AN ANALYSIS OF GOMORY CUTTING PLANE METHOD APPLICATION IN THE OPTIMIZATION OF PRODUCTION PROFIT: A CASE STUDY OF GRIYA BATIK NOTONEGORO JEMBER

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ABSTRACT

Gomory cutting plane method is one of the methods in linear programming that is needed to solve integer programming when the decision obtained is in the form of fractions with the addition of constraint known as Gomory constraint. The purpose of this research is to determine the best optimum solution by maximizing the profit of batik production using the Gomory cutting plane method. This type of research is applied research using a quantitative approach. Data collection methods used are interviews and documentation. This research is focused on four kinds of Jember batik motifs which are the best-selling, namely x_1 = mbako semak batik cloth; x_2 = sekar jagad batik cloth; x_3 = kopi daun batik cloth; and x_4 = parakopi batik cloth. The results showed that there was an increase in profit of Rp51.948,00 *or 2,16% per production when using the simplex method assisted by QM for Windows V5 software. Meanwhile, to make batik cloth, integer values are needed in the form of integers. Therefore, the application of Gomory cutting plane method in optimizing the profit of batik production is very appropriate to use with the obtained maximum settlement of Z =* Rp2.352.922,00 *which occurs when x_1 = 12 sheets, x_2 = 10 sheets, x_3 = 9 sheets, and x_4 = 5 sheets.*

1. INTRODUCTION

Linear programming is a mathematical modeling technique used to determine the best result or solution from a set of parameters or certain requirements and is represented in the form of a linear relationship. The linear programming problem is a problem of determining the optimal allocation of limited resources to fulfill a given goal [1]. The linear program is considered to be able to represent the conditions that exist in real life by including many parameter values determined by the researcher [2]. The concept of linear programming is based on the concept of linear equations and a system of linear inequalities of real numbers, so these properties are widely used as a guide in solving a linear programming problem [3]. Problems in linear programming talk a lot about optimization problems related to the process of forming mathematical models. The optimization model formed is used to solve various problems in the fields of government, business, engineering, economics, and physical and social sciences related to the limited allocation of resources [4]. Therefore, optimization is needed in various fields, one of which is the industrial sector.

Industries including the batik industry. The establishment of the industry will have a *multi-player affect* for the growth and development of the economy and the welfare of the surrounding community [5]. Each country must have a different type of industry and a characteristic of the country. This is due to the excess potential of resources owned by each country. In line with this, Jember Regency is a district that is famous for its tobacco commodity, which is in great demand in the world market, therefore, tobacco is made an icon of Jember Regency pride. Tobacco painting on each icon of Jember Regency can be seen in the visualization of Batik Jember. The Jember Batik motif has a characteristic tobacco leaf motif. The visualization of tobacco leaves in the Batik Jember motif is quite weak, which is lacking in character because the motifs that appear are like pictures of leaves in general [6]. In line with this, currently, the Jember Batik motif has experienced rapid development, where the tobacco leaf motif can collaborate with the natural resources of Jember Regency (such as coffee, cocoa, and edamame). As time goes by, the batik industry in Jember Regency is increasing, developing, and attracting business players. One of the batik industries in Jember Regency is Griya Batik Notonegoro Jember.

Griya Batik Notonegoro Jember is a company engaged in the industry that produces various types of batik cloth with most of the basic motifs of batik typical of Jember Regency. Griya Batik Notonegoro Jember is a private company, so its business management is still traditional. Planning in terms of production certainly has an important role in the industrial world [7]. Production planning is an activity to produce a product according to the needs of the company and its customers [8]. Calculations in planning production activities at Griya Batik Notonegoro Jember are done manually. Planning that is not carried out systematically will have an impact on not meeting customer demand due to product shortages, which can result in reduced company profits, or product accumulation in warehouses due to excess products, and result in increased inventory costs [9]. Therefore, in making decisions regarding production management, it becomes a big challenge for business actors to optimize profits in their companies. A good optimization must know the magnitude of market demand and take into account various kinds of constraints in determining the number of products produced. Optimization can be done in various ways, one of which is linear programming.

Linear Program is a method used to solve optimization problems of a linear model with various objectives and constraints [10]. Solving using a linear program can be done using the graphical method (if the variable is only 2), if more than 2 variables are solved by the computer-aided simplex method to find the optimal solution [11]. The use of this method can produce the optimal solution in the form of real numbers, which means that the solution can be in the form of integer or fractional numbers. However, there are many problems in everyday life where the decision variable is in the form of a fractional number, so that optimal problem solving is needed in the form of an integer. For example, a solution that requires 8,3 pieces of cloth in the production of batik cloth. The problem is in the case of 7 or 8 pieces of batik cloth with the additional condition that one or more decision variables are integers and does not require that the parameters in the model are integers. In this case, it can be quite difficult to round the values of the fractions while still meeting all existing constraints and not being too far from the feasible region. In line with this, there is the development of a linear program, namely integer programming, where in this program all decision variables are integers.

Based on a survey conducted by Genova and Guliashki, it was stated that there are several appropriate methods for solving integer programming optimization problems, including: (1) Cutting Plane method; (2) Branch-and-Bound (B&B) method; (3) Branch-and-Cut (B&C) method; (4) Branch-and-Price (B&P) method; (5) Relaxation dan Decomposition method [12]. Furthermore, of the five methods, this study will

only discuss cutting plane method or Gomory cutting plane method. According to Nico et al., stating that in solving problems where the variables must be round, cutting plane method or Gomory cutting plane method can be used. [13]. Method Gomory cutting plane developed to find the optimum solution for integer programming [14]. This method is done by adding a new constraint called Gomory slice equation. Gomory cuts are generated from simplex table rows associated with a base variable with a fractional value [15]. The addition of a number of new constraints with the cutting plane can produce a new feasible region whose solution is in the form of integers. In line with relevant research, this study will discuss the analysis of the application of Gomory cutting plane method in optimizing production profits at Griya Batik Notonegoro Jember.

2. RESEARCH METHODS

This research is a type of applied research using a quantitative approach. The method used is the survey method with integer programming analysis technique using the Gomory cutting plane method. The area where the research was conducted is Griya Batik Notonegoro Jember, which is located on Jalan MT Haryono No. 136, Krajan, Wirolegi, Sumbersari District, Jember Regency with the research subjects used are financial admins and batik artisans of Griya Batik Notonegoro Jember. The data in this study are primary data obtained from direct research from the object of research by conducting direct observations through interviews with the person in charge and parties directly involved in batik production. Data collection methods used are interviews and documentation. In order to achieve the research objectives, there are steps that need to be passed (see Figure 1).
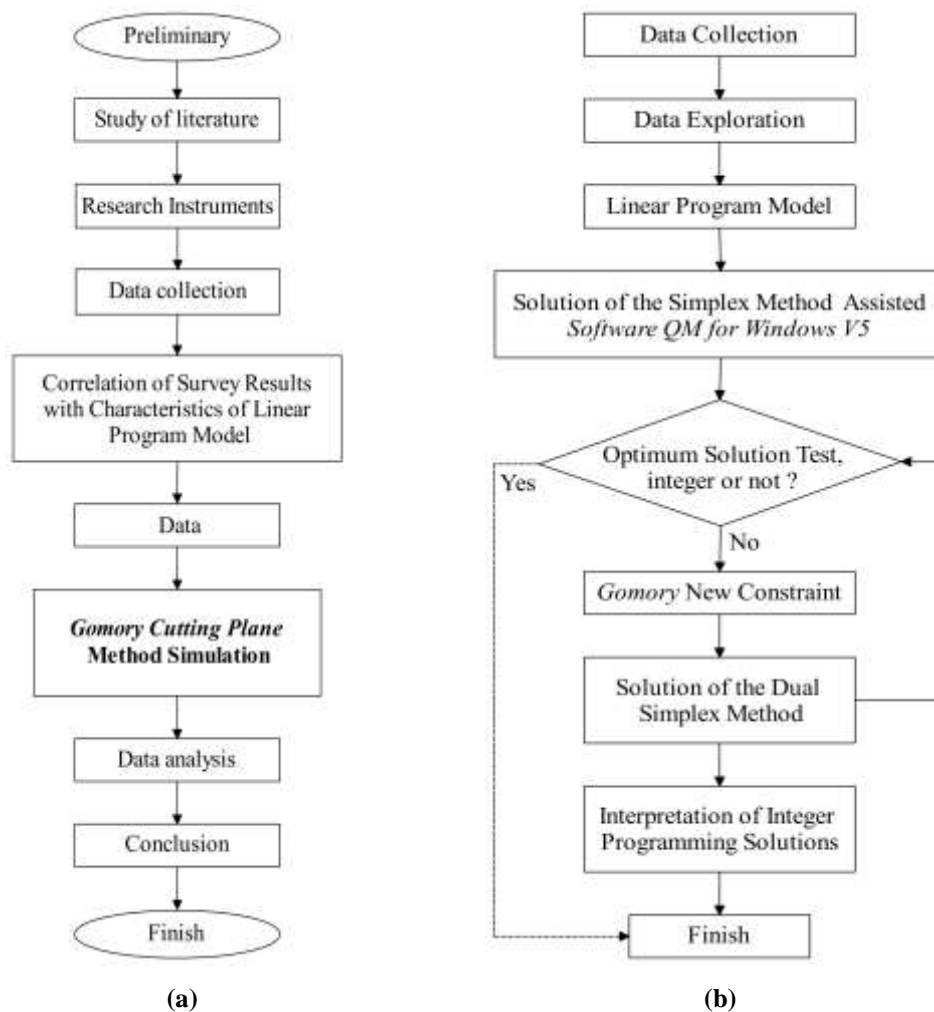

Figure 1. (a) Research Procedure; (b) *Gomory Cutting Plane* Method Simulation

3. RESULTS AND DISCUSSION

Analysis of the Gomory cutting plane method application in determining the optimal solution to integer programming problems related to batik production in the case study of Griya Batik Notonegoro Jember. The following is a linear program model for optimizing the profit of batik production at Griya Batik Notonegoro Jember.

3.1. Decision Variable

The decision variables in this study are variables related to the determination of the various batik motifs produced. The decision variables that will be used in this study are four kinds of batik cloth motifs whose sales are the most in-demand, namely:

x_1 = number of batik production of mbako semak motifs in units (sheets);

x_2 = number of batik production of sekar jagad motifs in units (sheets);

x_3 = number of batik production of kopi daun motifs in units (sheets);

x_4 = number of batik production of parakopi motifs in units (sheets).

| (a) | (b) | (c) | (d) |
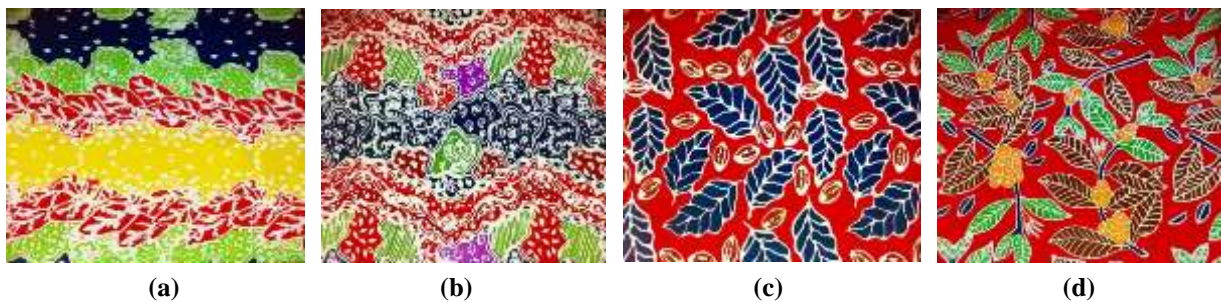
Figure 2. Batik motif (a) Mbako Semak; (b) Sekar Jagad; (c) Kopi Daun; (d) Parakopi

3.2. Constraint Function

The constraint function is a mathematical model of the various factors that affect production or limit the availability of production resources. Constraint functions that are the focus of this research are as follows:

1) Limited availability of materials

In the process of making batik cloth, a certain dose is needed in the use of raw materials and supporting materials. The resulting batik production should not exceed the availability of existing materials. The use of these materials is limited and modeled as follows: $\sum_{i=1}^{n} k_i x_i \leq K$, where k_i is the number of materials (raw materials/supporting materials) used from various types of batik motifs i (units) and K is the inventory of materials (raw materials/supporting materials) in one production (units).

Table 1. Material Needs Data in Batik Fabric Production

Material	Unit	Batik Fabric				Quantity Availability
		Motif Mbako Semak	Motif Sekar Jagad	Motif Kopi Daun	Motif Parakopi	
Raw Materials						
Primisima Cotton Fabric	Centimeter	220	220	220	220	9000
Candles/Batik Night	Gram	450	500	200	325	15000
Remasol Batik Dye	Kilogram	0,15	0,12	0,18	0,165	7
Color Lock (Waterglass)	Kilogram	0,5	0,35	0,75	0,65	20
Supporting Materials						
LPG gas size 3 kg (*pengecapan*)	Kilogram	0,045	0,05	0,03	0,025	6

Material	Unit	Batik Fabric				Quantity Availability
		Motif Mbako Semak	Motif Sekar Jagad	Motif Kopi Daun	Motif Parakopi	
LPG gas size 12 kg (*pelorodan*)	Kilogram	0,165	0,17	0,125	0,14	24

2) Time limit and maximum production quantity

The batik production process should not exceed the available time, so it can be modeled as follows: $\sum_{i=1}^{n} t_i x_i \leq MT$, where t_i adalah is the time required to make the type of batik motif i (minutes); M is the total number of workers; and T is the availability of working hours (minutes/day).

The types of batik motifs produced must not exceed the maximum production of existing batik fabrics, so they can be modeled as follows: $x_i \leq P$, where P is the maximum production amount of batik cloth products in one production.

Table 2. Maximum Production Time and Amount of Each Batik Fabric Product

No.	Batik Fabric Products	Build Time (minutes)	Maximum Production Quantity (sheets)
1.	Mbako Semak Motif Batik Fabric	115	12
2.	Sekar Jagad Motif Batik Fabric	120	10
3.	Kopi Daun Motif Batik Fabric	110	10
4.	Parakopi Motif Batik Fabric	109	8

3) Limitation of electricity costs

The electricity demand that needed for production must not exceed the availability of electricity costs, so the use of these production costs is limited and modeled as follows: $\sum_{i=1}^{n} e_i x_i \leq E$, where e_i is the cost of electricity required to produce batik motifs i (thousand rupiahs) and E is the total availability of electricity costs. Thus, the limit function model for electricity costs is obtained as follows:

$$875 x_1 + 875 x_2 + 875 x_3 + 875 x_4 \leq 175000$$

4) Limitation of packaging costs

The number of batik products that produced should not exceed the amount of available packaging costs provided, so it can be modeled as follows: $\sum_{i=1}^{n} d_i x_i \leq D$, where d_i is the cost required for packaging batik motifs i (thousand rupiahs) and D is the total availability of all packaging costs. Thus, the limit function model for production packaging costs can be written as follows:

$$7000 x_1 + 7000 x_2 + 7000 x_3 + 7000 x_4 \leq 280000$$

5) Production cost limitation

The purchase of materials that needed for production must not exceed the availability of production costs, so it can be modeled as follows: $\sum_{i=1}^{n} g_i x_i \leq G$, where g_i is the cost required to produce batik motifs i (thousand rupiahs) and G is the total availability of all production costs. Thus, the constraint function model for production costs can be written as follows:

$$177178 x_1 + 165680 x_2 + 180118 x_3 + 178760 x_4 \leq 7014196$$

6)   Limitation of labor wages

The constraint function for labor wages can be constrained and modeled as follows: $\sum_{i=1}^{n} r_i x_i \leq M$, where

r_i is the wages received by workers per type of batik motif and M is the availability of wages for workers in one production. Thus, the constraint function model for labor wages can be written as follows:

$$25000\,x_1 + 25000\,x_2 + 25000\,x_3 + 25000\,x_4 \leq 1000000$$

3.3.   Objective Function

The aim of this research is to maximize profits from the sale of batik by maximizing the production of each of the best-selling batik cloth products. The profit from selling batik cloth products is obtained from the selling price of batik cloth products i (α_i) minus the purchase price of basic materials (raw materials and supporting materials) needed in the process of making batik cloth products i (β_i), minus electricity costs in the process of making batik cloth products i $(\gamma_i$), minus packaging costs in the product packaging process batik cloth products i (θ_i) and minus the wages of labor in working on batik cloth products i per day (r_i). So, based on these calculations, a linear equation for the objective function model can be formed as follows: $Z = 72882\,x_1 + 84320\,x_2 + 44882\,x_3 + 46240\,x_4$

Based on **Table 1**, **Table 2**, and the description of the limiting or constraint function and the objective function above, a linear programming model can be formed as follows.

Maximize:

$$Z = 72882\,x_1 + 84320\,x_2 + 44882\,x_3 + 46240\,x_4$$

with constraints:

$$220\,x_1 + 220\,x_2 + 220\,x_3 + 220\,x_4 \leq 9000$$
$$450\,x_1 + 500\,x_2 + 200\,x_3 + 325\,x_4 \leq 15000$$
$$0{,}15\,x_1 + 0{,}12\,x_2 + 0{,}18\,x_3 + 0{,}165\,x_4 \leq 7$$
$$0{,}5\,x_1 + 0{,}35\,x_2 + 0{,}75\,x_3 + 0{,}65\,x_4 \leq 20$$
$$0{,}045\,x_1 + 0{,}05\,x_2 + 0{,}03\,x_3 + 0{,}025\,x_4 \leq 6$$
$$0{,}165\,x_1 + 0{,}17\,x_2 + 0{,}125\,x_3 + 0{,}14\,x_4 \leq 24$$
$$115\,x_1 + 120\,x_2 + 110\,x_3 + 109\,x_4 \leq 28800$$
$$x_1 \leq 12$$
$$x_2 \leq 10$$
$$x_3 \leq 10$$
$$x_4 \leq 8$$
$$875\,x_1 + 875\,x_2 + 875\,x_3 + 875\,x_4 \leq 175000$$
$$7000\,x_1 + 7000\,x_2 + 7000\,x_3 + 7000\,x_4 \leq 280000$$
$$177178\,x_1 + 165680\,x_2 + 180118\,x_3 + 178760\,x_4 \leq 7014196$$
$$25000\,x_1 + 25000\,x_2 + 25000\,x_3 + 25000\,x_4 \leq 1000000$$
$$x_1, x_2, x_3, x_4 \in Z$$

3.4.   Calculation of the Optimum Solution Using the Gomory Cutting Plane Method

Based on the data that has been obtained, the steps for finding an integer programming solution in solving the production profit optimization problem using the Gomory cutting plane method in the case study of Griya Batik Notonegoro Jember are as follows:

1)   Solve the integer programming problem using the simplex method assisted by *QM for Windows V5* software according to the linear programming model obtained previously with the condition that the integers are ignored.

Table 3. Optimum Solution Simplex Method in *QM Software for Windows V5* (4th Iteration)

	X1	X2	X3	X4		RHS	Dual
Maximize	72882	84320	44882	46240			
Constraint 1	220	220	220	220	<=	9000	0
Constraint 2	450	500	200	325	<=	15000	0
Constraint 3	,15	,12	,18	,17	<=	7	0
Constraint 4	,5	,35	,75	,65	<=	20	59842,67
Constraint 5	,05	,05	,03	,03	<=	6	0
Constraint 6	,17	,17	,13	,14	<=	24	0
Constraint 7	115	120	110	109	<=	28800	0
Constraint 8	1	0	0	0	<=	12	42960,67
Constraint 9	0	1	0	0	<=	10	63375,07
Constraint 10	0	0	1	0	<=	10	0
Constraint 11	0	0	0	1	<=	8	7342,27
Constraint 12	875	875	875	875	<=	175000	0
Constraint 13	7000	7000	7000	7000	<=	280000	0
Constraint 14	177178	165680	180118	178760	<=	7014196	0
Constraint 15	25000	25000	25000	25000	<=	1000000	0
Solution	12	10	7,07	8		2404870,0	

Based on **Table 3**, the optimum solution using the simplex method assisted by *QM for Windows V5* software is obtained as the maximum settlement $Z = \text{Rp } 2.404.870,00$ that occurs when $x_1 = 12$ sheets, $x_2 = 10$ sheets, $x_3 = 7,07$ sheets, and $x_4 = 8$ sheets. This means that the variable $x_1 = $ mbako semak motif batik cloth, $x_2 = $ sekar jagad motif batik cloth, and $x_4 = $ parakopi motif batik cloth the production process has been maximized, while for the variable $x_3 = $ kopi daun motif batik cloth, the production is still not the best due to the availability of existing materials, only 7,07 pieces can be made batik fabric. In addition, another reason is that the optimal solution value of the decision variables produced using the simplex method assisted by *QM for Windows V5* software is still not an integer, while to make batik cloth, integer values are needed in the form of integers. Therefore, the search for a new optimum solution using the Gomory cutting plane method can be continued in step 2.

2)   Check the optimum solution obtained from step 1. To check the optimum solution of solving the linear programming problem using the simplex method, it can be seen in **Table 3**.

Based on **Table 3**, it can be seen that the optimum solution using the simplex method is achieved when it is in the 4th iteration, which is indicated by the value of $Z_j - C_j$ which has no negative value. Furthermore, because the optimum solution of one or more decision variables in **Table 3** is still a fraction and the desired optimum solution is an integer, the process of finding the optimum solution can be continued to the next step.

3)   Formation of the 1st Gomory slice equation which will be used as a new constraint/constraint, by randomly selecting a row in the simplex optimal table which contains a fractional number in the column on the right, where the selected row will be used as a new Gomory constraint. Based on **Table 3**, x_3 is selected as the Gomory constraint, the equation for the 1st Gomory cut is obtained as follows:

For example:

Assume base variable x_3 is non-integer, the third equation can be written as follows:

$$x_i = b_i - \sum_{j=1}^{n} a_{ij} S_j \text{ , where } b_i \text{ is non-integer}$$

$$x_3 = 7,06667 - \left(1,33333\ S_4 + \left(-0,66667\ S_8\right) + \left(-0,46667\ S_9\right) + \left(-0,86667\ S_{11}\right)\right)$$

$$x_3 + 1,33333\ S_4 - 0,66667\ S_8 - 0,46667\ S_9 - 0,86667\ S_{11} = 7,06667$$

Next, b_i and a_{ij} separated into the integer part and the non-negative fraction part as follows:

$$b_i = \lfloor b_i \rfloor + f_i \text{ , with } 0 \le f_i \le 1$$

$$b_4 = 7,06667 = \frac{706.667}{100.000} = 7 + \frac{6.667}{100.000}$$

$$a_{ij} = \lfloor a_{ij} \rfloor + f_{ij} \text{ , with } 0 \le f_{ij} \le 1$$

$$a_{4,8} = 1{,}33333 = \frac{133.333}{100.000} = 1 + \frac{33.333}{100.000}$$

$$a_{4,12} = -0{,}66667 = -\frac{66.667}{100.000} = -1 + \frac{33.333}{100.000}$$

$$a_{4,13} = -0{,}46667 = -\frac{46.667}{100.000} = -1 + \frac{53.333}{100.000}$$

$$a_{4,15} = -0{,}86667 = -\frac{86.667}{100.000} = -1 + \frac{13.333}{100.000}$$

So that,

$$x_3 + 1{,}33333\ S_4 + (-0{,}66667\ S_8) + (-0{,}46667\ S_9) + (-0{,}86667\ S_{11}) = 7{,}06667$$

$$x_3 + \frac{133.333}{100.000} S_4 + \left(-\frac{66.667}{100.000} S_8\right) + \left(-\frac{46.667}{100.000} S_9\right) + \left(-\frac{86.667}{100.000} S_{11}\right) = \frac{706.667}{100.000}$$

$$x_3 + \left(1 + \frac{33.333}{100.000}\right) S_4 + \left(-1 + \frac{33.333}{100.000} S_8\right) + \left(-1 + \frac{53.333}{100.000} S_9\right) + \left(-1 + \frac{13.333}{100.000} S_{11}\right) = 7 + \frac{6.667}{100.000} \tag{1}$$

Based on **Equation (1)**, an equation for the 1st Gomory constraint can be formed by ignoring the coefficients with integer values, while the coefficients with fractional values are substituted in **Equation (2)**:

$$S_{gi} - \sum_{j=1}^{n} a_{ij} s_j = -f_i$$

$$x_3 - \frac{33.333}{100.000} S_4 - \frac{33.333}{100.000} S_8 - \frac{53.333}{100.000} S_9 - \frac{13.333}{100.000} S_{11} = -\frac{6.667}{100.000}$$

$$S_g 1 - 0{,}33333\ S_4 - 0{,}33333\ S_8 - 0{,}53333\ S_9 - 0{,}13333\ S_{11} = -0{,}06667 \tag{2}$$

4)   Adding **Equation (2)** that was formed in step 3 to the last row in the optimum simplex table where $S_g 1$ the 1st non-negative slack Gomory variable is the basis variable. The addition of the 1st Gomory constraint can be seen in **Table 4**.

In **Table 4**, it can be seen that the value of $z_j - c_j$ is no longer negative, meaning that the solution is optimal, but there is a value of b_i or the value of the right side which is negative, it means that it indicates an unfeasible condition, so it can be said that Gomory constraint is not yet feasible. Therefore, the dual simplex method can be used to solve this unfeasibility condition.

5)   Solve **Table 4** using the dual simplex method to get a new optimal solution in the following way:
   a.   Make sure **Table 4** is in optimal condition.

      In **Table 4**, it can be seen that the value of $z_j - c_j$ has no negative value (maximization case), meaning that the solution is optimal.
   b.   Check whether the solution of **Table 4** is feasible, i.e.: $b_i \geq 0$ for all i.

      In Table 4 it can be seen that the row $S_g 1$ has b_i negative, i.e. $-0{,}06667$, it means that the solution is not yet feasible, so it can proceed to the next step.
   c.   Determine the key row (leaving variable) by selecting the base variable that has the most negative right-hand side value (b_i). In **Table 4** it can be seen that the base variable which has the most negative right-hand side value (b_i) is row $S_g 1$.

   d.   Determine the key column (entering variable) among the non-basic variables by selecting the smallest ratio value (the ratio between the coefficients of the equation z and the coefficients of the leaving variable equation) as follows.

      Column ratio $S_j = \dfrac{z_j - c_j}{a_{ij}}$; where a_{ij} coefficient of the constraint function on the key row is <0.

      In **Table 4** it can be seen that the smallest ratio value is column S_{11}.

   e.   Create a new table by doing row operations as in the usual simplex algorithm. Return to step b.

Table 4. Dual Simplex Table after Adding the 1st *Gomory* Piece

		72882	84320	44882	46240	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
	BV	X1	X2	X3	X4	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15	Sg1	bi
S1	0	0	0	0	0	1	0	0	-293,333	0	0	0	-73,3333	-117,333	0	-29,3333	0	0	0	0	0	845,3333
S2	0	0	0	0	0	0	1	0	-266,667	0	0	0	-316,667	-406,667	0	-151,667	0	0	0	0	0	586,6667
S3	0	0	0	0	0	0	0	1	-0,24	0	0	0	-0,03	-0,036	0	-0,009	0	0	0	0	0	1,408
X3	44882	0	0	1	0	0	0	0	1,333333	0	0	0	-0,66667	-0,46667	0	-0,86667	0	0	0	0	0	7,066667
S5	0	0	0	0	0	0	0	0	-0,04	1	0	0	-0,025	-0,036	0	0,001	0	0	0	0	0	4,548
S6	0	0	0	0	0	0	0	0	-0,16667	0	1	0	-0,08167	-0,11167	0	-0,03167	0	0	0	0	0	18,31667
S7	0	0	0	0	0	0	0	0	-146,667	0	0	1	-41,6667	-68,6667	0	-13,6667	0	0	0	0	0	24570,67
X1	72882	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	12
X2	84320	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	10
S10	0	0	0	0	0	0	0	0	-1,33333	0	0	0	0,666667	0,466667	1	0,866667	0	0	0	0	0	2,933333
X4	46240	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	8
S12	0	0	0	0	0	0	0	0	-1166,67	0	0	0	-291,667	-466,667	0	-116,667	1	0	0	0	0	142566,7
S13	0	0	0	0	0	0	0	0	-9333,33	0	0	0	-2333,33	-3733,33	0	-933,333	0	1	0	0	0	20533,33
S14	0	0	0	0	0	0	0	0	-240157	0	0	0	-57099,3	-81624,9	0	-22657,7	0	0	1	0	0	528346,1
S15	0	0	0	0	0	0	0	0	-33333,3	0	0	0	-8333,33	-13333,3	0	-3333,33	0	0	0	1	0	73333,33
Sg1	0	0	0	0	0	0	0	0	-0,33333	0	0	0	-0,33333	-0,53333	0	-0,13333	0	0	0	0	1	-0,06667
	Zj	72882	84320	44882	46240	0	0	0	59842,67	0	0	0	42960,67	63375,07	0	7342,267	0	0	0	0	0	
	Zj - Cj	72882	84320	44882	46240	0	0	0	59842,67	0	0	0	42960,67	63375,07	0	7342,267	0	0	0	0	0	2404870
	Ratio	–	–	–	–	–	–	–	179528	–	–	–	128882	118828,3	–	55067	–	–	–	–	–	

6) Return to step 2. This process is repeated until the optimum simplex table is obtained as shown in **Table 5**.

Table 5. Optimum Solution after Addition of 5th *Gomory* Piece

		72882	84320	44882	46240	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
	BV	X1	X2	X3	X4	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15	Sg1	Sg2	Sg3	Sg4	Sg5	bi
S1	0	0	0	0	0	1	0	0	0	0	0	0	220	0	0	0	0	0	0	0	0	-440	0	0	0	1080
S2	0	0	0	0	0	0	1	0	0	0	0	0	50	0	0	0	0	0	0	0	0	-500	0	-425	100	1175
S3	0	0	0	0	0	0	0	1	0	0	0	0	0,21	0	0	0	0	0	0	0	0	-0,36	0	0,075	0	1,555
X3	44882	0	0	1	0	0	0	0	0	0	0	0	-0,5	0	0	0	0	0	0	0	0	0,5	0	-2	1,5	9
S5	0	0	0	0	0	0	0	0	0	1	0	0	-0,005	0	0	0	0	0	0	0	0	-0,04	0	-0,015	-0,02	4,565
S6	0	0	0	0	0	0	0	0	0	0	1	0	0,0925	0	0	0	0	0	0	0	0	-0,2575	0	-0,06	0,0075	18,495
S7	0	0	0	0	0	0	0	0	0	0	0	1	98	0	0	0	0	0	0	0	0	-213	0	-9	-7	24685
X1	72882	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	12
X2	84320	0	1	0	0	0	0	0	0	0	0	0	0,5	0	0	0	0	0	0	0	0	-0,5	0	1	0,5	10
S4	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	-1,5	0	0,5	0	0,5
X4	46240	0	0	0	1	0	0	0	0	0	0	0	-2	0	0	0	0	0	0	0	0	2	0	1	-2	5
S12	0	0	0	0	0	0	0	0	0	0	0	0	875	0	0	0	1	0	0	0	0	-1750	0	0	0	143500
S13	0	0	0	0	0	0	0	0	0	0	0	0	7000	0	0	0	0	1	0	0	0	-14000	0	0	0	28000
S14	0	0	0	0	0	0	0	0	0	0	0	0	187561	0	0	0	0	0	1	0	0	-364739	0	15796	4503	716398
S15	0	0	0	0	0	0	0	0	0	0	0	0	25000	0	0	0	0	0	0	1	0	-50000	0	0	0	100000
Sg1	0	0	0	0	0	0	0	0	0	0	0	0	7,18869E-15	0	0	0	0	0	0	0	1	-0,5	0	-0,5	-5,82867E-16	0,5
S9	0	0	0	0	0	0	0	0	0	0	0	0	-0,5	1	0	0	0	0	0	0	0	0,5	0	-1	-0,5	6,75016E-14
Sg3	0	0	0	0	0	0	0	0	0	0	0	0	1,5	0	0	0	0	0	0	0	0	-2	1	-1,5	1,5	2,5
S11	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	1	0	0	0	0	0	-2	0	-1	2	3
S10	0	0	0	0	0	0	0	0	0	0	0	0	0,5	0	1	0	0	0	0	0	0	-0,5	0	2	-1,5	1
	Zj	72882	84320	44882	46240	0	0	0	0	0	0	0	121	0	0	0	0	0	0	0	0	72761	0	40796	17003	
	Zj - Cj	0	0	0	0	0	0	0	0	0	0	0	121	0	0	0	0	0	0	0	0	72761	0	40796	17003	2352922

Table 5 shows the results of finding an integer programming solution using the Gomory cutting plane method with the assistance of *Microsoft Excel* software on batik production at Griya Batik Notonegoro Jember. **Table 5** shows that none of the values in the $Z_j - C_j$ rows have negative values, meaning that the solution is optimal, then all b_i values or right-hand side values are no longer negative, meaning that they indicate a feasible condition, and other than that. It can be seen that all decision variable values have integer

values in the form of integers, meaning that by using the Gomory cutting plane method, the optimum integer programming solution has been achieved. The optimum solution for integer programming using the Gomory cutting plane method obtained by Griya Batik Notonegoro Jember, with the assistance of *Microsoft Excel* software, obtained the maximum settlement $Z = \text{Rp } 2.352.922,00$ that occurs when $x_1 = 12$ sheets, $x_2 = 10$ sheets, $x_3 = 9$ sheets, and $x_4 = 5$ sheets.

4. CONCLUSIONS

Based on the results of the analysis and discussion that has been carried out, the conclusions that can be drawn from this research are as follows:

1. From the results of manual calculations with *Microsoft Excel* software, it can be seen that the optimal amount of batik production at Griya Batik Notonegoro Jember is:

    - Number of batik production of mbako semak motifs $(x_1) = 12$ sheets;

    - Number of batik production of sekar jagad motifs $(x_2) = 10$ sheets;

    - Number of batik production of kopi daun motifs $(x_3) = 9$ sheets;

    - Number of batik production of parakopi motifs $(x_4) = 5$ sheets.

2. The profit of finding an integer programming solution that is obtained using the Gomory cutting plane method with the help of *Microsoft Excel* software is Rp2.352.922,00, while for production optimization using the simplex method assisted by *QM for Windows V5* software, the profit obtained is Rp2.404.870,00. In this case, it can be said that there has been an increase in profit of Rp51.948,00 or 2,16% per production. Thus, for production optimization using the simplex method is the most optimal solution, although there are deficiencies in the optimal solution, namely the coefficients of one or more decision variables that are not integers. Meanwhile, to make batik cloth, an integer value is needed in the form of integers.

3. The application of Gomory cutting plane method in optimizing the profit of batik production is very appropriate to use. This is because Gomory cutting plane method algorithm is practically able to cut unwanted fractional solutions by eliminating the non-feasible integer solution points, although none of the feasible integer solution points in this way is removed, so that this method is practically able to shorten the calculation by producing a very realistic optimum solution in the form of integers in the problem of optimizing the profit of batik production at Griya Batik Notonegoro Jember.

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