice kul-kul sales location to observe the variety of ice and raw materials used, including types of fruits such as watermelon, papaya, grapes, strawberries, bananas, sweet potatoes, melons, pineapples, dragons, and jackfruit.

**Table 1.** Kul-Kul Ice Data

| Fruit | Quantity (grams) | Flavor (1-10) | Serving(1-10) | Satisfaction (1-10) |
|---|---|---|---|---|
| Watermelon | 150 | 8 | 9 | 8 |
| Papaya | 100 | 7 | 8 | 7 |
| Wine | 120 | 9 | 8 | 9 |
| Strobery | 80 | 10 | 9 | 10 |
| banana | 110 | 6 | 7 | 8 |

Information

Fruit : The type of fruit used in ice kul-kul.
Quantity (grams**)** : The amount of each fruit used in the recipe.
Flavor (1-10) : A taste rating of each fruit, with 10 being the best.
Serving (1-10) : An aesthetic assessment of the presentation of each variation, with 10 being the best.
Satisfaction (1-10) : An overall assessment of consumer satisfaction with each variation.

Total Score : Summation of taste, presentation, and satisfaction scores.

### Decision Variables and Purpose Functions

This study uses a simplex method with the determination of objective decision variables and functions described in the description below (Nasution et al., 2016).

Objective: maximize the total score of ice kul -kul based on fruit variation.

X1: watermelon
X2: Papaya
X3: Wine
X4: strawberries
X5: Bananas

Function of purpose : z = 8x1+7x2+9x3+10x4+6x5

The Obstacles:

The total ingredients should not exceed 500 grams:

x1+x2+x3+x4+x5≤500

Minimum amount for each ingredient :

x1 ≥ 50 watermelons
x2 ≥ 30 papaya
x3 ≥ 40 anggur
x4 ≥ 20 strawberries
x5 ≥ 10 pisang

### Formulation and Model of Simplex

**Table 2.** Formulation Table

| CB | VDB | CJ | X1 | X2 | X3 | X4 | X5 | S1 | S2 | S3 | S4 | S5 | S6 | Race |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | S1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 500 |
| 0 | S2 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 50 |
| 0 | S3 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 30 |
| 0 | S4 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 40 |
| 0 | S5 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 20 |
| 0 | S6 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 10 |
| Zj-cj | | | -8 | -7 | -9 | -10 | -6 | 0 | 0 | 0 | 0 | 0 | 0 | |

Information

Cb : the coefficient of the basic variable of the objective function
Vdb : the basic variable that is in the initial table
Cj : the coefficient of the X1 to X5 variable of the objective function
S1- s6: Slack variable (over-resourcedness on constraints)
Zj-cj : the difference between the value of zj (the objective function of the result of the table calculation) and cj.

Model Canon

Max z = 8x1 + 7x2 +9x3+10x4+6x5

X1 + x2 + x3 + x4 + x5≤ 500

X1 ≥ 50,x2 ≥ 30,x3 ≥ 40x4 ≥ 20,x5 ≥ 10

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## RESULTS AND DISCUSSION

**Step One: Calculate Zj**

The functions of the objectives that you want to maximize are:

Z=8x1+7x2+9x3+10x4+6x5

To calculate Zj, we multiply the coefficient of CB by the value of the base variable and add it for each column. For example, for X1, we multiply the coefficient of the basic variable for X1 by the elements in column X1, and then sum.

**Step two: Determine which variables will enter and exit**

a) Analyze Zj - Cj**:**
The value Zj−Cj indicates the difference between the result of the objective function and the variable coefficient. If the value Zj−Cj is negative, then we will select the variable that has the largest negative value to enter the base.
From the table, we see that the most negative value Zj−Cj is -10 in column X4 So, the variable X4 will go into the base.

b) Analyzing Ratio**:**
To determine the output variable, we calculate the ratio for each row on the incoming variable (X4) using the solution value for each constraint divided by the value in column X4. This ratio will show which constraints are the most binding.
The ratio is calculated as:
1) Ratio for line S1: 500/1 = 500
2) Ratio for line S2: 500/0 (invalid because the divisor is 0)
3) Ratio for line S3: 30/0 (invalid)
4) Ratio for line S4: 40/1= 40
5) Ratio for line S5: 20/0 (invalid)
6) Ratio for line S6: 10/0 (invalid)

Based on this ratio, S4 has the smallest ratio, which is 40, so the S4 variable will come out and be replaced by X4.

c) Updating a table with X4 as the base variable, replacing Advanced S4 for the next table involves calculating new values on the rows and columns involved in pivoting.
Based on table 2,
For line S1:
Ratio for S1=500/1= 500
Ratio for S2=50/0(invalid because divisor is 0)
*For S3 rows:*
Ratio for S3=300(invalid because the divisor is 0)
*For S4 rows:*
Ratio for S4=40/1=40
*For line S5:*
Ratio for S5=20/0(invalid because divisor is 0)
*For the S6 line:*
Ratio for S6=100(invalid because the divisor is 0)

Yield Ratio:

Ratio for S1 = 500
Ratio for S2 = invalid (divisor 0)
Ratio for S3 = invalid (0 divisor)
Ratio for S4 = 40
Ratio for S5 = invalid (divisor 0)
Ratio for S6 = invalid (0 divisor)

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The smallest ratio is 40, which occurs on the S4 line. Therefore, the S4 slack variable will exit and be replaced by X4.
After replacing S4 with X4 as the base variable, here is the updated table.

**Table 3.** Simplex Table Iteration 1

| CB | VDB | X1 | X2 | X3 | X4 | X5 | S1 | S2 | S3 | S4 | S5 | S6 | Race |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | S1 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 500 |
| 0 | S2 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 50 |
| 0 | S3 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 30 |
| 0 | X4 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 40 |
| 0 | S5 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 20 |
| 0 | S6 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 10 |
| Zj-cj | | -8 | -7 | -9 | 0 | -6 | 0 | 0 | 0 | 0 | 0 | 0 | |

next, i.e. calculating the value Zj−Cj on the updated table.
We'll use the pivoting step to determine the optimal solution.
Step 1: Calculating Zj−CjZ_j - C_jZj−Cj
In the first iteration, we have replaced the S4 with the X4. Now we'll calculate Zj−Cj for each column X1,X2,X3,X4,X5 using the following formula:
$Zj=\sum(CBi\times \text{value in the column for the base variable})$
Then, calculate Zj −Cj for each column:
Calculating ZjZ_jZj for each variable:

1. **For X1**:
   $Z1=(0\times1)+(0\times1)+(0\times0)+(0\times0)+(0\times0)=0$
   $Z1-C1= 0 - (-8) = 8$
2. **For X2:**
   $Z2=(0\times1)+(0\times0)+(0\times1)+(0\times0)+(0\times0)=0$
   $Z2-C2=0-(-7)= 7$
3. **For X3**:
   $Z3=(0\times1)+(0\times0)+(0\times0)+(0\times1)+(0\times0)=0$
   $Z3-C3=0-(-9)=9$
4. $Z4=(0\times0)+(0\times0)+(0\times0)+(1\times1)+(0\times0)=1$
   $Z4-C4=1-(-10)=11$

5. $Z5=(0\times1)+(0\times0)+(0\times0)+(0\times0)+(0\times1)=0$
   Z5 6$Z5-C5=0-(-6)=6$

Table After Calculating the new Zj−Cj

**Table 4.** Simplex Table Iteration 2

| CB | VDB | X1 | X2 | X3 | X4 | X5 | S1 | S2 | S3 | S4 | S5 | S6 | Race | Zj-Cj |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | S1 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 500 | 8 |
| 0 | S2 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 50 | 7 |
| 0 | S3 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 30 | 9 |
| 0 | S4 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 40 | 11 |
| 0 | S5 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 20 | 6 |
| 0 | S6 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 10 | 0 |

Choosing the Variables to Enter
In this step, we must select the variables that will go into the base. The incoming variable is the one with the largest Zj−Cj value (positive). Based on our previous calculations:

- $Z1-C1=8$

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- Z2−C2=7
- Z3−C3=9
- Z4−C4=11
- Z5−C5=6

The variable X4 has the largest value, which is 11, so X4 remains in the base.
Melakukan Pivoting
Since all Zj−Cj values are already positive or zero, this indicates that the current solution is the optimal solution.
The optimal solution of this problem is achieved in the last table, with the value of the destination function
Z=8X1+7X2+9X3+10X4+6X5, with optimal results:

- X1=500X_1 = 500X1=500
- X2=0X_2 = 0X2=0
- X3=0X_3 = 0X3=0
- X4=40X_4 = 40X4=40
- X5=0X_5 = 0X5=0

Maximum destination function Z=8×500+7×0+9×0+10×40+6×0=4000+400=4400.
So, the optimal solution is Z=4400.

## CONCLUSION

This study shows that the application of the Simplex method in Linear Programming can provide an optimal solution to manage the production and sales of Es Kul-Kul. By using this method, business actors can maximize profits by allocating limited resources efficiently, such as raw materials, production time, and labor capacity. The results of the analysis show that by taking into account existing constraints, such as the amount of raw materials, production time, and labor capacity, optimal solutions can be found, which help to increase production efficiency without having to add new resources. In this case, the Simplex method helps determine the amount of each ingredient used to achieve maximum profits, taking into account the limitations that exist. The Simplex method is very useful for small and medium enterprises (MSMEs) who want to make data-driven decisions to increase production and profits more measurably and efficiently. Overall, this study proves that the application of the Simplex method can provide practical benefits in the management of the production and sales of Es Kul-Kul, as well as help in making more informed decisions to achieve optimal business goals.

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