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SIMPLEX ALGORITHM BY MIXED ACTIVITY-BASED COSTING FOR OPTIMIZATION OF BATIK MADURA PRODUCTION

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ABSTRACT

Each production activity will generate financing and have limitations on every resource needed in the production. Limitations of production resources other than due to capital, the ability of labor and machinery, the production time available in fact give an influence on the planned production capacity. Therefore this study provides an overview of how production financing combined with production limitations can significantly affect the number of units produced. The merging process is explained with an example that the application uses Batik Madura, which is one of the original culture-based products from Indonesia. Based on these problems, this research is focused on identifying all the resources involved that affect production capacity.

To clarify the scope of the object under study, this study focuses on calculating the financing and production capacity of Batik Madura based on the number of coloring. The purpose of determining production capacity is to increase the profits of Batik products, set as an objective function and based on the advantages of each type of Batik. While the constraint factors that limit the amount of production that is determined include, the use of the amount of material, the time required in each activity such as *membatik*, coloring, *nglorod*, and finishing, the number of employee salaries and minimum production targets, which then becomes a limiting function in this study. The next most important part is formulating the problem in a mathematical model or linear equation. The test results with the simplex algorithm show that the optimum solution has been obtained, and the change coefficient of the objective function and the limiting function are also obtained through sensitivity analysis. Thus, this system is able to answer the needs of batik producers or craftsmen for a system that is used as a guideline to determine production capacity.

Keywords: *Production Capacity, Optimation, Activity-Based Costing, Linear Equation, Sensitivity Analysis.*

1. INTRODUCTION

The simplex algorithm is one of the most widely used linear programming tools. The linear programming itself is a mathematical model designed to help management in planning and solving problems based on existing alternatives by allocating limited resources to achieve a set goal [1]. Linear programming is related to the optimization of linear functions in meeting equality and inequality constraints or limiting a linear set [2].

A problem can be solved using linear programming if it fulfills a number of things [3] that is solving the problem based on the optimization goal that is the minimum or maximum, there are constraints that limit the achievement of objectives, related to existing resources, there are several alternative objectives that are used as the basis for decision making, and mathematical models in linear programming are linear. Technically, there are additional requirements for linear program problems that must be considered as basic assumptions, namely certainty, proportionality, additivity, divisibility and non-negative.

In this study, to describe the application of linear programming with the simplex algorithm, we use Batik as the object of research. Batik is a superior product in Indonesia, as well as one of the forms of culture that has been passed down from generation to generation. The variety of batik in Indonesia is

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very much, representing the culture in each region. One of the famous batiks is Batik Madura. Unlike batik in other areas, the uniqueness of Batik Madura lies in the color motives and courage given. The ability to make batik continues to be passed on to the next generation, as well as the business processes carried out.

Several studies have been developed to improve the Batik making process through the use of computational technology [4-7]. Computational technology is used to explore batik design through new patterns that are used to get a more diverse Batik design. But besides the development of the new Batik design, the use of information technology for business management in the field of creative industries is also a necessary thing.

During this time batik craftsmen only focus on the stages of the production process and marketing techniques that will be used. In addition, they are of the view that producing as many products as possible will bring opportunities to gain a lot of profit. In some cases often the quality is downgraded even excluded by the reason for winning the competition in terms of product prices. Whereas profits not only can be calculated through the amount of revenue from the sale of products only, but profits are also greatly influenced by existing product stock.

This fact shows that production quantity planning needs to be considered before the business produces its products. Consideration of excess stock or shortage of stock will directly affect business profits where the excess stock will inhibit business financial turnover while lack of stock will eliminate the opportunity for businesses to gain profits [8]. Therefore production planning is a thing that has a big influence on the decision-making process that is very important to optimize business profits.

As support for planning the quantity of a production, a mature calculation is needed so that the risk of loss can be minimized. In this case, the optimization method is needed to get the right analysis so that the problems faced can be solved. This optimization problem is one of which is faced by business actors or Batik Madura craftsmen in Pamekasan Regency. The products owned by the flagship centers in Pamekasan Regency are Batik Tulis and Batik Cap, each of which consists one coloring, twice of coloring, and thrice of coloring.

To overcome the optimization problem, the model used to obtain the best solution is linear programming with the Simplex method. These problems are observed and formulated in accordance with their optimization goals and alternative decisions are identified to solve the problems and resources that limit them. The results obtained are further analyzed with sensitivity analysis so that changes to the coefficients in the model do not affect the optimal table so that it does not require a recalculation process with linear programming.

Therefore, this research is focused on designing the application for determining the quantity of Batik Madura production with a systematic and integrated system. This system uses the calculation of production costs by Activity-Based Costing (ABC) analysis to determine the amount of profit obtained and the details of costs incurred, which will then be used in the process of determining the formulation in linear programming.

2. THEORITICAL FRAMEWORK

2.1 Forms of Linear Programming Standards

The mathematical model formulation on linear programming through three stages includes:

a. Determine unknown variables and declare them on symbols.
b. Forming an objective function that is shown as a linear relationship of the decision variable is the goal of maximizing or minimizing.
c. Determine all the problem constraints and express them in equations, inequalities or functions.

In general, the linear programming mathematical model formulation model [9-10], can be defined as:

$$\text{Max/Min } \tilde{z} = \tilde{c}^t . \tilde{x} \quad (1)$$

$$\text{s.t. } \tilde{A}.\tilde{x} \leq \tilde{b}, \tilde{x} \geq 0 \quad (2)$$

where Max/Min z is the objective function, while the limiting function is obtained from the constraints that affect the achievement of the goal.

2.2 Simplex Algorithm

The simplex algorithm is an algebraic procedure that is used to find the optimum value of the objective function in the optimization problem that has constraints. In the simplex method to find the optimum value, the repetition or iteration process starts from the initial formulation until the final result is known where the objective function has been optimum [10].

The simplex method formulation is adopted from the general linear programming form which is then added with variable slack and other variables if needed. As per the previous description, there are

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two functions in linear programming which are included in the equation, namely the objective function and the limiting function [11-13] the following:

Objective function:

Max/Min: $Z= C_1X_1+C_2X_2+...+C_nX_n$ (3)

Constraint :

$a_{11}X_1+a_{12}X_2+...+a_{1n}X_n \leq b_1$ (3a)

$a_{21}X_1+a_{22}X_2+...+a_{2n}X_n \leq b_2$ (3b)

....

$a_{m1}X_1+a_{m2}X_2+...+a_{mn}X_n \leq b_m$ (3c)

$X_1, X_2, ... X_n \geq$ (3d)

2.3 Sensitivity Analysis

The optimum solution to the problem of linear programming can be known by the simplex method, but the ability to provide resources is likely to experience changes in the future. Facing these problems can be modified to the optimum solution with direct sensitivity analysis [14-15]. The information needed in the sensitivity analysis is the optimum table of the simplex method. The results will answer how many changes are allowed without changing the optimum solution.

Changes that may be encountered in the sensitivity analysis are as follows:

a. Changes in the coefficient of the objective function, namely base, and non-base variables.
b. Changes in right-hand side constants with additional or reduced resource capacity.
c. Changes in constraint functions with the addition of new constraints.
d. Addition of decision-making variables.

After the optimum solution is obtained, then it is used as a basis for the calculation of sensitivity analysis which functions to measure how much the change in the coefficient in the table is allowed to remain optimum [16]. The steps that can be taken are as follows:

1. Calculates changes in the objective function coefficients for base variables.

   To find the range of changes in the coefficient of the objective function of the base variable can be used the equation:

   $$\widehat{C}_j = C_BY_j - C_j \quad (4)$$

   where $\widehat{C}_j$ is number on a non-base variable whose value must be ≥ 0, C_B is constant of the base variable in the optimum table, Y_j is cell constant on non-base variables, and C_j is value on non-base variables

   The calculation is performed on all non-base variables whose results are in the form of a range of changes in the objective function in each of the allowed based variables.
2. Calculate the coefficient of the objective function for non-base variables.

   To calculate the range of changes in the objective function coefficient on non-base variables where the variable in question is not the slack variable but does not enter the base. In this case, the equation used is the same as the first step.
3. Calculate changes in obstacle capacity.

   Capacity constraints can be reduced or increased with the optimum fixed solution. To find the new right-hand constant value due to changes in capacity, the formula is used:

   $$\widehat{b}_j = B^{-1}.b_j \quad (5)$$

   where $\widehat{b}_1$ is a number on the value of the constraint whose value must be greater than 0, B^{-1} is a matrix whose elements or cells are derived from the equation of constraints in the initial formulation, which are then searched for the inverse, and b_i is the constant right in the constraint.

2.4 Activity-Based Costing (ABC) Method

ABC method is a method of cost planning systems that are developed to anticipate weaknesses in conventional cost accounting systems. The ABC method is also defined as the calculation of costs in each activity and imposes costs on objects of costs such as products and services based on activities needed to produce each product and service [17]. Thus the ABC system facilitates accurate calculation of the cost of goods and increases the effectiveness of decision making by management. The basis of the ABC system is the activity of all resources utilized for production, thus there is a relationship with the constraints or limitations of resources in the production process [18].

One part that is considered in the ABC method is Cost Driver, which is an activity or transaction that causes the production cost of goods or services [19]. Cost triggers must be limited and chosen to match their usage functions. There are two types of cost drivers, including:

a. Unit Cost Driver, which is charging overhead costs on products through the use of a single overhead rate by all departments.

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b. Non-Unit Cost Driver, are causative factors other than units that explain overhead consumption.

The formula used to calculate production costs with the ABC Method is:

$$Profit = rm\ cost + dl\ cost + oh\ cost \quad (6)$$

where rm is raw material cost, dl is direct labor cost, and oh is overhead cost.

3. RESEARCH METHOD

This study aims to calculate the cost and production capacity of Batik Madura based on the number of coloring done. The focus of this research is to calculate the production capacity based on the number of coloring for six types of Madura Batik. The six types of Batik are Batik Tulis with one coloring (BT-1C), Batik Tulis with twice of coloring (BT-2C), Batik Tulis with thrice of coloring (BT-3C), Batik Cap with one coloring (BC-1C), Batik Cap with twice of coloring (BC-2C) and Batik Cap with thrice of coloring (BC-3C). Figure 1 shows an example of a type of Batik Madura.

Figure 1: Type of Batik Madura

All aspects in this study, it takes some data that supports the achievement of the goals set. The indicators of Batik production that are taken into account in this study as follows:

a. raw material
b. auxiliary material
c. labor
d. production activity

The first stage is to calculate the cost of Batik Madura production with the ABC method, by calculating the financing of the four indicators. Production costs are used to calculate profits which then contribute to the process of calculating production capacity. Calculation of production capacity of Batik Madura is also influenced by the four indicators of Batik production. The research framework can be seen in Figure 2.

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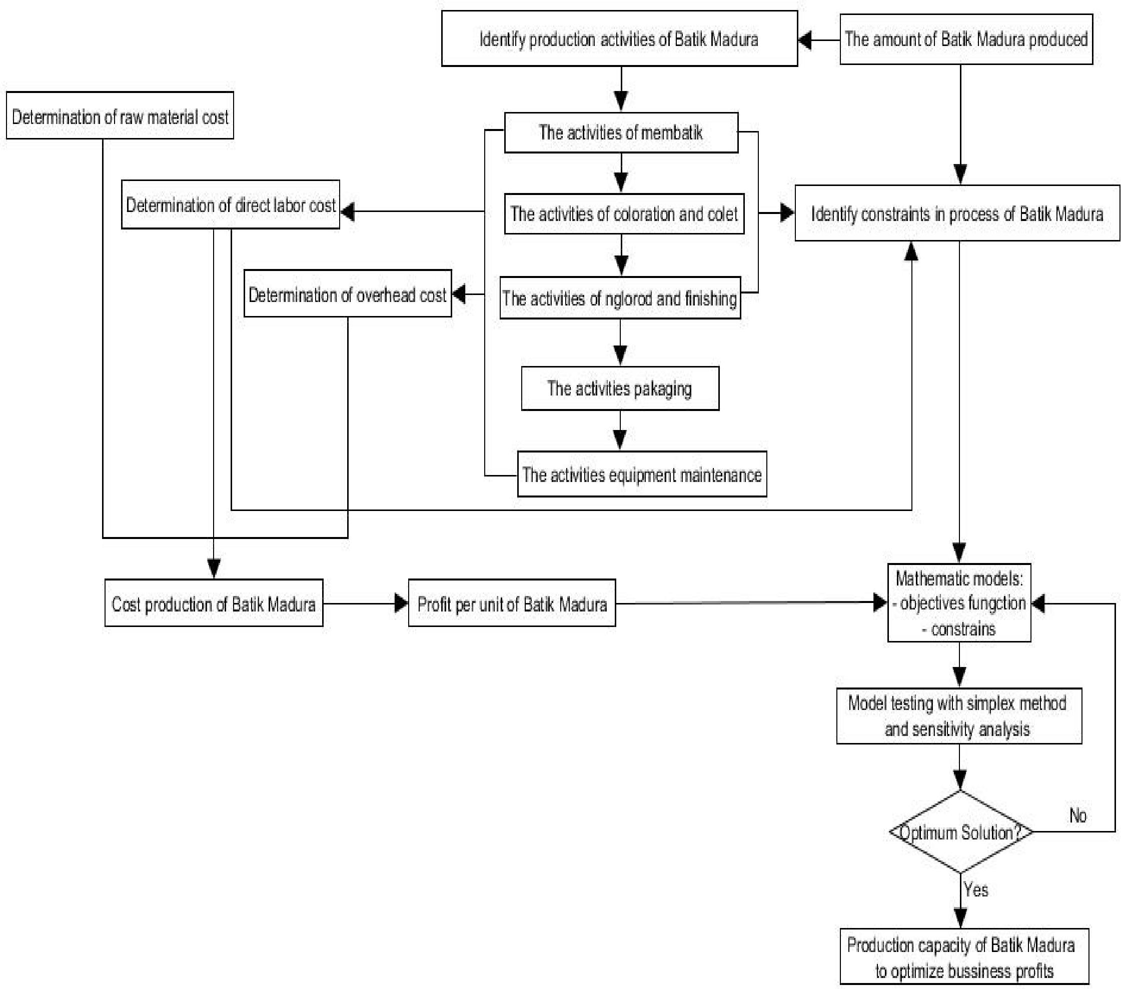

Figure 2: Research Framework

4. RESULTS AND DISCUSSION

4.1 Production Costs

The initial data in this study are all production activities that cause costs, which are then used to calculate the cost of production of batik products. By using the ABC method, the benefits of each type of product can be calculated, which is then used to calculate production capacity in order to determine the optimal profit for business owners or batik craftsmen.

a. Determination of the Raw Materials Cost

One of the costs calculated for the ABC method is raw material cost. In the production process of Batik Madura, the main raw material used is *primisima*, *prima*, and *prisma* cotton. The material chosen is in accordance with the wishes of the craftsmen, but in general, the more the amount of coloring, the better the quality of the cloth used. The price of cloth/meter for each Batik Madura unit is IDR 17,000 to IDR 22,000 with a total requirement of 2 m.

b. Determination of Direct Labor Costs

The direct labor financing needed to produce Batik Madura is as follows:

- *Membatik* is the activity of designing batik motifs using two choices of tools namely canting to make Batik Tulis, as well as a stamp tool to make Batik Cap. Batik is attaching the wax that has been boiled to the cloth according to the motif made.

This process is carried out thoroughly to cover the part of the motif that will be colored. In this activity, there are fundamental differences in the process carried out in Batik Cap and Batik Tulis. The canting is traditional equipment, while Batik stamp tools are more modern. Batik Cap does not go through the stages of making patterns or designs, so the work done is much lighter than the motive-making work on Batik Tulis.

- Coloring, given to certain parts or motifs on batik that is not covered by the night. This activity is carried out repeatedly according to the needs or the number of colors that will be applied to batik. The batik is soaked for some time until the color sticks perfectly to be dried.
- *Nglorod* and finishing are decay activities or eliminate the night that is still attached to Batik cloth due to the coloring process on the batik. The quantity of nglorod activity is the same as the coloring activity.
- Packaging, in this process, batik is packaged in several ways, which are packed in plastic bags, generally for both those sold in the Batik market, or batik that is bought directly at the place of business. The second way is to package batik on the textile plastic packaging.

c. Determination of Overhead Costs

Costs included in factory overhead costs are costs that do not directly influence the determination of the cost of production. These costs are caused by activities carried out during the making of batik by grouping in each section. The activities included in the overhead financing are as follows:

- *Membatik* activities

  This activity is related to making patterns based on the motives that will be made. In this activity, the wax is melted in a pan with a charcoal or wood burner on the stove or *anglo*, then applied to the cloth which will be given the motif using a canting or stamp. Thus the costs of this activity are used for candles and wood or charcoal. This activity is also used when the coloring process takes place, where the wax is also used to cover parts of the motif that are not colored. The unit driver on *membatik* is a meter.
- Coloring activities

  Coloring activities, the cost of activities is the cost of dyes. The coloring activity of batik is to immerse or soak batik in dyes with the aim of coloring the part that is not covered in wax. In this activity for a small motive, it is followed by *colet* or the process of painting on the motif and done at the end of this process. This activity is repeated until all dyes are given. The unit driver of this activity is the number of dyes. In coloring activities, Batik craftsmen do not specifically distinguish the financing of each type of Batik, because the coloring is done together, without differentiating each type of Batik.
- *Nglorod* and finishing activities

  The costs incurred as a result of this activity are electricity costs for pumping water used as a medium to reduce water and the wood used for cooking water. The electricity costs used for the Batik process are assumed to be 40% of the total electricity bill per month and adjusted for the estimated electricity usage in each type of batik. The unit driver for this activity is the number of *nglorod*.
- Maintenance activities

  Maintenance activities, costs incurred because of this activity are all maintenance costs of equipment which includes the stamp, canting, pan, stove or *anglo*, *gawangan*, bucket, drum, and rack. In this activity canting is used in both types of batik to cover parts that are not dyed in the coloring process. In this activity, maintenance costs are calculated based on the economic age of the equipment used in production.
- Packaging activities

  Costs for this activity include the cost of plastic used to package batik. From the amount of material used, each batik product requires 1 plastic package. Thus the cost driver of this activity is the unit.
- Marketing Activities

  This activity is related to the distribution of products to consumers. In its implementation, this activity is subject to pulses, fuel oil and rent of premises or restitution. In this activity, the calculation of group rates is based on the number of units produced for 1 month. Cost drivers in marketing activities are the number of products (units).

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Table 1: Profit of Batik Madura with ABC Method

Product Type	BT-1C	BT-2C	BT-3C	BC-1C	BC-2C	BC-3C
Raw Material Cost (IDR/unit)	34,000	39,000	44,000	34,000	39,000	44,000
*the use of raw materials is included in the constraints of production						
Direct Labor Cost (IDR/unit)						
membatik	25,000	33,000	40,000	8,000	14,000	21,000
coloring	3,000	6,000	9,000	3,000	6,000	9,000
nglorod and finishing	4,500	9,000	13,500	4,500	9,000	13,500
packaging	1,000	1,000	1,000	1,000	1,000	1,000
*the use of direct labor cost is included in the constraints of production						
Overhead Cost (IDR)						
membatik/unit	1,442	1,442	1,442	1,442	1,442	1,442
coloring/unit	741	1,482	2,223	741	1,482	2,223
nglorod and finishing/unit	385	1600	2400	800	1600	2400
packaging/unit	450	450	450	450	450	450
maintenance/batch	150	150	150	150	150	150
marketing/unit	1,500	1,500	1,500	1,500	1,500	1,500
* the use of activity time is included in the constraints of production						
Production Cost (IDR/unit)	72,168	94,624	115,665	55,583	75,624	96,665
Price (IDR/unit)	85,000	110,000	160,000	65,000	95,000	130,000
Profit (IDR/unit)	12,832	15,376	44,335	9,417	19,376	33,335

Calculation of raw material costs, direct labor, and subsequent overhead costs are accumulated in the financing of production. Based on the calculation of the production costs described in table 1, the profit of each type of Batik Madura among-others Batik Tulis with one coloring is IDR 12,832; Batik Tulis with twice of coloring is IDR 15,376; Batik Tulis with thrice of coloring is IDR 44,335; Batik Cap with one coloring is IDR 9,417; Batik Cap with twice of coloring is IDR 19,376; Batik Cap with thrice of coloring is IDR 33,335. So that it can be seen that Batik Madura with thrice of coloring has the greatest profit than the other.

4.2 Production Capacity

The first step before the problem is formulated in the form of standard linear programming that is equipped with the objective and limiting functions is to identify and simplify the problem. The objective function of the problems discussed in this study is to maximize the profit of Batik, thus the benefits of each batik are formulated in the form of objective functions.

For the limiting function, further identification of resources whose existence is limited or in other words limits the ongoing production process. There are several factors in production that are used together between the ABC method and the simplex algorithm, which is shown in table 2. The production factor is used to determine the objective function and constraint. Some factors or resources that limit the production process include the following:

a. Raw materials used
b. The time used to produce batik with the indicators considered is the number of hours worked by employees and the amount of batik produced.
c. Employee salary.
d. Minimum production target.

Table 2: Variable Used to Calculate Production Capacity

Factor in production	Production variable	
	ABC Methods	Simplex Algorithm
raw material	total cost	constraint: total material
direct labor	total cost	constraint: - total cost - total work time
total product	total profit	constraint: production target
profit	the final result	objective function: maximun of profit

After the profit of each Batik is known, the next step is to determine batik production capacity using Linear Programming with the Simplex Method. In accordance with the problems to be analyzed in this study, namely calculating production capacity, it is necessary to determine the base variable based on the number of products produced. The basic variables in this study include:

X_1 = the number of Batik Tulis with one coloring produced
X_2 = the number of Batik Tulis with twice of coloring
X_3 = the number of Batik Tulis with thrice of coloring produced
X_4 = the number of Batik Cap with one coloring produced produced
X_5 = the number of Batik Cap with twice of coloring produced
X_6 = the number of Batik Cap with thrice of coloring produced

The purpose of determining production capacity is to maximize profits, therefore the objective function in this study is to determine profits based on the number of products multiplied by the profit amount of each of these products. The equation for the delimiting function is as follows:

$$\text{Max profit} = 12{,}832X_1+15{,}376X_2+44{,}334X_3+ 9{,}417X_4+19{,}376X_5+33{,}334X_6 \quad (7)$$

In addition to the objective function, to examine the limitations of the batik production process, the boundary function is determined by the following specifications:

a. The use of raw materials, namely cotton, primisima and prism with a number of 1000 meters. In the process, the number of all types of batik produced must not exceed the amount of material possessed by craftsmen. The amount of cloth used in each batik is 2 meters. Based on the allocation of materials used, the limiting function in batik production is:

$$2X_1 + 2X_2 + 2X_3 + 2X_4 + 2X_5 + 2X_6 \leq 1000$$
or
$$X_1 + X_2 + X_3 + X_4 + X_5 + X_6 \leq 500 \quad (8)$$

b. The time for membatik activities has limitations due to the use of labor which also has a time limit regarding the number of working hours used. In addition to *membatik* with canting or stamp devices, this activity is carried out during the coloring process. In coloring activities, the dyes that is maintained must be covered by the wax, and it is repeated according to the amount of coloring that is done.
The allocation of time usage for *membatik* activities involve Batik Tulis with one coloring as much as 12 hours, Batik Tulis with twice of coloring as much as 13 hours, Batik Tulis with thrice of coloring for 14 hours, Batik Cap with one coloring for 2 hours, Batik Cap with twice of coloring for 3 hours and Batik Cap with thrice of coloring for 4 hours.
Based on observations, the number of workers in *membatik* activities is as many as 8 people, then the total time used to make Batik Tulis for 26 days is 1,664 hours. Thus the limiting function in Batik Tulis production is:

$$12X_1 + 13X_2 + 14X_3 \leq 1664 \quad (9)$$

While the Batik Cap requires workers as many as 6 people, with a total work time of 1248 hours. Thus the limiting function in Batik Cap production is:

$$2X_4 + 3X_5 + 4X_6 \leq 1248 \quad (10)$$

c. The time limit for coloring activities is also limited by the use of working hours of workers used. In this activity the number of workers is 6 people, so the total number of working hours for workers is 74,880 minutes. The number of batik coloring processes which includes dyeing, *menolet*, and drying, in Batik Tulis and Batik Cap with one coloring which amounts to 250 units, it is known as 150 minutes/unit. Batik Tulis and Batik Cap with twice of coloring as much as 150 units, known as 300 minutes/unit. Whereas for Batik Tulis and Batik Cap with thrice of coloring, the length of time used to color each Batik unit is 450 minutes/unit. Based on the amount of time used for coloring activities for each type of Batik Madura, the limiting function for coloring activities for 1 month is as follows:

$$150X_1+300X_2+450X_3+150X_4+300X_5+450X_6 \leq 74.880$$
or
$$5X_1+10X_2+15X_3+5X_4+10X_5+15X_6 \leq 2.496 \quad (11)$$

d. The time limit for the process of *nglorod* and finishing of each batik unit through observations made known the length of time to

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do nglorod and finishing on Batik Tulis and Batik Cap with one coloring is 130 minutes/unit, Batik Tulis and Batik Cap with twice of coloring are known as 260 minutes/unit. Whereas for Batik Tulis and Batik Cap with thrice of coloring, the length of time used for *nglorod* and finishing for each Batik unit is 390 minutes/unit.

Based on the amount of time used for the nglorod and finishing activities of each type of Batik Madura, by optimizing the working time of 5 workers, which is as much as 62,400 minutes, then the limiting function for coloring activities for 1 month is as follows:

$130X_1+260X_2+390X_3+130X_4+260X_5+390X_6 \leq 62.400$

or

$X_1 + 2X_2 + 3X_3 + X_4 + 2X_5 + 3X_6 \leq 480$ (12)

e. Use of labor salaries.
In running a business, sometimes batik craftsmen have a salary or wage given to their workforce, according to the financial conditions of each producer. Based on the direct labor costs discussed in table 1, it can be seen that the making of Batik Cap and Batik Tulis, the labor used is not the same as the different wages.
In table 1, the total is IDR 16,485,000. The basic variable equation at the labor wage limit is as follows:

$33,500X_1+49,000X_2+63,500X_3+16,500X_4+30,000X_5+44,500X_6 \leq 16,485,000$

or

$335X_1 + 490X_2 + 635X_3 + 165X_4 + 300X_5 + 445X_6 \leq 164,850$ (13)

f. Use of minimum production limits, namely production targets set by Batik craftsmen. The minimum production targets are then to be the limiting function for the following minimum production quantities:

$X_1 \geq 30$ (14a)
$X_2 \geq 20$ (14b)
$X_3 \geq 20$ (14c)
$X_4 \geq 30$ (14d)
$X_5 \geq 20$ (14e)
$X_6 \geq 20$ (14f)

The linear programming formulation for the complete objective function and limiting function is as follows.

```
Max = 12832*x1 + 15376*x2 + 44334*x3 + 9413*x4 + 19376*x5 + 33334*x6;
x1 + x1 + x3 + x4 + x5 + x6<= 500;
12*x1 + 13*x2 + 14*x3 <= 1664;
2*x4 + 3*x5 + 4*x6 <= 1248;
5*x1 + 10*x2 + 15*x3 + 5*x3 + 10*x5 + 15*x6 <= 2496;
x1 + 2*x2 + 3*x3 + 1*x4 + 2*x5 + 3*x6 <= 480;
335*x1 + 490*x2 + 635*x3 + 165*x4 + 300*x5 + 445*x6 <= 164850;
x1 >= 30;
x2 >= 20;
x3 >= 20;
x4 >= 30;
x5 >= 20;
x6 >= 20;
```

Figure 3: Linear Equation of Batik Madura Production at Lingo 13

After the standard form of the simplex method is obtained on the previous page, then the data is obtained by using Lingo 13. The results of the optimum decision of this problem can be seen in Figure 4. With 5 iterations, it can be seen that to achieve a maximum profit of IDR 5,747,90, Batik Madura must be produced for Batik Tulis with one coloring as much as 50 units, Batik Tulis with twice of coloring as many as 10 units, Batik Tulis with thrice of coloring as many as 57 units, Batik Cap with one coloring as many as 50 units, Batik Cap with twice of coloring as many as 50 units, and Batik Cap with thrice of coloring as many as 30 units.

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```
Objective value:                          5917440.
Infeasibilities:                          0.000000
Total solver iterations:                         5

Model Class:                                    LP

Total variables:                   6
Nonlinear variables:               0
Integer variables:                 0

Total constraints:                13
Nonlinear constraints:             0

Total nonzeros:                   40
Nonlinear nonzeros:                0
```

Variable	Value	Reduced Cost
X1	30.00000	0.000000
X2	20.00000	0.000000
X3	74.57143	0.000000
X4	55.37143	0.000000
X5	20.00000	0.000000
X6	30.30476	0.000000

Row	Slack or Surplus	Dual Price
1	5917440.	1.000000
2	259.7524	0.000000
3	0.000000	664.4048
4	956.0381	0.000000
5	0.000000	339.6667
6	0.000000	9413.000
7	69025.24	0.000000
8	0.000000	-6252.190
9	0.000000	-15483.93
10	54.57143	0.000000
11	25.37143	0.000000
12	0.000000	-2846.667
13	10.30476	0.000000

Figure 4: Problem-Solving of Batik Madura Production Capacity with The Simplex Method

4.3 The Range of Function Coefficients

Sensitivity analysis is used to determine how much change is allowed in the objective function coefficient and limited so that the resulting solution remains optimal. Based on the output of Lingo 13.0 at Figure 5, it can be seen that the objective coefficient in Batik Tulis with one coloring can be increased by IDR 6,252 and lowered to infinity. Batik Tulis with twice of coloring can be increased by IDR 15,484. In Batik Tulis with thrice of coloring of the solution will remain optimal if it is lowered to IDR 7,294. While Batik Cap one coloring can be increased as much as IDR 1,698 and can be reduced to IDR 7,294; Batik Cap with twice of coloring will be raised as much as IDR 2,747. Finally, Batik Cap with thice of coloring can be increased as much as IDR 4,976 and can be reduced to IDR 4,270.

The profit target can be optimized by increasing batik production capacity by increasing the use of materials unlimitedly, but the solution will remain optimum if the use of materials is added up to 260 meters. For the time limit for *membatik*, the solution remains optimal if Batik Tulis, by optimizing eight workers for 1664 hours, is increased by 108 hours and can be reduced by 355 hours. As for Batik Cap, with a total of 6 workers or 1248 hours, it can be reduced by 956 hours.

At the second time limit, which is coloring activity, with the number of workers as many as 6 people or for 74,880 minutes, the fixed solution will be optimum if it is increased by 127 minutes, and can be reduced by 155 minutes. As for *nglorod* and finishing activities, with 5 workers or as many as 62,400 minutes, the time limit can be increased by 260 minutes and reduced by 25 minutes. At the limit of the use of work time, an increase in work time can be done by utilizing overtime hours or by increasing the number of workers in each activity that has limited time.

The output of the sensitivity analysis also shows that limits on the use of workers' salaries can be reduced by IDR 69,025. This salary limit is of course influenced by the additional hours of workers discussed earlier. The last part of the sensitivity analysis is an increase in the production target of Batik Tulis with one coloring as many as 30 units and lowered by 13 units. Batik Tulis with twice of coloring can be increased by 27 units and lowered to 18 units. While Batik Tulis with thrice

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of coloring of production can be increased to 55 units.
Furthermore, in Batik Cap with one coloring can be increased to 25 units. Batik Cap with twice of coloring production is increased to 15 units and is reduced to 20 units or not produced. Finally, Batik Cap with thrice of coloring can be increased by 10 units.

Objective Coefficient Ranges:

Variable	Current Coefficient	Allowable Increase	Allowable Decrease
X1	12832.00	6252.190	INFINITY
X2	15376.00	15483.93	INFINITY
X3	44334.00	INFINITY	7294.222
X4	9413.000	1698.333	7294.222
X5	19376.00	2846.667	INFINITY
X6	33334.00	6976.250	4270.000

Righthand Side Ranges:

Row	Current RHS	Allowable Increase	Allowable Decrease
2	500.0000	INFINITY	259.7524
3	1664.000	108.2000	355.2000
4	1248.000	INFINITY	956.0381
5	2496.000	126.8571	154.5714
6	480.0000	259.7524	25.37143
7	164850.0	INFINITY	69025.24
8	30.00000	29.60000	12.72941
9	20.00000	27.32308	18.03333
10	20.00000	54.57143	INFINITY
11	30.00000	25.37143	INFINITY
12	20.00000	15.45714	20.00000
13	20.00000	10.30476	INFINITY

Figure 5: Change in objective function coefficient and delimiter with sensitivity analysis

5. CONCLUSION

Determination of Batik Madura production capacity based on limited resources basically has a relationship with the calculation of profits using ABC Method, where the method uses the activity as the main core calculation. The advantages of this study, the problem structure in linear programming is displayed so that each method has a role to get the output in accordance with the desired target.

Production costs calculated by activities where the products produced involve several activities have a significant relationship with constraints in production. So in this study, it is clear that the determinants of production capacity in linear programming are also influenced by activities that give rise to financing in the ABC analysis.

This research is focused on calculating production capacity based on production costs. Based on the scope of the discussion, this study has several limitations. Therefore, it is expected that further studies can complement or provide solutions to other solutions that are better, more effective and efficient. In addition, this research is only limited to the calculation of the cost and production capacity of Batik Madura globally, which includes two types of Batik, including Batik Cap and Batik Tulis, based on the amount of coloring.

If further explored, the cost of producing Batik Madura is also influenced by the batik motif itself or the level of difficulty of its manufacture. The level of complexity of the motive, of course, will affect the number of work activities carried out. Therefore we will conduct further research aimed at classifying Batik motifs so that the calculation of the cost and production capacity of batik can be calculated more optimally. The density of Batik motifs can be analyzed using digital imagery, in order to classify production costs based on the complexity of the motif.

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