

Implementation of Preemptive Goal Programming and Branch and Bound in Production Planning at the Istiqomah Tofu Factory, Bandar Lampung City

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ARTICLE INFO	ABSTRACT
Article History Received : 04-09-2023 Revised : 11-10-2023 Accepted : 13-10-2023 Keyword Linear Programming; Simplex Method; Preemptive Goal Programming; Branch and Bound; DOI: ...	In a production process, it is necessary to carry out a production planning so that the company gets the maximum profit at the minimum cost. Each place of production has several goals to be achieved, these goals do not always have the same level of importance. There are several goals that have varying degrees of importance. This problem can be solved by using the preemptive goal and continuing with the branch and bond method to get integer results. The results of the study show that, to achieve all the desired goals/objectives by using this method, the factory experienced an increase in profits of 13,43%.

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1. INTRODUCTION

In the era of free markets that are increasingly full of fierce competition, companies need to improve the effectiveness and efficiency of production processes to be able to survive with existing competition. This situation brings the business world to modern thinking in accompanying the level of competition that always increases from year to year. Therefore, the available production results are reevaluated by optimizing production planning with the aim of minimizing costs incurred so that profits can be greater. Every emerging industry needs experts to assist and nurture its industry in overcoming emerging problems.

Industry plays an important role in the development of the Indonesian economy. One industry that is very numerous and widespread in Indonesia is tofu factories. Based on data from BPS Bandar Lampung City in 2016, most of the economic development of Bandar Lampung City is supported by the Processing Industry sector. The processing industry that is growing a lot in Bandar Lampung City is a tofu factory. Tofu is a source of nutrition that is affordable for all levels of society. In addition, processed soybean-based foods are also very popular with the wider community. Tofu has a high nutritional content. The calcium contained in tofu is equivalent to the calcium content of milk, which is as much as 124 mg. This type of food is also a source of high-quality protein and can lower cholesterol levels in the blood and cure diarrhea, as researched by Faruk (2021).

Based on data obtained from the Primer Cooperative of Indonesian Tempeh Tofu Producers (PRIMKOPTI) in 2016 there were 238 tofu craftsmen in Bandar Lampung City and the Istiqomah tofu factory is one of the *home industries* that produces white tofu, yellow tofu and Chinese tofu in Bandar Lampung City. Each production site certainly has goals to be achieved in order to get maximum profit by spending the minimum possible costs. The Istiqomah tofu factory has various goals or targets to be achieved and each of these targets has a priority level. However, the problem that occurs is the difficulty of meeting all these targets as a whole with the availability of existing raw materials and production costs to a minimum. This is because there is no production planning that can meet all these aspects. Therefore, it is necessary to carry out production planning so that the desired goals (targets) can be achieved.

The determination of production planning can be overcome using the preemptive goal programming method. The preemptive goal programming method is a derivative of the goal programming method. This method is often called the priority method that can set the priority of each goal to be achieved. These goals are sorted by how important they are to other goals. So that the goal solution that has a higher priority is obtained first and then will continue to find the next goal solution that has a lower priority than the previous goal. In the preemptive goal programming method to express deviations from the model formulation, a deviation variable is needed to express the achievement of the goal. Negative deviation variable (d_q^-) is the deviation value below the target and the positive deviation variable (d_q^+) is the deviation value above the target (Gusnita, 2011). Research on preemptive goal programming has been conducted by Hasbiyati, Desri, and Gamal, (2023) with the title "pre-emptive Goal Programming Method for Optimizing Production Planning". In the study, researchers conducted production planning at a bakery that had several goals to be achieved.

In preemptive goal programming, solutions are often produced that are not integers. But in the case of tofu production planning at the Istiqomah Tofu Factory, the expected solution is an integer. One method that can be used to produce an integer solution in solving this problem is the branch and bound method (Nasution, Trihastuti, & Irwan, 2023).

2. METHODS

Optimization is a process to find optimal solutions (maximum or minimum) by paying attention to existing constraints. The concept of optimization can be used in solving production problems. Production planning is an activity carried out to determine what products will be produced and how much of the product is produced.

2.1. Linear Programming

Linear programming is a method used in making decisions to allocate limited resources so that the desired goals are achieved. Linear programs were first discovered and introduced by George B. Danzing in 1947 in the form of methods to obtain optimal results with many decision variables and using only one goal function (Abdillah, 2013). The general form of linear programming is as follows.

Maximize or minimize:

$$Z = \sum_{j=1}^n c_j x_j \quad (1)$$

Subject to:

$$\begin{aligned} \sum_{j=1}^n a_{ij} x_j (\leq, =, \geq) b_i & \quad \forall i = 1, 2, \dots, m \\ & \quad \forall j = 1, 2, \dots, n \\ x_j & \geq 0 \end{aligned} \quad (2)$$

Information:

There are as many n decision variables as possible

There are as many m linear constraints as possible m

Z : objective function

c_j : coefficients of the decision variable j th on the objective function

x_j : Decision variables j th

a_{ij} : coefficients of the decision variable j th on constraints i th
 b_i : value of the right-hand value constraint i th

2.2.Goal Programming

Goal programming is a modification of linear programming that has many goals or goals. Goal programming was introduced by Charnes and Cooper (1961). Various goals are not always achieved simultaneously because there can be deviations or deviations from the goals to be achieved. In the formulation of goal programming, the solution sought is to minimize deviations from each goal. The purpose of goal programming is to approach the planned targets as close as possible and if there is a deviation, then the deviation is as minimal as possible Darmawan (2013).

To express deviations from the model formulation, a deviation variable is needed to express the level of goal achievement, namely a negative deviation variable (d_q^-) in the form of deviation values below the target and positive deviation variables (d_q^+) in the form of deviation values above the target. In the formulation of the goal programming model, each goal is converted into a form of constraints called goal constraints. This goal constraint is written in the decision variable and also deviation, but in the objective function, the decision variable is not shown.

According to Charnes & Cooper (1977), the general form of goal programming can be expressed as follows:

Objective function:

$$\text{Min } Z = \sum_{q=1}^m d_q^+ + d_q^- \quad (3)$$

Goal constraints:

$$\sum_{j=1}^n a_{qj}x_j + d_q^- - d_q^+ = b_q, \quad \forall q = 1, 2, \dots, m \\ \forall j = 1, 2, \dots, n \quad (4)$$

Non negative constraints:

$$x_j, d_q^-, d_q^+ \geq 0 \quad (5)$$

Information:

There are as many decision n variables as possible

There are as many m goal constraints

Z : objective function

a_{qj} : coefficient of decision variable j th on goal constraint q th

x_j : Decision variables j th

b_q : The value of the right field of the goal constraint q th

d_q^- : The value of deviations below the target of the goal q th

d_q^+ : The value of deviations above the target from the goal q th

In goal programming, both deviation variables can be zero or one deviation variable must be zero if the other deviation variable is greater than zero.

Table 1. Procedure to achieve goals

Function Type Linear Constraint Programming	Formulation of Goal Programming Form	Minimized deviation variables
$F_i(x) \geq b_i$	$F_q(x) + d_q^- - d_q^+ = b_q$	d_q^-
$F_i(x) \leq b_i$	$F_q(x) + d_q^- - d_q^+ = b_q$	d_q^+
$F_i(x) = b_i$	$F_q(x) + d_q^- - d_q^+ = b_q$	d_q^+, d_q^-

2.3.Preemptive Goal Programming

Preemptive goal programming can also be called lexicographic goal programming. This method is used if the goal function has different levels so that the priority level can be used for each goal. The first step of preemptive goal programming begins with determining which goal is considered the most important of the others and placing the function of that goal as the first priority. The first priority is considered much more important than the second priority and the second priority is more important than the third priority, and so on. This means that the lower priority order will only be completed if the higher priority order has already been completed. This sequence system can be written as follows:

$$P_1 \gg P_2 \gg \dots \gg P_k$$

where is the symbol ">> " It has the meaning of "much more important". The general form of preemptive goal programming can be expressed as follows.

Objective function:

$$\text{Min } Z = \sum_{q=1}^m P_k (d_q^+ + d_q^-) \quad , \forall k = 1, 2, \dots, s \quad (6)$$

Goal constraints:

$$\sum_{j=1}^n a_{qj} x_j + d_q^- - d_q^+ = b_q \quad , \forall q = 1, 2, \dots, m \quad (7)$$

$$\forall j = 1, 2, \dots, n$$

Non negative constraints:

$$x_j, d_q^-, d_q^+ \geq 0 \quad (8)$$

Keterangan:

There are as many s priorities as possible

There are as many n decision variables as possible

There are as many m goal constraints

Z : objective function

a_{qj} : coefficient of decision variable jth constraint goal qth

x_j : decision variable jth

b_q : The value of the right field of the goal constraint qth

d_q^- : The value of deviations below the target from the second goal qth

d_q^+ : the value of deviation above the target from the fourth goal qth

P_k : priority kth

There are two advantages to using preemptive goal programming. First, this method can be applied to goal programming problems whose goals have different units of measure. Second, it can be set that two or more goals are at the same priority level (Balakrishnan, Render,

& Stair, 2014). In solving this preemptive goal programming, the simplex method used is a modified simplex where the model variables are set at the top, starting with the decision variable column, negative deviation variable, and positive deviation variable. According to Charnes, and Cooper (1977), the difference between a simplex and a modified simplex is that if the simplex has one line while the modified simplex requires n rows z .

2.4.Branch and Bound

Branch and Bound method are a method used to produce optimal completion of a linear programming in order to produce integer decision variables. This method limits the optimum solution that will produce a fractional number by making the upper and lower bounds for each fractional decision variable to be integer so that each restriction will produce a new branch. The Branch and Bound method were first proposed in 1960 by A. H. Land and A. G. Doig for the problem of spherical programs both pure and mixed. Then E. Reply developed an algorithm on a special integer program zero one in 1965 (Nari, 2013).

The branch and bound method algorithm assume the case of maximizing the function of the objectives as follows:

1. Stage 1 : Solve problems into optimal tables of linear programs.
2. Stage 2 : Choose any variable x_i which is a fraction on the optimal solution of the previous linear program.
3. Stage 3 : Create two new constraints by branching or bound to x_i that is $x_i \leq [x_i]$ (Upper bound) and $x_i \geq [x_i]$ (Lower bound).
4. Stage 4 : Perform variable insertion techniques x_i to the initial linear program problem so that it becomes two subproblems.
5. Stage 5 : Measure the value of the objective function z . The solution is said to be optimal or iteration stops if the required variable is already integer and gains the largest z . If there is a variable x_i what is required is that the integer is not yet an integer, then return to stage 2 to do the next branching.

3. RESULTS AND DISCUSSION

Istiqomah Tofu Factory produces various types of tofu namely, white tofu, yellow tofu and Chinese tofu. This factory also has a variety of goals or targets to be achieved and each of these targets has a priority level. However, the problem that occurs there is the difficulty of meeting all these targets as a whole with the availability of existing raw materials and production costs to a minimum. To solve this problem, data from the Istiqomah Tofu Factory is needed as follows:

Table 2. Profit Data for Each Type of Tofu

No	Type of Tofu	Selling Price (Rp)	Profit (Rp)	Profit Target (Rp)
1	White Tofu	5.000	1.500	
2	Yellow Tofu	5.000	1.400	2.000.000
3	Chinese Tofu	5.500	1.500	

Table 3. Production Cost Data for Each Type of Tofu

No	Type of Tofu	Production Cost (Rp)	Production Cost Target (Rp)
1	White Tofu	3.500	
2	Yellow Tofu	3.600	5.000.000
3	Chinese Tofu	4.000	

Table 4. Data on the number of production targets for each type of tofu

No	Type of Tofu	Production Quantity (packs)
1	White Tofu	480
2	Yellow Tofu	360
3	Chinese Tofu	360

Table 5. Raw Material Data for Each Type of Tofu

No	Raw Material	Types of Tofu			Availability (gr/hari)
		White Tofu (gr)	Yellow Tofu (gr)	Chinese Tofu (gr)	
1	Soy bean	200	200	210	300.000
2	Salt	2,5	2,5	2,5	5.000
3	Turmeric	-	5	-	2.000

Factory owners have several goals / targets to be achieved, namely:

1. Goal 1 : minimum profit of Rp2.000.000,00/day
2. Goal 2 : maximum production cost of Rp5.000.000,00/day
3. Goal 3 : white tofu production not less than 480 packs/day
4. Goal 4 : yellow tofu production of no less than 360 bugkus/day
5. Goal 5 : Chinese tofu production not less than 360 packs/day
6. Goal 6 : the use of soybean raw materials should not exceed 300,000 grams/day
7. Goal 7 : the use of salt raw materials should not exceed 5,000 grams/day
8. Goal 8 : the use of turmeric raw materials should not exceed 2,000 grams/day

Then the factory owner also sets the priorities of these goals, as follows:

1. Priority 1st (P_1) : Goal 1
2. Priority 2nd (P_2) : Goal 2
3. Priority 3rd (P_3) : Goal 3, Goal 4, Goal 5
4. Priority 4th (P_4) : Goal 6, Goal 7, Goal 8.

From the data that has been obtained, then the problem is modeled into the form of *preemptive goal programming*. There are 3 decision variables in this problem, namely:

- x_1 : The amount of white tofu that must be produced every day
 x_2 : The amount of yellow tofu that must be produced every day
 x_3 : The abundance of Chinese tofu has to be produced every day.

The first priority of P_1 to be achieved is *goal 1*, which is a minimum profit of Rp2,000,000.00/day. To represent the possibility of deviations below target and deviations above target in the first priority, it can be formulated into the constraints of the initial linear program as follows:

$$1500x_1 + 1400x_2 + 1500x_3 \geq 2000000$$

Then it became:

$$1500x_1 + 1400x_2 + 1500x_3 + d_1^- - d_1^+ = 2000000 \quad (9)$$

Description of variable deviation:

- d_1^- : the value of deviation from the profit achieved is less than Rp2,000,000.00/day
 d_1^+ : the value of deviation from the profit achieved is more than Rp2,000,000.00/day

After making a linear program constraint a goal programming constraint, the next step is to declare the first priority into an objective function. The objective functions corresponding to the first priority are:

$$\text{Min } P_1(d_1^-) \quad (10)$$

That is to minimize the value of deviations below the target of the profit to be achieved. The symbol states that minimizing variables d_1^- is the first priority P_1 that the plant owner wants to achieve. Furthermore, using the same method as equations (9) and (10) will be obtained constraints for priority 2 (P_2), priority 3 (P_3) and priority 4 (P_4). In accordance with the level of priorities and goals to be achieved by the factory owner so that it can be modeled into the form of preemptive goal programming as follows:

$$\text{Min } Z = P_1(d_1^-) + P_2(d_2^+) + P_3(d_3^- + d_4^- + d_5^-) + P_4(d_6^+ + d_7^+ + d_8^+) \quad (11)$$

$$\text{Subject to:} \quad (12)$$

$$\begin{aligned} 1500x_1 + 1400x_2 + 1500x_3 + d_1^- - d_1^+ &= 2000000 \\ 3500x_1 + 3600x_2 + 4000x_3 + d_2^- - d_2^+ &= 5000000 \\ x_1 + d_3^- - d_3^+ &= 480 \\ x_2 + d_4^- - d_4^+ &= 360 \\ x_3 + d_5^- - d_5^+ &= 360 \\ 200x_1 + 200x_2 + 210x_3 + d_6^- - d_6^+ &= 300000 \\ 2,5x_1 + 2,5x_2 + 2,5x_3 + d_7^- - d_7^+ &= 5000 \\ 5x_2 + d_8^- - d_8^+ &= 2000 \\ x_1, x_2, x_3, d_q^-, d_q^+ &\geq 0 \text{ untuk } q = 1, 2, 3, \dots, 8 \end{aligned}$$

After obtaining a complete model of Preemptive goal programming, then the equation is compiled into a simplex table. Based on calculations using modified simplexes, optimal results are obtained as follows.

Tabel 6. Output Tabel Optimal Preemptive Goal Programming

Priority	Goal	Deviation Variable	Results
P_1	1	d_1^-	0
		d_1^+	0
P_2	2	d_2^-	33333,5
		d_2^+	0
P_3	3	d_3^-	0
		d_3^+	157,33
	4	d_4^-	0
		d_4^+	0
	5	d_5^-	0
		d_5^+	0
P_4	6	d_6^-	24933,33
		d_6^+	0
	7	d_7^-	1606,67
		d_7^+	0
	8	d_8^-	200
		d_8^+	0
Optimal Solution		x_1	637,33
		x_2	360
		x_3	360

In Table 6 it can be seen that all deviation variables in the objective function are 0. Thus, all the goals desired by the factory owner have been achieved. However, in the decision variable, there is still a solution that is not unanimous. Therefore, the branch and bound method will be applied to find solutions that are worthy of integer value, namely by determining the upper and lower limits of the solution obtained. Then on decision variables that have not been integer values, branching will be done by adding new constraints. Branching will continue until the best solution is obtained, namely the optimal solution where all decision variables are integers. A settlement tree with the branch and bound method is obtained as follows

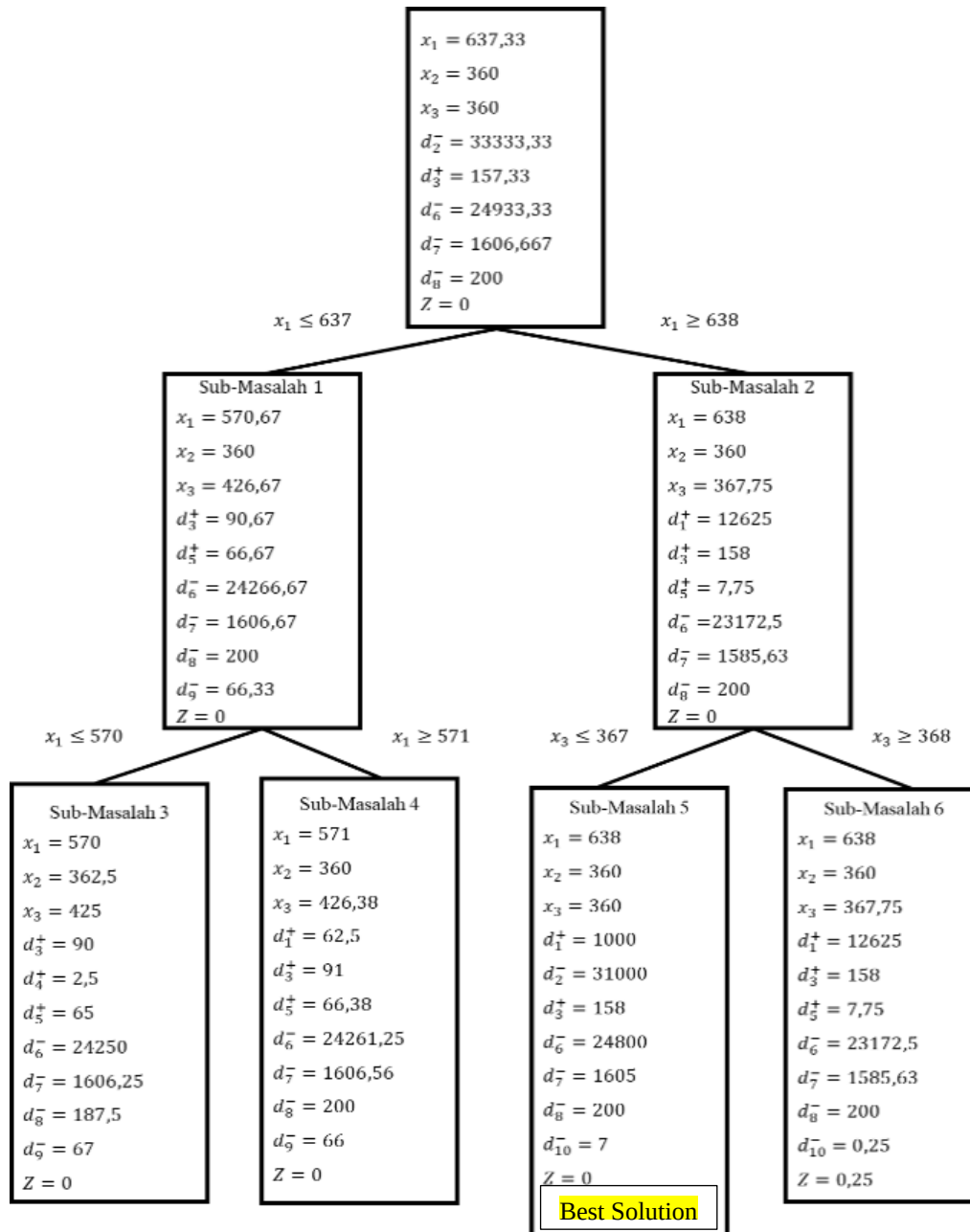


Figure 1. Completion diagram with branch and bound method

Figure 1 shows the solution obtained from using the branch and bound method. The optimal solution obtained is in sub-problem 5, because in sub-problem 5 all decision variables are integer values, namely $x_1 = 638$, $x_2 = 360$, $x_3 = 360$ and $Z = 0$.

Information:

1. The first priority aims to minimize the value of deviations below the target of the profit to be achieved, with a minimum daily profit target of Rp2,000,000.00. It can be seen in Figure 1 that the value of $d_1^- = 0$ and $d_1^+ = 1000$, these values mean that goal 1 in the first priority has been achieved with a profit to be achieved of more than Rp1,000.00.
2. The second priority aims to minimize the value of deviations above the target from the production costs to be achieved, with a maximum daily production cost of Rp5,000,000.00. It can be seen in Figure 1 that the value of $d_2^- = 31000$ and $d_2^+ = 0$, these values mean that goal 2 in the second priority has been achieved with the remaining production cost of Rp31,000.00.
3. The third priority aims to minimize the value of deviations below target from the production of white tofu, yellow tofu and Chinese tofu. It can be seen in Figure 1 that the value of $d_3^- = 0$, $d_3^+ = 158$, $d_4^- = 0$, $d_4^+ = 0$, $d_5^- = 0$, and $d_5^+ = 0$, these values mean that Goal 3, Goal 4 and Goal 5 in the third priority have been achieved with the production of more than 158 packs of white tofu.
4. The fourth priority aims to minimize the value of deviations above the target from the use of soybean raw materials, salt and turmeric. It can be seen in Figure 1 that the value of $d_6^- = 24800$, $d_6^+ = 0$, $d_7^- = 1605$, $d_7^+ = 0$, $d_8^- = 200$, and $d_8^+ = 0$, these values mean that goal 6, goal 7 and goal 8, in the fourth priority has been achieved with the remaining raw materials of soybeans as much as 24,800 grams, salt as much as 1,605 grams and turmeric as much as 200 grams

Table 7. Comparison of Factory Profit Using Branch and Bound

No	Type of Tofu	Factory		Branch and Bound	
		Production Quantity	Profit	Production Quantity	Profit
1	White Tofu	480	Rp720.000,00	638	Rp957.000,00
2	Yellow Tofu	360	Rp504.000,00	360	Rp504.000,00
3	Chinese Tofu	360	Rp540.000,00	360	Rp540.000,00
Total		1200	Rp1.764.000,00	1358	Rp2.001.000,00

Table 7 shows that the total profit of tofu production at the Istiqomah factory has increased with a total profit using branches and bonds of Rp2,001,000.00 which means that the minimum profit goal of Rp2,000,000.00 / day has been achieved. In addition, the factory's profit increased by 13.43% or Rp237,000.00 / day by producing 638 packs of white tofu, 360 packs of yellow tofu and 360 packs of Chinese tofu.

4. CONCLUSION

Based on the analysis of the results of the discussions that have been carried out. The application of preemptive goal programming and branch and bound methods is suitable for optimizing production planning which has various goals by paying attention to the desired priority level, because it can optimize profits, production costs and use of raw materials. In order for all the desired goals to be achieved, the Istiqomah Tofu Factory must produce 638 packs of white tofu, 360 packs of yellow tofu and 360 packs of Chinese tofu so that factory profits increase by 13.43%.

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