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การหาค่าเหมาะที่สุดของการผลิตผ้าบาติกโดยใช้วิธีซิมเพล็กซ์อย่างรวดเร็ว

Optimization of Batik Production Using the Quick Simplex Method

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บทคัดย่อ

วัตถุประสงค์และที่มา : เพื่อคำนวณหาจำนวนการผลิตผ้าบาติกที่เหมาะสมที่สุดของบริษัทอันดานันบาติกลัมปุง ในประเทศอินโดเนียเซีย ซึ่งมีอยู่ 3 ประเภท ได้แก่ ผ้าบาติกพิมพ์ลาย ผ้าบาติกทำมือ และผ้าพันคอบาติก เพื่อให้ได้กำไรสูงสุด โดยใช้วิธีซิมเพล็กซ์อย่างรวดเร็ว ซึ่งผลลัพธ์ที่ได้ได้นำมาเปรียบเทียบกับวิธีซิมเพล็กซ์

วิธีดำเนินการวิจัย : ศึกษาปัญหากำไรสูงสุดของบริษัทอันดานันบาติกลัมปุง ศึกษาวิธีซิมเพล็กซ์และวิธีซิมเพล็กซ์อย่างรวดเร็ว ประยุกต์วิธีซิมเพล็กซ์อย่างรวดเร็วกับปัญหากำไรสูงสุดของบริษัทอันดานันบาติกลัมปุง นำผลลัพธ์ที่ได้เปรียบเทียบกับวิธีซิมเพล็กซ์ สรุปผลการวิจัยและให้ข้อเสนอแนะ

ผลการวิจัย : ทั้งสองวิธีให้ผลการคำนวณจำนวนการผลิตผ้าบาติกที่เหมาะที่สุดมีค่าเท่ากันคือ ควรจะผลิตผ้าบาติกพิมพ์ลายจำนวน 4.05 โหล และควรจะผลิตผ้าบาติกทำมือจำนวน 5.51 โหล เพื่อให้ได้กำไรสูงสุดคือ 652,530 รูเปียห์

สรุปผลการวิจัย : เมื่อเปรียบเทียบกระบวนการคำนวณของทั้งสองวิธีแล้วพบว่า วิธีซิมเพล็กซ์อย่างรวดเร็วจะลดขั้นตอนการคำนวณตารางซิมเพล็กซ์ โดยวิธีซิมเพล็กซ์ใช้ 3 ตารางการคำนวณ แต่วิธีซิมเพล็กซ์อย่างรวดเร็วใช้เพียง 2 ตารางการคำนวณ นอกจากนี้ได้มีการนำโปรแกรมไพทอนมาช่วยในการตรวจสอบผลลัพธ์และเปรียบเทียบประสิทธิภาพด้านเวลาของการคำนวณ พบว่าวิธีซิมเพล็กซ์อย่างรวดเร็วจะใช้เวลาในการคำนวณน้อยกว่าวิธีซิมเพล็กซ์อยู่ 0.201457 วินาที

คำสำคัญ : การหาค่าเหมาะที่สุด ; กำหนดการเชิงเส้น ; วิธีซิมเพล็กซ์ ; วิธีซิมเพล็กซ์อย่างรวดเร็ว ; ผ้าบาติก

Abstract

Background and Objectives : To calculate the amount of Lampung batik production of the Andanan Batik Lampung company in Indonesia. There are 3 types of batik: printed batik, handmade batik and batik scarf that resulted in that resulted in the maximum profit using the quick simplex method compared with the simplex method.

Methodology : Study the problem of the maximum profit from batik production. Study the simplex method and the quick simplex method. Apply the quick simplex method to the problem of maximizing the profit of batik production. Compare the results with the simplex method. Summarize and discuss the finding.

Main Results : It was found that the Lampung batik production of the Andanan Batik Lampung company should be produced printed batik (4.05 dozen) and handmade batik (5.51 dozen) for the maximum profit 652,530 IDR.

Conclusions : When we calculated using the quick simplex method it was found that this method reduced the calculation process of the simplex table. The simplex method used three tables, but the quick simplex method used only two tables, which gave the same answer as the simplex method. In addition, Python programs were used to help verify the results. In order to achieve the maximum profitability of each type of batik production, it was found that the quick simplex method took time less than the simplex method, which was 0.21457 seconds.

Keywords : optimization ; linear programming ; simplex method ; quick simplex method

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Introduction

Batik is also known as pateh. It is a term used to refer to a type of fabric that is made using candles to cover the parts that do not want to be colored, and to use the point method. Drain or dye only the part that needs to be colored. Batik Some pieces may go through the candle-closing process, coloring, and dyeing dozens of times. Back then, batik or pateh was a Javanese word used to refer to a fabric with a dotted pattern. Therefore, the word batik means a fabric with dotted patterns. Although the current batik method has advanced a lot with technology and organization, one of the characteristics of batik remains that it must be produced using candles that do not want to be attached as standard. It is a method that truly demonstrates the wisdom of the villagers. Batik is most commonly used in Southeast Asian countries, including Indonesia, Malaysia, and Brunei Darussalam. The southern islands of the Philippines and southern Thailand, especially in the three southernmost provinces, have prepared batik as a local product and participated in the One Subdistrict One Product or "OTOP" project. It generates a lot of income for the community. In 2014, Vaidya, N. V., *et al*. studied and compared methods to solve linear programming, including the simplex method, the Criteria-I method, the Criteria-II method, and the quick simplex method. It was found that the quick simplex method got the ideal answer with a smaller number of steps than the others (Vaidya, *et al.*, 2014). In 2020, Vaidya, N. V., *et al.* studied the comparison between the simplex method and the quick simplex method in solving linear programming problems and checking answers from graphical methods (Vaidya, *et al.*, 2020). However, due to the Graphical Method's limitations, solving linear programming problems with more than two basic variables becomes increasingly challenging. Graphical representation becomes more complex, especially when dealing with a higher number of basic variables. In the process of searching for a feasible solution, it is necessary to test every possible point on the graph to find the one that satisfies all the given constraints. Therefore, for problems involving a higher number of basic variables, alternative methods such as the simplex method and quick simplex method are relied upon. However, upon considering a comparison between the Quick Simplex Method and the Simplex Method, it becomes evident that a quick simplex method starts from the default simplex table, which still doesn't give the best results. Therefore, more than one basic variable has been replaced whenever possible, and the total number of simplex tables after such substitution is less than or equal to the simplex method. It shows that the quick simplex method is more effective than the simplex method. In addition, there are several studies that demonstrate the effectiveness of requesting a quick simplex method (Vaidya, *et al.*, 2016). In 2021, Aldino, A. A., *et al.* studied the simplex method and the use of the Python program to solve the linear programming of Andanan Batik Lampung in Indonesia and found that batik production should produce 4.05 dozen printed batik fabrics and 5.51 dozen handmade batik fabrics in order to achieve the maximum profit of 652,530 IDR. In the calculation process, there will be the use of three tables in the simplex method. (Aldino, *et al.*, 2021). Therefore, in this article, the idea is to use a quick simplex method to help calculate the optimal batik production amount for Andanan Batik Lampung Company in Indonesia, where there are three types of batik prints, handmade batik, and batik scarves, for maximum profit by comparing the results with the simplex method. This comparison aims to highlight the efficiency of the quick simplex method in the context of solving real-world applied problems. This article is divided into 3 sections: Part 1 is the research methodology; Part 2 is the research results and discussion; and Part 3 is the summary.

Methods

1. Research Procedures

This research was carried out according to the following diagram stages (Figure 1).

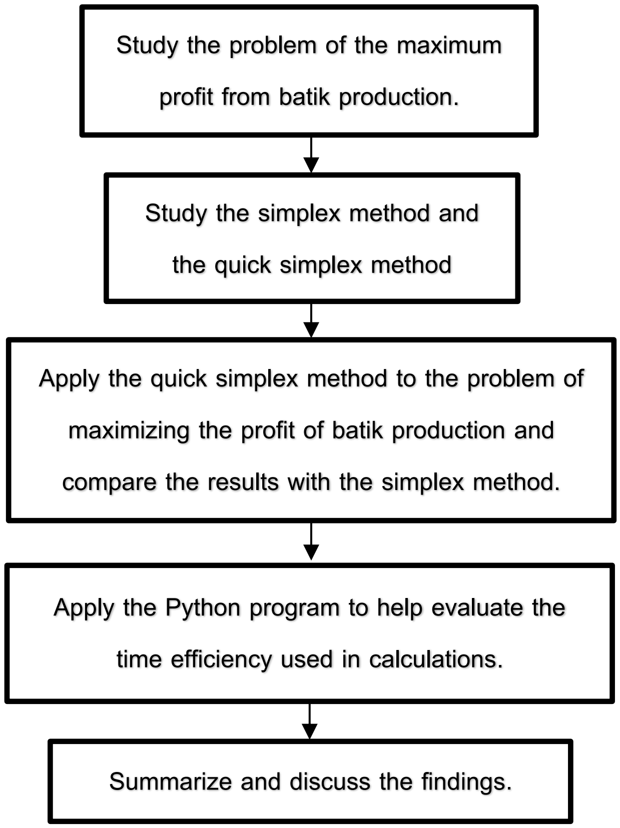

Figure 1 Research procedures diagram.

2. Linear Programming

Linear programs are constrained optimization models that satisfy three requirements.

1. The decision variables (x_j) must be continuous; they can take on any value within some restricted range.

2. The objective function (Z) must be a linear function.

3. The left-hand sides of the constraints must be linear functions.

Thus, linear programs are written in the following form:

Maximize or minimize $Z = c_1x_1 + c_2x_2 + \ldots + c_nx_n$

Subject to

$$a_{11}x_1 + a_{12}x_2 + \ldots + a_{1n}x_n \ (\le, \ge, =)\ b_1$$

$$a_{21}x_1 + a_{22}x_2 + \ldots + a_{2n}x_n \ (\le, \ge, =)\ b_2$$

$$\vdots$$

$$a_{m1}x_1 + a_{m2}x_2 + \ldots + a_{mn}x_n \ (\le, \ge, =)\ b_m$$

where c_j , a_{ij} and b_i values are constants, also called parameters or coefficients, that are given or specified by the problem assumptions. Most linear programs require that all decision variables be nonnegative.

3. Simplex Method

In 1949, George Dantzig developed an efficient procedure for solving linear programs called the simplex method. The simplex method (Ficken, 2015) relies on the principles of the matrix to help find the most suitable result. By changing the variables affects the objective function, which focuses on getting to the objective as quickly as possible solving the linear programming problem. The Simplex Method can be used for linear programming with two or more basic variables.

4. Quick Simplex Method

The quick simplex method was invented by Vaidya, N.V., Kasturiwale, N.N. (2014). It is another method that provides quick answers, and the number of tables is less than or equal to the simplex method (Vaidya, *et al.*, 2014). The steps are as follows:

1. Format linear programming in a standard format. Consider the following objective functions:

$$Maximize\ Z = c_1x_1 + c_2x_2 + \ldots + c_nx_n$$

Subject to

$$\begin{aligned} a_{11}x_1 + a_{12}x_2 + \ldots + a_{1n}x_n &\le b_1 \\ a_{21}x_1 + a_{22}x_2 + \ldots + a_{2n}x_n &\le b_2 \\ &\vdots \\ a_{m1}x_1 + a_{m2}x_2 + \ldots + a_{mn}x_n &\le b_m \end{aligned}$$

where $x_j (j = 1,2,3,...,n)$ is the decision variable, called basic variable.

$c_j (j = 1,2,3,...,n)$ is referred to as the objective function coefficient of x_j .

$b_i (i = 1,2,3,...,m)$ is the right-hand side of equation i .

$a_{ij} (i = 1,2,3,...,m,\ j = 1,2,3,...,n)$ is referred to as the constraint's coefficient of x_j .

Written in the standard format will be

$$Minimize\ Z = -(c_1x_1 + c_2x_2 + \ldots + c_nx_n) + 0S_1 + 0S_2 + \ldots + 0S_m$$

Subject to

$$a_{11}x_1 + a_{12}x_2 + \ldots + a_{1n}x_n + S_1 = b_1$$
$$a_{21}x_1 + a_{22}x_2 + \ldots + a_{2n}x_n + S_2 = b_2$$
$$\vdots$$
$$a_{m1}x_1 + a_{m2}x_2 + \ldots + a_{mn}x_n + S_m = b_m$$

where $S_1, S_2, \ldots, S_m$ are new non-negative variable for transform that inequality constraint into an equality constraint which will measure the difference between the left and the right parts of the constraint, called slack variables. The slack variables are included in the objective function with coefficient zero.

2. Check the values of all b_i are non-negative. If b_i any of the values is negative, then multiply the corresponding inequalities of the constraints by -1, to get all b_i non-negative.

3. Create a simplex table :

Table 1 Simplex table

	C_j	$-c_1$	$-c_2$	$\ldots$	$-c_n$	0	0	$\ldots$	0	x_B
C_B	S_B	x_1	x_2	$\ldots$	x_n	S_1	S_2	$\ldots$	S_m	
0	S_1	a_{11}	a_{12}	$\ldots$	a_{1n}	1	0	$\ldots$	0	b_1
0	S_2	a_{21}	a_{22}	$\ldots$	a_{2n}	0	1	$\ldots$	0	b_2
$\vdots$	$\vdots$	$\vdots$	$\vdots$	$\ldots$	$\vdots$	0	0	$\ddots$	$\vdots$	$\vdots$
0	S_m	a_{m1}	a_{m2}	$\ldots$	a_{mn}	0	0	$\ldots$	1	b_m
Z_j										
$Z_j - C_j$										

4. Select the entering variable and the leaving variable at the same time, with the main elements in each column must be in different rows. For the example in Table 2.

Table 2 Example table

	C_j	$-c_1$	$-c_2$	$-c_3$	0	0	0	x_B
C_B	S_B	x_1	x_2	x_3	S_1	S_2	S_3	
0	S_1	Pivot a_1	b_1	c_1	1	0	0	b_1
0	S_2	a_2	Pivot b_2	c_2	0	1	0	b_2
0	S_3	a_3	b_3	c_3	0	0	1	b_3
Z_j								
$Z_j - C_j$								

Here, a_1 and b_2 are the primary elements (Pivot Element), which the imported variable is in the default simplex table.

5. Define determinants with $R = \begin{vmatrix} a_1 & b_1 \\ a_2 & b_2 \end{vmatrix}$. Provided that the new value x_B must not be negative.

6. Calculate the new values in each element of each column with the following formula:

$$c_1^{**} = (-1)^1 \frac{\begin{vmatrix} b_1 & c_1 \\ b_2 & c_2 \end{vmatrix}}{R} \quad (1)$$

$$c_2^{**} = (-1)^2 \frac{\begin{vmatrix} a_1 & c_1 \\ a_2 & c_2 \end{vmatrix}}{R} \quad (2)$$

$$c_3^{**} = \frac{\begin{vmatrix} a_1 & b_1 & c_1 \\ a_2 & b_2 & c_2 \\ a_3 & b_3 & c_3 \end{vmatrix}}{R} \quad (3)$$

7. Then enter the new values obtained from the calculations into Table 3. Where $a_1^{**}, a_2^{**}, a_3^{**}, b_1^{**}, b_2^{**}, b_3^{**}, c_1^{**}, c_2^{**}, c_3^{**}$ are the new values obtained from the calculations according to formula (1) to (3).

Table 3 Substitution in the table

	C_j	$-c_1$	$-c_2$	$-c_3$	0	0	0	x_B
C_B	S_B	x_1	x_2	x_3	S_1	S_2	S_3	
...	...	a_1^{**}	b_1^{**}	c_1^{**}	...	...	...	...
...	...	a_2^{**}	b_2^{**}	c_2^{**}	...	...	...	...
...	...	a_3^{**}	b_3^{**}	c_3^{**}	...	...	...	...
Z_j		...	...	...	...	...	...	...
$Z_j - C_j$		...	...	...	...	...	...	...

8. Check that every value of $Z_j - C_j$ must be less than or equal to zero. Then, conclude that the optimal solution is the value of the element in column x_B.

Results

In this research, a quick simplex method was applied to calculate the optimal batik production amount of the Andanan Batik Lampung company in Indonesia. There are three types of printed batik. Handmade batiks and batik scarves for maximum profit. From the production cost report on November 2020 at Andanan Batik Lampung company (Aldino, *et. al,* 2021). The results are as shown in the following table.

Table 4 The production cost report on November 2020 at the Andanan Batik Lampung company.

Product	Cost of goods sold (IDR/dozen)	Production Cost (IDR/dozen)	Profit (IDR/dozen)
Printed Batik	615,000	560,000	55,000
Handmade Batik	805,000	727,000	78,000
Batik Scarf	280,000	248,000	32,000

The constraints faced by the company are only 1500 kilograms of raw materials, 540 hours of time, and 175 units of machines. In order to produce batik, each of the dozen ingredients must be used, including raw materials, time, and machines, as shown in the following table.

Table 5 The constraints faced report on November 2020 at the Andanan Batik Lampung company.

Product	Raw Materials (Kg./dozen)	Time (hours/dozen)	machines (unit/dozen)
Printed Batik	141.75	41.5	16
Handmade Batik	131.25	67.5	20
Batik Scarf	87.03	27	10

Therefore, it can be written as a linear programming as follows:

The objective function is: $Maximize\ Z = 55,000x_1 + 78,000x_2 + 32,000x_3$

Where Z is the maximum profit (IDR). x_1 is the number of printed batik (dozen). x_2 is the number of handmade batik (dozen). x_3 is the number of batik scarf (dozen).

Subject to $141.75x_1 + 131.25x_2 + 87.03x_3 \le 1,500$

$$41.5x_1 + 67.5x_2 + 27x_3 \le 540$$

$$16x_1 + 20x_2 + 10x_3 \le 175$$

$$x_1, x_2, x_3 \ge 0$$

Use the quick simplex method. This linear programming can be rewritten in the following standard format:

The objective function is: $Minimize\ Z = -55,000x_1 - 78,000x_2 - 32,000x_3 + 0S_1 + 0S_2 + 0S_3$

Subject to $141.75x_1 + 131.25x_2 + 87.03x_3 + S_1 = 1,500$

$$41.5x_1 + 67.5x_2 + 27x_3 + S_2 = 540$$

$$16x_1 + 20x_2 + 10x_3 + S_3 = 175$$

$$x_1, x_2, x_3, S_1, S_2, S_3 \ge 0$$

Create a default simplex table: Insert the coefficients and constants from the right-hand side of the linear programming into the table 6, then assign values to variables $a_1, a_2, a_3, b_1, b_2, b_3$ as shown in Table 6.

Table 6 A default simplex table.

	C_j	-55,000	-78,000	-32,000	0	0	0	x_B	x_B / x_1	x_B / x_2
C_B	S_B	x_1	x_2	x_3	S_1	S_2	S_3			
0	S_1	$b_3 = 141.75$	$a_3 = 131.25$	87.03	1	0	0	1,500	10.58	11.43
0	S_2	$b_1 = 41.5$	$a_1 = 67.5$	27	0	1	0	540	13.01	8
0	S_3	$b_2 = 16$	$a_2 = 20$	10	0	0	1	175	10.94	8.75
Z_j		0	0	0	0	0	0			
$Z_j - C_j$		55,000	78,000	32,000	0	0	0			
		↑	↑			↓	↓			

Select the two columns with the most possible value of $Z_j - C_j$, which 55,000 and 78,000. Therefore, x_1 and x_2 are selected as entering variables. Then consider the rations x_B / x_1 and x_B / x_2 with the least positive values, which are 8 and 8.75. Therefore, S_2 and S_3 are selected as leaving variables. Provided that the new value x_B must not be negative. a_1 and b_2 are called the pivot elements. Recalculate the values in each element of each column with the following formula (1) to (3).

Consider $x_1 = \begin{bmatrix} 141.75 \\ 41.5 \\ 16 \end{bmatrix} = \begin{bmatrix} c_3 \\ c_1 \\ c_2 \end{bmatrix}$ Substitute the values of $a_1, a_2, a_3, b_1, b_2, b_3$ from the initial table into formulas

(1) to (3), and will get:

$$R = \begin{vmatrix} a_1 & b_1 \\ a_2 & b_2 \end{vmatrix} = \begin{vmatrix} 67.5 & 41.5 \\ 20 & 16 \end{vmatrix} = 250$$

$$c_1^{**} = (-1)^1 \frac{\begin{vmatrix} b_1 & c_1 \\ b_2 & c_2 \end{vmatrix}}{R} = (-1)^1 \frac{\begin{vmatrix} 41.5 & 41.5 \\ 16 & 16 \end{vmatrix}}{250} = 0$$

$$c_2^{**} = (-1)^1 \frac{\begin{vmatrix} a_1 & c_1 \\ a_2 & c_2 \end{vmatrix}}{R} = (-1)^2 \frac{\begin{vmatrix} 67.5 & 41.5 \\ 20 & 16 \end{vmatrix}}{250} = 1$$

$$c_3^{**} = \frac{\begin{vmatrix} a_1 & b_1 & c_1 \\ a_2 & b_2 & c_2 \\ a_3 & b_3 & c_3 \end{vmatrix}}{R} = \frac{\begin{vmatrix} 67.5 & 41.5 & 41.5 \\ 20 & 16 & 16 \\ 131.25 & 141.75 & 141.75 \end{vmatrix}}{250} = 0$$

That is the new value of $x_1 = \begin{bmatrix} c_3^{**} \\ c_1^{**} \\ c_2^{**} \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix}$.

Calculate the new values in each element of each column by formula (1) to (3) until to column x_B.

Consider $x_B = \begin{bmatrix} 1500 \\ 540 \\ 175 \end{bmatrix} = \begin{bmatrix} c_3 \\ c_1 \\ c_2 \end{bmatrix}$. Substitute the values of $a_1, a_2, a_3, b_1, b_2, b_3$ from the initial table into formulas (1) to (3), and will get:

$$R = \begin{vmatrix} a_1 & b_1 \\ a_2 & b_2 \end{vmatrix} = \begin{vmatrix} 67.5 & 41.5 \\ 20 & 16 \end{vmatrix} = 250$$

$$c_1^{**} = (-1)^1 \frac{\begin{vmatrix} b_1 & c_1 \\ b_2 & c_2 \end{vmatrix}}{R} = (-1)^1 \frac{\begin{vmatrix} 41.5 & 540 \\ 16 & 175 \end{vmatrix}}{250} = 5.51$$

$$c_2^{**} = (-1)^1 \frac{\begin{vmatrix} a_1 & c_1 \\ a_2 & c_2 \end{vmatrix}}{R} = (-1)^2 \frac{\begin{vmatrix} 67.5 & 540 \\ 20 & 175 \end{vmatrix}}{250} = 4.05$$

$$c_3^{**} = \frac{\begin{vmatrix} a_1 & b_1 & c_1 \\ a_2 & b_2 & c_2 \\ a_3 & b_3 & c_3 \end{vmatrix}}{R} = \frac{\begin{vmatrix} 67.5 & 41.5 & 540 \\ 20 & 16 & 175 \\ 131.25 & 141.75 & 1500 \end{vmatrix}}{250} = 202.73$$

Then enter the new values obtained from the calculations into Table 7. The final result is shown in the Table 7.

Table 7 The final result by using the quick simplex method.

	C_j	-55000	-78000	-32000	0	0	0	x_B
C_B	S_B	x_1	x_2	x_3	S_1	S_2	S_3	
0	S_1	0	0	1.55	1	2.94	-16.49	202.73
-78000	x_2	0	1	0.07	0	0.06	-0.17	5.51
-55000	x_1	1	0	0.54	0	-0.08	0.27	4.05
Z_j		-55000	-78000	-35004	0	-1155.6	0	652530
$Z_j - C_j$		0	0	-3004	0	-1902	0	

Because all $Z_j - C_j \le 0$. Therefor the optimal solution is $x_1 = 4.05,\ x_2 = 5.51, x_3 = 0, S_1 = 202.73$ that make $Maximize\ Z = 55,000(4.05) + 78,000(5.51) + 32,000(0) = 652,530$.

Discussion

Based on the results of such calculations. We suggest that the results of such calculations can be used as information for making decisions on batik production. However, in the actual situation of the company, the needs of customers may be considered. If the customer needs all 3 types of batik, the manufacturing company may produce products to meet the customer's needs. Production still makes the company profitable but may not be the most profitable.

Conclusions

Based on the results of the research, we calculated the optimal batik production amount for Andanan Batik Lampung Company. In Indonesia, to achieve maximum profit by using the quick simplex method, the results have been compared with the simplex method. It was found that both methods gave the same calculation of the optimal batik production amount: 4.05 dozen printed batik should be produced and 5.51 dozen handmade batik should be produced to achieve the maximum profit of 652,530 IDR and consistent with the computational results in the research conducted by Aldino*, et al.*, 2021, using the simplex method. But calculation by using the quick simplex method it was found that this method reduced the calculation process of the simplex table. The simplex method used three tables, but the quick simplex method used only two tables. Furthermore, it has been found that using the quick simplex method takes less time to calculate than the simplex method exists 0.201457 seconds compared to Python programming helps to evaluate time performance.

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