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IMPLEMENTATION OF INTEGER PROGRAMMING USING THE BRANCH AND BOUND METHOD ASSISTED BY PYTHON IN OPTIMIZING THE PRODUCTION OF COOKIES

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ABSTRACT

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Many people are interested in cookies. Due to the high consumer interest in cookies, many companies produce cookies with various variants, one of which is Rizky Bakery. The problem faced by Rizky Bakery is how to determine the amount of production of 6 types of cookies to reach the maximum profit. Rizky Bakery carries out production activities to meet high market demand and standard demand. This study constructs a model that accommodates both conditions. The model is solved by using the Branch and Bound method constraints on materials, manufacturing time, fee labor, payment for resellers, and production targets. The purpose of this research is to determine the total number program model and the optimal solution by maximizing the profit of cookie production using Branch and Bound. Optimization using the Branch and Bound method can utilize the Python programming language with a limit of 50 iterations. Data collection methods used for this research are interviews and documentation. The limitation of the problem in this research is that the model to be studied is limited to the average condition of demand is standard and when demand is high. The results of the analysis at times of high demand showed that the production of nastar cookies, castangel cookies, mawar cookies, putri salju cookies, peanut cookies, and custard cookies in 300-gram packaging respectively are 250, 45, 80, 39, 90, 150 and in 500-gram packages are 40, 10, 10, 6, 45, and 45. While, the result of standard demand in 300-gram packaging respectively are 100, 25, 50, 16, 50, 60 and the 500-gram packaging respectively are 10, 3, 10, 2, 10, 20. The profit earned when the demand is high is IDR 8,769,412.00 and the standard demand is IDR 3,769,504.00.

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1. INTRODUCTION

UMKM (Usaha Mikro Kecil Menengah) are a form of people's economic enterprise that is widely carried out by the community as a driver of the Indonesian economy. Most micro businesses are also carried out in the form of home industries which are widely spread in society [1]. Home industry activities are currently entrepreneurial activities that are in great demand among housewives. Some of the reasons are, starting from not requiring a large amount of capital, implementing hobbies, and being able to increase income to help the family economy [2].

Rizky Bakery is one of the culinary home industries in Ngawi Regency. Cookies production at Rizky Bakery consists of six types of products, namely nastar cookies, castangel cookies, mawar cookies, putri salju cookies, peanut cookies, and custard cookies. Each type of product is packaged in 300-grams and 500-grams. This business carries out production activities to meet high market demand and standard demand. This study builds a model that accommodates both conditions. Rizky Bakery still uses manual calculations or just estimates in calculating profits. Lage of management and planning of production quantities that are not optimal have an impact on the profits obtained being not optimal and difficult to predict [3]. Therefore, for the company to obtain maximum profits, a plan is needed to determine the optimal production amount. In business and economics, many applications involve a process called optimization to determine the maximum or minimum value of a certain quantity by taking into account several existing constraints [4]. Optimization is an approach that aims to obtain maximum or minimum results from the problem [5].

The problem of optimizing profits from cookies production at Rizky Bakery is modeled in integer programming. Integer programming is a case of linear programming where all the variables are whole numbers [6]. Integer programming can also be interpreted as a mathematical model that allows the results of solving cases in linear programs in the form of integers [7]. In fact, in the business world, there is often a provision that the value of a certain decision variable must be an integer and cannot be a fraction [8]. The method used to complete the whole number program is the Branch and Bound method. The Branch and Bound method is a method that is often used to produce optimal solutions for linear programs that produce integer decision variables [9]. As the name suggests, this method limits the optimal solution that will produce fractional numbers by creating upper and lower branches 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 [10].

With technological developments continuing to advance, data processing has become sophisticated and rapid, computerization is an appropriate alternative that someone needs to process data from information to help complete their tasks [11]. One programming language that can be used to help solve this research problem is Python. Python as a higher-level programming language is a language of general purpose, object-oriented, with dynamic structure and a large number of libraries. Python is used to call libraries that function as an interface between the user and the solver used. The Python library used in this research is PuLP. PuLP (Python Linear Programming) is a Linear Programming modeler and free open source software written in Python [12][13]. Google Interactive Notebook is required to run Python. Google Interactive Notebook or commonly called Google Colab is an Integrated Development Environment (IDE) created by Google for Python programming. Google Colab can be accessed via its official website www.colab.research.google.com for free [14].

The problem of optimizing profits from cookies production at Rizky Bakery can be used as a supporting topic for integer programming teaching materials in the form of e-monographs. A monograph is a scientific writing in the form of a book about a specific subfield of science within a field of science of the author's competence [15][16]. Based on the description of the problem, this research is entitled "Implementation of Integer Programming Using Python to Optimize Profits of Rizky Bakery Cookies".

2. RESEARCH METHODS

The type of research used in this research is applied research using a quantitative approach. The data in this study are primary data and secondary data. Primary data was collected by the researchers themselves directly from the results of interviews with business owners. Secondary data was obtained through literature and literature studies. The data collection stage in this study was obtained from interviews and documentation. The steps that need to be taken to achieve the research objectives can be seen in **Figure 1**.

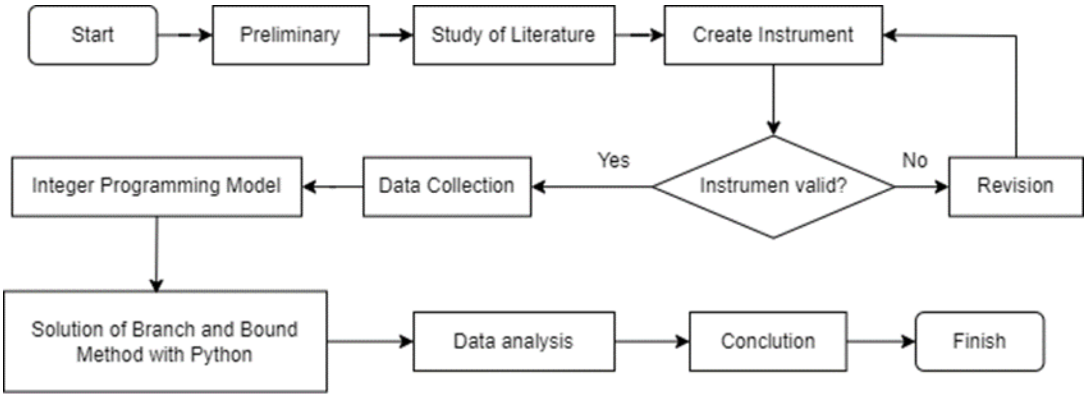

Figure 1. Research Procedure

Based on **Figure 1**, The preliminary stage of this research was carried out by determining the research area and asking for approval from the company. Literature study is a stage of searching for information obtained through books, journals, or other written sources related to whole number programs in production optimization. The instrument creation in this research consisted of an interview guide and an E-monograph validation instrument. Then a validation test of the instrument is carried out, if it is declared feasible, it continues to the next stage. The data collection stage in this research was obtained from joint interviews with company owners. At the whole number program model stage, the data that has been obtained is converted into mathematical form to determine the objective function and constraint function. The Branch and Bound method solution is used to determine the results of Rizky Bakery's production profit problem during high demand and standard demand with the help of Python. The data analysis stage in this research aims to obtain an optimal solution to the problem of optimizing profits for cookies production using a whole number program assisted by Python. Finally, conclude from the results of the data analysis carried out to answer the formulation of this research problem.

3. RESULTS AND DISCUSSION

The following is the Branch and Bound method for optimizing profits from cookies production at Rizky Bakery.

3.1 Integer Programming Model

3.1.1 Decision Variable

The following are decision variables for optimizing profits from cookies production at Rizky Bakery.

x_1 = number of nastar cookies packaged in 300 − grams
x_2 = number of castangel cookies packaged in 300 − grams
x_3 = number of mawar cookies packaged in 300 − grams
x_4 = number of putri salju cookies packaged in 300 − grams
x_5 = number of peanut cookies packaged in 300 − grams
x_6 = number of custard cookies packaged in 300 − grams
x_7 = number of nastar cookies packaged in 500 − grams
x_8 = number of castangel cookies packaged in 500 − grams
x_9 = number of mawar cookies packaged in 500 − grams
x_{10} = number of putri salju cookies packaged in 500 − grams
x_{11} = number of peanut cookies packaged in 500 − grams
x_{12} = number of custard cookies packaged in 500 − grams

3.1.2 Objective Function

The goal to be achieved is to maximize profits from sales of cookies by maximizing the production of each type of cookies. The profit on cookies is obtained from the selling price minus production costs (the price of raw materials used, packaging costs, payment for reseller, and fee labor). The profit of nastar cookies, castangel cookies, mawar cookies, putri salju cookies, peanut cookies, and custard cookies in 300-gram packaging respectively are IDR 10,220; IDR 9,286; IDR 9,994; IDR 9,762; IDR 8,708; and IDR 9,336 while in 500-gram packages are IDR 16,848; IDR 15,118; IDR 16,490; IDR 16,114; IDR 14,506; and IDR 15,394. Then, the objective function of each type of cookies is as follows.

$$Z = 10220x_1 + 9286x_2 + 9994x_3 + 9762x_4 + 8708x_5 + 9336x_6 + 16848x_7$$
$$+15118x_8 + 16490x_9 + 16114x_{10} + 14506x_{11} + 15394x_{12}$$

3.1.3 Constraint Function

The constraint functions that will be used in this research are the materials (raw materials and LPG) used, the time to make each type of cookies, fee labor, payment for reseller, and production targets. Limitations on the use of materials, the products produced must not exceed the available materials. Details of the materials for production of each type of cookies can be seen in **Table 1**.

Table 1. Material

Material	x_1	x_2	x_3	x_4	x_5	x_6	x_7	x_8	x_9	x_{10}	x_{11}	x_{12}	Quantity Availability (High Demand)	Quantity Availability (Standard Demand)
Flour	200	135	200	75	200	200	350	225	350	125	350	350	175,000	75,000
Egg Yolk	24	24	24	12	0	24	40	40	40	20	0	40	24,000	9,600
Butter	50	50	100	100	0	100	80	80	175	175	0	175	75,000	30,000
Icing sugar	75	0	75	50	100	50	125	0	125	75	175	75	65,000	30,000
Skim Milk	20	3	20	10	0	0	35	5	35	15	0	0	10,000	5,000
Maizena	10	0	10	20	0	0	15	0	15	35	0	0	10,000	3,000
Rum	50	50	50	0	0	0	80	80	80	0	0	0	25,000	15,000
Pineapple Jam	100	0	50	0	0	0	175	0	80	0	0	0	40,000	18,000
Cheese	0	30	0	0	0	0	0	50	0	0	0	0	3,000	1,000
Peanut	0	0	0	75	100	0	0	0	0	125	175	0	25,000	9,000
Cheese Sugar	0	0	0	100	0	0	0	0	0	175	0	0	5,000	2,000
Chopped Nuts	0	0	0	0	0	20	0	0	0	0	0	35	5,000	2,000
Cooking Oil	0	0	0	0	100	0	0	0	0	0	175	0	20,000	8,000
Chocolate	0	0	0	0	0	25	0	0	0	0	0	40	10,000	4,000
Custard Flour	0	0	0	0	0	10	0	0	0	0	0	15	5,000	1,000
LPG	120	120	75	120	120	75	200	200	125	200	200	125	12,0000	48,000

The cookie production process at Rizky Bakery is carried out 7 hours a day. The time available for one production during times of high demand is 14400 minutes. Meanwhile, during standard demand, it is 5280 minutes. Based on the accumulated calculations of the time used to make nastar cookies, castangel cookies, mawar cookies, putri salju cookies, peanut cookies, custard cookies in one 300-gram package, respectively are 18, 12, 12, 12, 12, and 12 minutes. Meanwhile, for each cookie with a 500-gram package respectively are 30, 20, 20, 20, 20, and 20 minutes as shown in **Table 1**.

There are 6 workers at Rizky Bakery consisting of 4 baker and 2 packaging workers. The fee received by workers is IDR 50,000 per day. Meanwhile, the daily target for the production of cookies is 50 pieces. Based on the calculations that have been done, the fee received by workers is IDR 6,000 per package. The owner of Rizky Bakery provides workers with fee of IDR 5,000,000 for high demand and IDR 2,500,000 for standard demand. The profit that resellers get for each type of Rizky Bakery cookie is IDR 2,000 for a 300-gram package and IDR 5,000 for a 500-gram package. The owner of Rizky Bakery provides payment for resellers of IDR 2,500,000 during high demand and IDR 1,000,000 during standard demand.

Cookies that are produced at least reach the expected target during times of high demand and standard demand. The production targets for nastar cookies, chestnut cookies, mawar cookies, putri salju cookies, peanut cookies, and custard cookies in 300-gram packages at times of high demand are respectively 250, 20, 80, 30, 90, and 150. As for the cookies production target in 500-gram packages respectively are 40, 10, 10, 5, 45, and 45. Meanwhile, for each cookie production target with 300-gram packages at times of standard demand respectively are 100, 10, 50, 10, 50, and 60. The production targets for packaging 500-grams respectively are 10, 2, 10, 2, 10, and 20.

Table 2. Constraint Function of High Demand

No.	Constraint	Inequality
1.	Flour	$200x_1 + 135x_2 + 200x_3 + 75x_4 + 200x_5 + 200x_6 + 350x_7 + 225x_8 + 350x_9 + 125x_{10} + 350x_{11} + 350x_{12} \leq 175000$
2.	Egg Yolk	$24x_1 + 24x_2 + 24x_3 + 12x_4 + 24x_6 + 40x_7 + 40x_8 + 40x_9 + 10x_{10} + 40x_{12} \leq 24000$
3.	Butter	$50x_1 + 50x_2 + 100x_3 + 100x_4 + 100x_6 + 80x_7 + 80x_8 + 175x_9 + 175x_{10} + 175x_{12} \leq 75000$
4.	Icing sugar	$75x_1 + 75x_3 + 50x_4 + 100x_5 + 50x_6 + 125x_7 + 175x_9 + 75x_{10} + 175x_{11} + 75x_{12} \leq 65000$
5.	Skim Milk	$20x_1 + 3x_2 + 20x_3 + 10x_4 + 35x_7 + 5x_8 + 35x_9 + 15x_{10} \leq 10000$
6.	Maizena	$10x_1 + 10x_3 + 20x_4 + 15x_7 + 15x_9 + 35x_{10} \leq 10000$
7.	Rum	$50x_1 + 50x_2 + 50x_3 + 80x_7 + 80x_8 + 80x_9 \leq 25000$
8.	Pineapple Jam	$100x_1 + 50x_3 + 175x_7 + 80x_9 \leq 40000$
9.	Cheese	$30x_2 + 50x_8 \leq 3000$
10.	Peanut	$75x_4 + 100x_5 + 125x_{10} + 175x_{11} \leq 25000$
11.	Cheese Sugar	$100x_4 + 175x_{10} \leq 5000$
12.	Chopped Nuts	$20x_6 + 35x_{12} \leq 5000$
13.	Cooking Oil	$100x_5 + 175x_{11} \leq 20000$
14.	Chocolate	$25x_6 + 40x_{12} \leq 10000$
15.	Custard Flour	$10x_6 + 15x_{12} \leq 5000$
16.	LPG	$120x_1 + 120x_2 + 75x_3 + 120x_4 + 120x_5 + 75x_6 + 200x_7 + 200x_8 + 125x_9 + 200x_{10} + 200x_{11} + 125x_{12} \leq 120000$
17	The time to make	$18x_1 + 12x_2 + 12x_3 + 12x_4 + 12x_5 + 12x_6 + 30x_7 + 20x_8 + 20x_9 + 20x_{10} + 20x_{11} + 20x_{12} \leq 35280$
18.	Payment for reseller	$2000x_1 + 2000x_2 + 2000x_3 + 2000x_4 + 2000x_5 + 2000x_6 + 5000x_7 + 5000x_8 + 5000x_9 + 5000x_{10} + 5000x_{11} + 5000x_{12} \leq 2500000$
19.	Fee labor	$6000x_1 + 6000x_2 + 6000x_3 + 6000x_4 + 6000x_5 + 6000x_6 + 6000x_7 + 6000x_8 + 6000x_9 + 6000x_{10} + 6000x_{11} + 6000x_{12} \leq 5000000$
20.	Target x_i	$x_1 \geq 250; x_2 \geq 20; x_3 \geq 80; x_4 \geq 30; x_5 \geq 90; x_6 \geq 150; x_7 \geq 40; x_8 \geq 10; x_9 \geq 10; x_{10} \geq 5; x_{11} \geq 45; x_{12} \geq 45$

Table 3. Constraint Function of Standard Demand

No.	Constraint	Inequality
1.	Flour	$200x_1 + 135x_2 + 200x_3 + 75x_4 + 200x_5 + 200x_6 + 350x_7 + 225x_8 + 350x_9 + 125x_{10} + 350x_{11} + 350x_{12} \leq 75000$
2.	Egg Yolk	$24x_1 + 24x_2 + 24x_3 + 12x_4 + 24x_6 + 40x_7 + 40x_8 + 40x_9 + 10x_{10} + 40x_{12} \leq 9600$
3.	Butter	$50x_1 + 50x_2 + 100x_3 + 100x_4 + 100x_6 + 80x_7 + 80x_8 + 175x_9 + 175x_{10} + 175x_{12} \leq 30000$
4.	Icing sugar	$75x_1 + 75x_3 + 50x_4 + 100x_5 + 50x_6 + 125x_7 + 175x_9 + 75x_{10} + 175x_{11} + 75x_{12} \leq 30000$
5.	Skim Milk	$20x_1 + 3x_2 + 20x_3 + 10x_4 + 35x_7 + 5x_8 + 35x_9 + 15x_{10} \leq 5000$
6.	Maizena	$10x_1 + 10x_3 + 20x_4 + 15x_7 + 15x_9 + 35x_{10} \leq 3000$
7.	Rum	$50x_1 + 50x_2 + 50x_3 + 80x_7 + 80x_8 + 80x_9 \leq 15000$
8.	Pineapple Jam	$100x_1 + 50x_3 + 175x_7 + 80x_9 \leq 18000$
9.	Cheese	$30x_2 + 50x_8 \leq 1000$
10.	Peanut	$75x_4 + 100x_5 + 125x_{10} + 175x_{11} \leq 9000$
11.	Cheese Sugar	$100x_4 + 175x_{10} \leq 2000$
12.	Chopped Nuts	$20x_6 + 35x_{12} \leq 2000$
13.	Cooking Oil	$100x_5 + 175x_{11} \leq 8000$
14.	Chocolate	$25x_6 + 40x_{12} \leq 4000$
15.	Custard Flour	$10x_6 + 15x_{12} \leq 1000$
16.	LPG	$120x_1 + 120x_2 + 75x_3 + 120x_4 + 120x_5 + 75x_6 + 200x_7 + 200x_8 + 125x_9 + 200x_{10}$

No.	Constraint	Inequality
		$+200x_{11} + 125x_{12} \leq 48000$
17	The time to make	$18x_1 + 12x_2 + 12x_3 + 12x_4 + 12x_5 + 12x_6 + 30x_7 + 20x_8 + 20x_9 + 20x_{10} + 20x_{11} + 20x_{12} \leq 12600$
18.	Payment for reseller	$2000x_1 + 2000x_2 + 2000x_3 + 2000x_4 + 2000x_5 + 2000x_6 + 5000x_7 + 5000x_8 + 5000x_9 + 5000x_{10} + 5000x_{11} + 5000x_{12} \leq 1000000$
19.	Fee labor	$6000x_1 + 6000x_2 + 6000x_3 + 6000x_4 + 6000x_5 + 6000x_6 + 6000x_7 + 6000x_8 + 6000x_9 + 6000x_{10} + 6000x_{11} + 6000x_{12} \leq 2500000$
20.	Target x_i	$x_1 \geq 100; x_2 \geq 10; x_3 \geq 50; x_4 \geq 10; x_5 \geq 50; x_6 \geq 60; x_7 \geq 10; x_8 \geq 2; x_9 \geq 10; x_{10} \geq 2; x_{11} \geq 10; x_{12} \geq 20$

Table 2 shows the High Demand Constraint Function to maximize the production of each type of cookies with limitations on the use of available materials. The constraint functions that used in this research are the materials (raw materials and LPG) used, the time to make each type of cookies, labor costs, reseller payments, and production targets. Meanwhile, **Table 3** shows the Constraint Function for Standard Demand with the same objective but different quantities of available materials.

3.2 Completion of Integer Programming with The Branch and Bound Method

The Branch and Bound method was first discovered in 1960 by A.H. Land and A.G. Doig. The Branch and Bound method is a method for finding optimal solutions for linear programming where the decision variables are integers. The basic concept of the Branch and Bound method is to divide problems that are too difficult to solve directly into sub-problems that get smaller until they can be solved. Many computer programs can help solve Branch and Bound method problems such as QM for Windows, LINGO, and LINDO. In this research, the Branch and Bound method solution will be searched using Python.

Google Colab is used to run Python. The steps for completing integer programming optimization using Python are as follows.

1. Open Google Colab website in https://colab.google/.

2. The integer programming model in the previous discussion was brought into Google Colab as in the following image.

Figure 2. Call The PuLP Library on Google Colab

To start the program in Python as in **Figure 2**, first import the PuLP modeler function to use in the "PuLP import" code. The "test" variable is created using the "LpProblem" function. It has two parameters, the first is an arbitrary name of the problem and the second parameter is "LpMaximize" because it has to maximize the objective function Z. Now create a problem variable X using the "LpVariable" class. It has four parameters, the first is the name of an arbitrary variable, the second is the lower bound of this variable, and the third is the data type.

```
test += 10220*X1 + 9286*X2 + 9994*X3 + 9762*X4 + 8708*X5 + 9336*X6 + 16848*X7 + 15118*X8 + 16490*X9 + 16114*X10 + 14506*X11 + 15394*X12, "Keuntungan"
test += 200*X1 + 135*X2 + 200*X3 + 75*X4 + 200*X5 + 200*X6 + 350*X7 + 225*X8 + 350*X9 + 125*X10 + 350*X11 + 350*X12 <= 175000
test += 24*X1 + 24*X2 + 24*X3 + 12*X4 + 24*X6 + 40*X7 + 40*X8 + 40*X9 + 10*X10 + 40*X12 <= 24000
test += 50*X1 + 50*X2 + 100*X3 + 100*X4 + 100*X6 + 80*X7 + 80*X8 + 175*X9 + 175*X10 + 175*X12 <= 75000
test += 75*X1 + 75*X3 + 50*X4 + 100*X5 + 50*X6 + 125*X7 + 175*X9 + 80*X10 + 175*X11 + 80*X12 <= 65000
test += 20*X1 + 3*X2 + 20*X3 + 10*X4 + 35*X7 + 5*X8 + 35*X9 + 15*X10 <= 10000
test += 10*X1 + 10*X3 + 20*X4 + 15*X7 + 15*X9 + 35*X10 <= 10000
test += 50*X1 + 50*X2 + 50*X3 + 80*X7 + 80*X8 + 80*X9 <= 25000
test += 100*X1 + 50*X3 + 175*X7 + 80*X9 <= 40000
test += 30*X2 + 50*X8 <=3000
test += 75*X4 + 100*X5 + 125*X10 + 175*X11 <= 25000
test += 100*X4 + 175*X10 <= 5000
test += 20*X6 + 35*X12 <= 5000
test += 100*X5 + 175*X10 <= 20000
test += 25*X6 + 40*X12 <= 10000
test += 10*X6 + 15*X12 <= 5000
test += 120*X1 + 120*X2 + 75*X3 + 120*X4 + 120*X5 + 75*X6 + 200*X7 + 200*X8 + 125*X9 + 200*X10 + 200*X11 + 125*X12 <= 120000
test += 18*X1 + 12*X2 + 12*X3 + 12*X4 + 12*X5 + 12*X6 + 30*X7 + 20*X8 + 20*X9 + 20*X10 + 20*X11 + 20*X12 <= 35280
test += 2000*X1 + 2000*X2 + 2000*X3 + 2000*X4 + 2000*X5 + 2000*X6 + 5000*X7 + 5000*X8 + 5000*X9 + 5000*X10 + 5000*X11 + 5000*X12 <= 2500000
test += 6000*X1 + 6000*X2 + 6000*X3 + 6000*X4 + 6000*X5 + 6000*X6 + 6000*X7 + 6000*X8 + 6000*X9 + 6000*X10 + 6000*X11 + 6000*X12 <= 5000000
test += 1*X1 >= 250
test += 1*X2 >= 20
test += 1*X3 >= 80
test += 1*X4 >= 30
test += 1*X5 >= 90
```

Figure 3. Constructs Mathematical Models on Google Colab

In **Figure 3**, write the program code "+=" for the constraint function of the whole number program model that has been created. There are 31 constraint functions in times of high demand and standard demand.

```
test += 1*X5 >= 90
test += 1*X6 >= 150
test += 1*X7 >= 40
test += 1*X8 >= 10
test += 1*X9 >= 10
test += 1*X10 >= 5
test += 1*X11 >= 45
test += 1*X12 >= 45
```

```
[ ] test.solve()
    LpStatus[test.status]

    'Optimal'
```

```
[ ] print ("Nilai X1 = ",X1.varValue)
    print ("Nilai X2 = ",X2.varValue)
    print ("Nilai X3 = ",X3.varValue)
    print ("Nilai X4 = ",X4.varValue)
    print ("Nilai X5 = ",X5.varValue)
    print ("Nilai X6 = ",X6.varValue)
    print ("Nilai X7 = ",X7.varValue)
    print ("Nilai X8 = ",X8.varValue)
```

Figure 4. Completion of Mathematical Models on Google Colab

Now, a test is carried out to determine the solution status of the whole number program model by writing the program code "test.solve()"as shown in **Figure 4**. The result of the solver call can be "Not Solved", "Infeasible", "Unbounded", "Undefined", or "Optimal". Next, if the result is optimal then proceed with writing the "print ()" program code to produce the optimal solution.

3. After entering the mathematical model, click run on each cell, an optimal solution will be generated in optimizing the production of cookies as shown in **Figure 5Figure 5**.

```
Nilai X1 =  250.0
Nilai X2 =  44.675926
Nilai X3 =  80.0
Nilai X4 =  41.25
Nilai X5 =  90.0
Nilai X6 =  150.0
Nilai X7 =  40.0
Nilai X8 =  10.0
Nilai X9 =  10.0
Nilai X10 =  5.0
Nilai X11 =  45.0
Nilai X12 =  45.0
Keuntungan maksimal =  8772253.148836
```

(a)

```
Nilai X1 =  100.0
Nilai X2 =  26.388889
Nilai X3 =  50.0
Nilai X4 =  16.5
Nilai X5 =  50.0
Nilai X6 =  60.0
Nilai X7 =  10.0
Nilai X8 =  2.0
Nilai X9 =  10.0
Nilai X10 =  2.0
Nilai X11 =  10.0
Nilai X12 =  20.0
Keuntungan maksimal =  3772164.223254
```

(b)

Figure 5. Mathematical Model Solution (a) High Demand, (b) Standard Demand

By running the program **Figure 6**, maximum net profit results can be obtained from the whole number program model during times of high demand and standard demand. It will display the optimized objective function "Z" along with the values of each "X" variable.

4. Perform the previous steps until you get the optimal solution.

3.2.1 High Demand

The results of calculating integer programming using the Branch and Bound method when high demand is limited to 50 iterations can be seen in **Table 4**. Based on the calculation results it is known that there are two optimal solutions for high demand, namely at iteration 39 and 49.

Table 4. High Demand Mathematical Model Calculation Results

Iteration	Level	Additional Constraints	Z	x_1	x_2	x_3	x_4	x_5	x_6	x_7	x_8	x_9	x_{10}	x_{11}	x_{12}
1	0		8,772,253.15	250	44.68	80	41.25	90	150	40	10	10	5	45	45
2	1	$x2 \leq 44$	8,772,107.70	250	44	80	41.25	90	150	40	10.41	10	5	45	45
3	2	$x4 \leq 41$	8,772,029.18	250	44	80	41	90	150	40	10.41	10	5.14	45	45
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
39	6	$x1 \geq 251$	8,753,756	251	45	80	38	90	150	40	10	10	5	45	45
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
49	3	$x10 \geq 6$	8,769,412	250	45	80	39	90	150	40	10	10	6	45	45
50	2	$x4 \geq 41$	Infeasible												

3.2.2 Standard Demand

The results of integer programming calculations using the Branch and Bound method when standard demand are limited to 50 iterations can be seen in **Table 5**. Based on the results of these calculations, it is known that there is one optimal solution for standard demand, namely at iteration 27.

Table 5. Standard Demand Mathematical Model Calculation Results

Iteration	Level	Additional Constraints	Z	x_1	x_2	x_3	x_4	x_5	x_6	x_7	x_8	x_9	x_{10}	x_{11}	x_{12}
1	0		3,772,164.22	100	26.39	50	16.5	50	60	10	2	10	2	10	20
2	1	$x2 \leq 26$	3,772,080.53	100	26	50	16,5	50	60	10	2.23	10	2	10	20
3	2	$x4 \leq 16$	3,771,923.52	100	26	50	16	50	60	10	2.24	10	2.29	10	20
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
27	4	$x2 \geq 25$	3,769,504	100	25	50	16	50	60	10	3	10	2	10	20
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
50	2	Infeasible													

Based on **Table 6**, The calculation, the optimal value is obtained when the demand is high and the demand is normal for the number of cookies produced and the benefits can be seen in **Table 6**.

Table 6. Optimal Solution of Branch and Bound Methods

x_i	High Demand		Standard Demand	
	Company	Research	Company	Research
x_1	250	250	100	100
x_2	20	45	10	25
x_3	80	80	50	50
x_4	30	39	10	16
x_5	90	90	50	50

x_i	High Demand		Standard Demand	
	Company	Research	Company	Research
x_6	150	150	60	60
x_7	40	40	10	10
x_8	10	10	2	3
x_9	10	10	10	10
x_{10}	5	6	2	2
x_{11}	45	45	10	10
x_{12}	45	45	20	20
Profit	IDR 8,433,290.00	IDR 8,769,412.00	IDR 3,556,524.00	IDR 3,769,504.00

Based on Table 6. The profit obtained at a time of high demand based on the company's production target was IDR 8,433,290.00, after calculating the whole number program using the help of Python the profit obtained was IDR 8,769,412.00. The profit obtained during normal demand based on the company's production target is IDR 3,556,524.00, after carrying out whole number program calculations using Python, the profit obtained is IDR 3,769,504.00.

4. CONCLUSIONS

Based on the results and discussion it can be concluded that:

1. The mathematical model for optimizing the profits of cookies at Rizky Bakery is an objective function in the form of production profits with 12 decision variables and a constraint function in the form of 15 raw materials, 1 LPG usage, 1 manufacturing time, 1 reseller fee, 1 labor wage, and 12 production targets. The whole number program model is solved using the Branch and Bound method with 50 iterations.
2. The solution to the whole number program problem carried out using Python at times of high demand shows a maximum of $Z = 8769412$ with $x_1 = 250$ packages, $x_2 = 45$ packages, $x_3 = 80$ packages, $x_4 = 39$ packages, $x_5 = 90$ packages, $x_6 = 150$ packages, $x_7 = 40$ packages, $x_8 = 10$ packages, $x_9 = 10$ packages, $x_{10} = 6$ packages, $x_{11} = 45$ packages, dan $x_{12} = 45$ packages.
3. The solution to the whole number program problem carried out using Python when a normal request shows a maximum of $Z = 3769504$ with $x_1 = 100$ packages, $x_2 = 25$ packages, $x_3 = 50$ packages, $x_4 = 16$ packages, $x_5 = 50$ packages, $x_6 = 60$ packages, $x_7 = 10$ packages, $x_8 = 3$ packages, $x_9 = 10$ packages, $x_{10} = 2$ packages, $x_{11} = 10$ packages, and $x_{12} = 20$ packages.
4. There is an increase in profit in one production of IDR 336,122.00 for high demand and IDR 212,980.00 for standard demand.

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