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Optimization Model of Clothing Production Plan using Branch and Bound Method

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ABSTRACT

The increasing number of clothing activities in Indonesia has resulted in companies having to increase their marketing and production activities in order to obtain maximum profit. One of the factors influencing the growth of basic clothing is the price of the middle class in Indonesia. This can be a strong foundation for a long-term clothing consumer base. One of the businesses engaged in the production of clothing is a garment production business. The problem that is often faced by companies is limited resources such as raw materials, capital, time, etc. Production planning is a process to produce goods in a certain period in accordance with those predicted through the organization of resources. Therefore, production optimization is one way to optimize profit and apparel production. This study aims to apply the Integer Linear Programming model and is completed using the Branch and Bound method to obtain the optimal number of clothing production in order to obtain maximum profit. The conclusion obtained from the research is the application of the Branch and Bound method to the problem of optimizing production planning at PT. GM Tactical to obtain more optimal results compared to the actual production carried out by the company.

1. Introduction

Economic development in Indonesia in the last 10 years recorded positive economic growth. Indonesia's economic growth is relatively stable above 4.5% with world economic conditions that are not conducive in 2019 to 2020. The economic indicator, namely GDP (Gross Domestic Product) per capita, also shows the same trend. From 2011 to 2021, Indonesia's GDP per capita growth rate is above 5% on average with GDP per capita per year reaching 56.9 million Rupiah at the end of 2020.

GDP per capita growth is strongly influenced by the development of Micro, Small and Medium Enterprises (MSMEs). Recorded by CNN Indonesia, in 2016 MSMEs contributed 58.5% to GDP growth per capita.

Technology has made production, marketing, distribution and business processes as a whole more efficient and effective. In this context, Philip Kotler 2017 describes a theory of marketing 4.0 or

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Digital Marketing with a new marketing approach to assist marketers in anticipating and managing the impact of technology.

The increasing market demand has made the clothing confectionery business owner PT GM Tactical take the decision to increase the amount of production in order to get maximum profit. However, it is constrained by the limited amount of raw materials and optimization in seeking maximum profit. Therefore, careful calculations are needed to optimize production profits, and determine the right amount of sales with good production results. One of the efforts to get maximum profit is to use Linear Programming in which there is Integer Programming (integer programming).

This study discusses the optimization of production planning on apparel with the aim of obtaining maximum profit with the help of Python software.

This paper is structured as follows: Part 1, explains the motivation for doing this research and discusses previous research on maximizing profits using the Branch and Bound method. Part 2, discusses the theories and models that will be used to solve the problem. Section 3, performs the calculation of the solution and describes the research results obtained. And in section 4, provides conclusions from the results of the research that has been done.

Research related to maximizing profits has previously been studied including by [1] about solving integer linear programming problems using the Branch and Bound method to maximize profits, [2] research on optimizing profits with Integer Linear Programming and the Branch and Bound method at QuinnaStory Flower Shop, and [3] conducted a study to optimize the energy consumption of robotic cells with the Branch and Bound algorithm.

2. Materials and Methods

2.1 Materials

The object of this research is PT. GM Tactical in Cimahi, West Java which covers the total production of apparel. The apparel products used in this study consisted of 3 types of pants, namely chino pants, cargo pants, and jogger pants.

2.2 Methods

2.2.1 Production Planning

Production planning is an activity to fulfill demand by determining the right production strategy and scheduling. Production planning can be done by evaluating past events, then improvements can be made based on mistakes that occurred in the past [1]. Factors in production planning are the nature of the production process, the type and quality of the goods produced, the types of goods, and other things needed to start production. The objectives of production planning [4] are:

1. To achieve a certain level of profit (profit).
2. To dominate certain markets so that the results or outputs of this company still have a certain market share.
3. To ensure that the company can work at a certain level of efficiency.
4. To seek and maintain that existing jobs and employment opportunities remain at their level and develop.
5. To use the best (efficient) facilities that already exist in the company concerned.

While the production planning functions are [5]:

1. Ensure that the sales plan and production plan are consistent with the company's strategic plan.
2. As a means of measuring the performance of the production planning process.
3. Ensure the production capability is consistent with the production plan.
4. Monitor production inventory in order to achieve production targets and strategic plans.
5. Directing the preparation and implementation of the master production schedule.

2.2.2 Optimization

Optimization is a process of achieving the best conditions that provide the minimum or maximum value of a function that is limited by certain conditions [6]. There are many types of quantitative models in classical optimization techniques that can be used, including Linear Programming, Integer Linear Programming, and Binnary Integer Linear Programming. In this research, Linear Programming and Integer Linear Programming optimization models will be used [7].

Linear Programming is an optimization model that is used to find a solution to a problem with the objective function and its constraint function in the form of a linear function of the decision variable [8]. The general characteristics of linear programming problems are as follows:

1. Decision variables to measure the level of activity.
2. The objective function is in the form of a linear function to maximize or minimize.
3. The set of several constraints which are linear equations or inequalities.

The general problem of Linear Programming can be expressed in the following form [6]:

$$\begin{aligned} &\text{max/min} \quad f(x_1, x_2, ..., x_n) = c_1x_1 + c_2x_2 + \cdots + c_nx_n \\ &s.t: \\ &\quad a_{11}x_1 + a_{12}x_2 + \cdots + a_{1n}x_n \geq b_1 \\ &\quad a_{21}x_1 + a_{22}x_2 + \cdots + a_{2n}x_n \geq b_2 \\ &\quad \vdots \qquad\qquad\qquad\quad \vdots \quad\;\; \vdots \\ &\quad a_{m1}x_1 + a_{m2}x_2 + \cdots + a_{mn}x_n \geq b_m \\ &\quad x_1, x_2, x_3, \cdots, x_n \geq 0 \end{aligned} \tag{1}$$

where

c_j : Cost coefficient

b_j : Right-hand side constant

a_{ij} : Element of technology coefficient matrix

x_j : Decision variable

$i = 1, 2, ..., m$

$j = 1, 2, ..., n$

Integer Linear Programming is a Linear Programming model with the decision variable is an integer number. Decision variables which are all integer values are referred to as All Integer Programming and which are only partially integer values are referred to as Mixed Integer Programming [6]. The Integer Linear Programming problem can be modeled as follows [8]:

$$
\begin{aligned}
\text{max/min} \quad & f(x_1, x_2, ..., x_n) = c_1x_1 + c_2x_2 + \cdots + c_nx_n \\
s.t: \quad & \\
& a_{11}x_1 + a_{12}x_2 + \cdots + a_{1n}x_n \geq b_1 \\
& a_{21}x_1 + a_{22}x_2 + \cdots + a_{2n}x_n \geq b_2 \\
& \quad \vdots \qquad\qquad\qquad \vdots \qquad \vdots \\
& a_{m1}x_1 + a_{m2}x_2 + \cdots + a_{mn}x_n \geq b_m \\
& x_1, x_2, x_3, \cdots, x_n \geq 0 \text{ integer}
\end{aligned} \tag{2}
$$

or in matrix form

$$
\begin{aligned}
\text{max/min} \quad & f(\mathbf{x}) = \mathbf{c}^T\mathbf{x} \\
s.t: \quad & \\
& \mathbf{Ax} = \mathbf{b} \\
& \mathbf{x} \geq \mathbf{0} \\
& \mathbf{x} \in \mathbb{Z}
\end{aligned} \tag{3}
$$

2.2.3 Branch and Bound Method

One essential and popular technique for generating precise solutions to NP-hard optimization problems is the branch-and-bound (B&B) framework. The method is initially proposed by [9]. Numerous optimization issues have been successfully solved using the branch-and-bound (B&B) computational framework [10]. The solution process is also described in the outstanding literature by [11], [12], and [13]. [14] gave an early summary of the core B&B method. The B&B method's implicit enumeration property makes it a helpful tool for resolving combinatorial issues like the Permutation Flowshop Problem [15], Supplier Selection Problems with Discounts [16], and the Travelling Salesman Problem [11].

The Branch and Bound method is one of the methods to produce an optimal solution for Linear Programming that produces integer decision variables. This method limits the optimum solution that will produce a fractional number by creating an upper or lower branch for each decision variable that has a fractional value so that it has an integer value so that each restriction will produce a new branch [17].

The basic concept underlying the Branch and Bound method is dividing and eliminating. Since the initial large case was too difficult to resolve directly, the case was divided into smaller subcases until these subcases were resolved. Branching is done by dividing the entire set of feasible solutions into smaller subsets. Partial fathoming is done by bounding how good the best solution is in the subset and then discarding the subset if the boundary indicates that the subset may not contain an optimal solution for the initial case. The stages of completion of the Branch and Bound method are as follows [18]:

Initialization Stage

At the initial stage, the value of $Z^* = -\infty$ is set for the maximizing objective function and $Z^* = \infty$ for the minimization objective function. Perform the stages of branching, limiting, disconnecting and testing for optimality for the existing subproblems. If disconnection is not done then classify the problem for the next subproblem.

Iteration Stage

There are three stages to solving integer programming problems using the Branch and Bound method:

1. Branching Stage
   This stage is carried out if there are still decision variables in the sub-problem that are not yet integer. Select the first variable as the variable to be branched between the constrained variables. For example x_j is the first variable to choose, then x_j^* is the value for this solution. Branch off the subproblems to create two new subproblems by adding the following constraint function:
   $$x_j \le [x_j^*] \tag{4}$$
   and
   $$x_j \ge [x_j^*]+1 \tag{5}$$
   where

   $[x_j^*]$: the largest integer or less than or equal to x.

2. Bounding Stage
   For each subproblem, it is necessary to determine the limit of the best possible solution. A common way to do this is to solve a relaxed subproblem. In most cases, the relaxation of an integer programming problem is to remove the integer value condition of the decision variables so that in solving problems and subproblems the constraints $x_j \in$ □ are eliminated [18].
3. Fathoming Stage
   For each new subproblem, all three fathoming tests are used and ignore the subproblem fathomed by any of the applied tests.
   The three fathoming tests are:
   i. Test 1: If the boundary value of the subproblem is $\le Z^*$, where Z^* is the optimal feasible solution (the best solution obtained). It is denoted by $F(1)$.
   ii. Test 2: If the relaxation of Linear Programming has an infeasible solution. It is denoted by $F(2)$.
   iii. Test 3: If the optimal solution for the relaxation of the Linear Programming problem has an integer value. If this solution is better than the incumbent (previous feasible solution) then this solution will be the new optimal solution and Test 1 is performed again on the subproblem that has not been fathomed with a larger Z^* value. It is denoted by $F(3)$.

Optimality Test
Stop the calculation if there are no more subproblems remaining, where the current incumbent has been optimal, but the iteration is continued if there are other subproblems.

2.2.4 Software Python

Python is a multipurpose interpretive programming language with a design philosophy that focuses on code readability. Python is claimed to be a language that combines capabilities, capabilities, with a very clear code syntax and is equipped with a large and comprehensive standard library functionality [19]. Python is an interpreter programming language, which means the code will be executed directly according to instructions written in a programming or scripting language without converting it into object code such as a compiler [20].

3. Results

3.1 Problem solving

The data used to calculate the maximum profit in apparel production are raw material inventory data, product manufacturing time data, production cost data and production profits as shown in Table 1.

Table 1
Raw Material Inventory Data for Each Type of Garment

No	Raw Material Type	Type of Apparel			Raw Material Inventory
		Chino	Kargo	Jogger	
1	Twill	1,2 yard	-	-	40.000 yard
2	Ripstok	-	1,4 yard	-	60.000 yard
3	Terry	-	-	200g	10.000 g
4	shirt button	1piece	1 piece	-	14.400 piece
5	yarn	200 yard	250 yard	200 yard	120.000 yard
6	Zipper	1piece	1 piece	-	10.000 piece
7	Rubber	-	10 cm	80 cm	10.000 cm

Table 2
Manufacturing Time for Each Clothing Product

No	Product	Time (Hours/Pcs)
1	Chino	3
2	Kargo	2,5
3	Jogger	4,5
Total Working Hours		1.230 hours/month

Table 3
Data on Production Costs, Selling Prices, Profits for Apparel Products

No	Product	Selling Price (IDR/Pcs)	Production Cost (IDR/Pcs)	Profit (IDR/Pcs)
1	Chino	70.000	50.940/Pcs	19.060
2	Kargo	65.000	37.640/Pcs	27.360
3	Jogger	29.000	17.500/Pcs	11.500
Modal				100.000.000

Table 4
Minimum and Maximum Production for Each Apparel Product

i	Product	Minimum Production (pcs/month)	Maximum Production (pcs/month)
1	Chino	80	150
2	Kargo	150	250
3	Jogger	50	50

Table 5
Actual Production Amount of Each Apparel Product

i	Product	Production Quantity (pcs/month)
1	Chino	100
2	Kargo	200
3	Jogger	50

Based on Table 1-5 can be formulated as follows:
Let
x_1 : Number of chino production
x_2 : Number of Kargo production
x_3 : Number of jogger production
Based on model (2), the optimization model for apparel production planning can be written as in equation (3).

$$
\begin{aligned}
\max \quad & Z = 19.060x_1 + 27.360x_2 + 11.500x_3 \\
s.t \quad & 1,2x_1 \le 40.000 \\
& 1,3x_2 \le 60.000 \\
& 200x_3 \le 10.000 \\
& x_1 + x_2 \le 14.400 \\
& 200x_1 + 250x_2 + 200x_3 \le 120.000 \\
& x_1 + x_2 \le 10.000 \\
& 10x_2 + 80x_3 \le 10.000 \\
& 3x_1 + 2,5x_2 + 4,5x_3 \le 1.230 \\
& 50.940x_1 + 37.640x_2 + 17.500x_3 \le 100.000.000 \\
& x_1 \ge 80 \\
& x_2 \ge 150 \\
& x_3 \ge 50 \\
& x_1 \le 150 \\
& x_2 \le 250 \\
& x_3 \le 50 \\
& x_i \ge 0, \forall i = 1,2,3 \\
& x_i \in \mathbb{Z}, \forall i = 1,2,3
\end{aligned} \tag{6}
$$

The optimal solution of equation (6) is as follows:

$$Z = 9.829.267$$
$$x_1 = 126,67;\ x_2 = 250;\ x_3 = 50$$

The optimal solution obtained has not been an integer value, so equation (6) will be solved using the Branch and Bound method. The first stage is the branching stage. Variables that are not yet integers are $x_1 = 126,67$. Two subproblems will be added as new constraints to equation (6) namely $x_1 \le 126$ for subproblem 1 and $x_1 \ge 127$ for subproblem 2.

Iteration 1

Table 6
Subproblem 1 and Subproblem 2

Subproblem 1	Subproblem 2
Equation (6) add constraint	Equation (6) add constraint
$x_1 \le 126$	$x_1 \ge 127$
Solution of Linear Programming :	Solution of Linear Programming:

$Z = 9.816.560;$ $x_1 = 126; x_2 = 250; x_3 = 50$	$Z = 9.824.676;$ $x_1 = 127; x_2 = 249,60; x_3 = 50$

The Z value in subproblem 1 is 9,816,560 and the optimal solution obtained has an integer value, $x_1 = 126; x_2 = 250; x_3 = 50$. Therefore, subproblem 1 is fathomed because it satisfies test 3 at the fathoming stage, so that the obtained solution becomes a new feasible solution.

The branching stage is carried out again in subproblem 2 because the Z value for subproblem 2 is 9,824,676 greater than the Z value for subproblem 1, which is 9,816,560. Choose $x_2 = 249,60$ as the decision variable to branch. Two subproblems to be added as new constraints are $x_2 \le 249$ for subproblem 3 and $x_2 \ge 250$ for subproblem 4.

Iteration 2

Table 7
Subproblem 3 and Subproblem 4

Subproblem 3	Subproblem 4
Equation of subproblem 2 plus constraint $x_2 \le 249$	Equation of subproblem 2 plus constraint $x_2 \ge 250$
Solution of Linear Programming :	Has no feasible solution
$Z = 9.817.790;$ $x_1 = 127,50;\ x_2 = 249; x_3 = 50$	

Subproblem 4 has no feasible solution so that subproblem 4 satisfies test 2 at the fathoming stage and is denoted by $F(2)$.

The solution obtained in subproblem 3 is that there are still decision variables that are not integers so that the branching stage is carried out. Choose $x_1 = 127,50$ as the decision variable to branch. Two subproblems to be added as new constraints are $x_1 \le 127$ for subproblem 5 and $x_1 \ge 128$ for subproblem 6.

Iteration 3

Table 8
Subproblem 5 and Subproblem 6

Subproblem 5	Subproblem 6
Equation of subproblem 3 plus constraint $x_1 \le 127$	Equation of subproblem 3 plus constraint $x_1 \ge 128$
Solution of Linear Programming :	Solution of Linear Programming :
$Z = 9.808.260;$ $x_1 = 127;\ x_2 = 249; x_3 = 50$	$Z = 9.810.904;$ $x_1 = 128;\ x_2 = 248,40; x_3 = 50$

Subproblem 5 and subproblem 6 are fathomed based on test 1 at the fathoming stage due to $Z \leq Z^*$ and denoted by $F(1)$.

3.2 Python Pseudo Codes on Branch and Bound Algorithms

Pulp module installation to solve LP problem

```
!pip install pulp

Import pulp as lp
```

Declaring decision variables and objective functions

```
Sub = lp.LpProblem('sub',lp.LpMaximize)

X = lp.LpVariable.dicts('x',((i) for I range(1,4)) lowerBound=0,
upbound=none)
```

Input all constraints on the model

```
Sub += 1.2*x[1] <= 40000

Sub += 1.3*x[2] <= 60000

Sub += 200*x[3] <= 10000

Sub += x[1]+x[2] <= 14400

Sub += 200*x[1]+250*x[2]+200*x[3] <= 120000

Sub += x[1]+x[2] <= 10000

Sub += 10*x[2]+80*x[3] <= 10000

Sub += 3*x[1]+2.5*x[3]+4.5*x[3] <= 1230

Sub += 50940*x[1]+37640*x[2]+17500*x[3] <= 100000000

Sub += x[1] >= 80

Sub += x[2] >= 150

Sub += x[3] >= 50

Sub += x[1] <= 150

Sub += x[2] <= 250

Sub += x[3] <= 50
```

Solve the Linear problem

```
Sub.solve()

Print(Lp.Status[sub.status], '\n')
```

Show optimal solution

```
For i in range(1,4):

Print("x[{}]: {}". Format(i, x[i].varValue))
```

```
Print("max z = ", Lp.value(sub.objective))
```

3.3 Results of the Analysis of the Application of the Branch and Bound Method

Based on calculations using the Branch and Bound method with the help of Python software, the following equation is obtained.

$$
\begin{aligned}
\max \quad & Z = 19.060x_1 + 27.360x_2 + 11.500x_3 \\
s.t \quad & 1,2x_1 \leq 40.000 \\
& 1,3x_2 \leq 60.000 \\
& 200x_3 \leq 10.000 \\
& x_1 + x_2 \leq 14.400 \\
& 200x_1 + 250x_2 + 200x_3 \leq 120.000 \\
& x_1 + x_2 \leq 10.000 \\
& 10x_2 + 80x_3 \leq 10.000 \\
& 3x_1 + 2,5x_2 + 4,5x_3 \leq 1.230 \\
& 50.940x_1 + 37.640x_2 + 17.500x_3 \leq 100.000.000 \\
& x_1 \geq 80 \\
& x_2 \geq 150 \\
& x_3 \geq 50 \\
& x_1 \leq 150 \\
& x_2 \leq 250 \\
& x_3 \leq 50 \\
& x_i \geq 0, \forall i = 1,2,3 \\
& x_i \in \mathbb{Z}, \forall i = 1,2,3
\end{aligned}
\tag{7}
$$

Table 9
Comparison of Total Production by Companies with Total Production using the Branch and Bound Method

Product	Total production by company	Total production by applying the Branch and Bound method
Chino	100	126
Kargo	200	250
Jogger	50	50
Total Profit	7.953.000	9.816.560

It can be seen in Table 9 that PT. GM Tactical made a profit of Rp. 7,953,000, while in optimal conditions with the Branch and Bound method, the profit was Rp. 9,816,560. There is a profit difference of IDR 1,863,560. Therefore, the application of the Branch and Bound method in determining the amount of apparel production will obtain a greater profit compared to apparel production carried out by business owners in actual conditions.

4. Conclusions

Based on the results of the analysis of production planning at PT. GM Tactical obtained optimization model equation (6). By using the Branch and Bound method, the maximum profit is IDR. 9,816,560, namely that the company can produce 126 units of chino pants, 250 units of cargo pants and 50 units of jogger pants.

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References

[1] Angeline, Angeline, Iryanto Iryanto, and Gim Tarigan. "Penerapan metode branch and bound dalam menentukan jumlah produksi optimum pada cv. Xyz." Saintia Matematika 2, no. 2 (2014): 137-145.

[2] Zuserain, Ayunda, Winarno Winarno, Billy Nugraha, and Ade Momon. "Analisa optimalisasi keuntungan dengan integer linear programming dan metode branch and bound pada toko bunga QuinnaStory." *Journal Industrial Servicess* 6, no. 2 (2021): 99-104. https://doi.org/10.36055/62003

[3] Bukata, Libor, Přemysl Šůcha, and Zdeněk Hanzálek. "Optimizing energy consumption of robotic cells by a Branch & Bound algorithm." *Computers & Operations Research* 102 (2019): 52-66. https://doi.org/10.1016/j.cor.2018.09.012

[4] Assauri, Sofjan. "Manajemen Produksi dan Operasi edisi revisi." *Jakarta: Lembaga Penerbit Fakultas Ekonomi Universitas Indonesia* 299 (2008).

[5] R. Ginting, "Sistem Produksi: Yogyakarta," *Graha ilmu*, 2007.

[6] Rao, Singiresu S. *Engineering optimization: theory and practice*. John Wiley & Sons, 2019. https://doi.org/10.1002/9781119454816

[7] Suwirmayanti, Ni Luh Gede Pivin. "Aplikasi optimasi produksi menggunakan metode simpleks berbasis web." *Techno. Com* 17, no. 1 (2018): 61-69. https://doi.org/10.33633/tc.v17i1.1592

[8] Nico, Iryanto, and Gim Tarigan. "Aplikasi metode cutting plane dalam optimisasi jumlah produksi tahunan pada PT. XYZ." *Saintia Matematika* 2, no. 2 (2014): 127-136.

[9] Land, Ailsa H., and Alison G. Doig. *An automatic method for solving discrete programming problems*. Springer Berlin Heidelberg, 2010.

[10] Morrison, David R., Sheldon H. Jacobson, Jason J. Sauppe, and Edward C. Sewell. "Branch-and-bound algorithms: A survey of recent advances in searching, branching, and pruning." *Discrete Optimization* 19 (2016): 79-102. https://doi.org/10.1016/j.disopt.2016.01.005

[11] Wolsey, Laurence A., and George L. Nemhauser. *Integer and combinatorial optimization*. John Wiley & Sons, 2014.

[12] D. Bertsimas and J. N. Tsitsiklis, *Introduction to linear optimization*, vol. 6. Athena scientific Belmont, MA, 1997.

[13] Papadimitriou, Christos H., and Kenneth Steiglitz. *Combinatorial optimization: algorithms and complexity*. Courier Corporation, 1998.

[14] Lawler, Eugene L., and David E. Wood. "Branch-and-bound methods: A survey." *Operations research* 14, no. 4 (1966): 699-719. https://doi.org/10.1287/opre.14.4.699

[15] Ignall, Edward, and Linus Schrage. "Application of the branch and bound technique to some flow-shop

scheduling problems." *Operations research* 13, no. 3 (1965): 400-412. https://doi.org/10.1287/opre.13.3.400

[16] Goossens, Dries R., A. J. T. Maas, Frits CR Spieksma, and J. J. Van de Klundert. "Exact algorithms for procurement problems under a total quantity discount structure." *European Journal of Operational Research* 178, no. 2 (2007): 603-626. https://doi.org/10.1016/j.ejor.2006.03.010

[17] Pratiwi, Arum, Mulyono Mulyono, and Rochmad Rochmad. "Implementasi Algoritma Branch and Bound pada 0-1 Knapsack Problem untuk Mengoptimalkan Muatan Barang." Unnes Journal of Mathematics 3, no. 2 (2014).

[18] F. S. Hillier and G. J. Lieberman, *Introduction to Operations Research*, vol. 8. New York: McGraw-Hill Higher Education, 2005.

[19] Syahrudin, Akbar Nur, and Tedi Kurniawan. "Input dan output pada bahasa pemrograman python." *Jurnal Dasar Pemograman Python STMIK* 20 (2018): 1-7.

[20] Y. M. Rangkuti, S. I. Al Idrus, and D. D. Tarigan, *Pengantar Pemrograman Python*. Media Sains Indonesia, 2021.