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# PRE-EMPTIVE GOAL PROGRAMMING METHOD FOR OPTIMIZING PRODUCTION PLANNING

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## ABSTRACT

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*In this paper, the mathematical modelling of production planning is put forward using the pre-emptive goal programming method for priority-based decision making. The objective of this problem is to design production planning satisfying the specified-constraints while minimizing deviations from each goal to be achieved. The goals consist of five types of best seller bread, production profits, production costs, production quantities, and availability of bread raw materials. LINGO 11.0 package is implemented for computational purposes. Computational results show that pre-emptive goal programming is an efficient method for optimizing the production planning of multiple goals based on the order of priority.*



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## 1. INTRODUCTION

Coronavirus disease 2019 or Covid-19, whose first case was reported in Wuhan, China, at the end of December 2019, spread to dozens of countries in a few months. The rapid spread of the disease forced many countries to apply the regulation to lockdown their countries to prevent the spreading of this virus. This regulation caused a decrease in public income and caused the market demand for bread also decreases.

In this situation, it becomes an obligation for every company to be able to survive in the existing competition by increasing its effectiveness and efficiency in carrying out production. This is absolutely necessary to maintain the company's existence in the face of increasingly competitive competition during the pandemic. The purpose of increasing effectiveness and efficiency in the production process is to optimize the planning for the amount of production to minimize production costs so that the profits obtained can be as much as possible. Therefore, it is important to make a plan in making decisions, so that a mathematical model is needed that can find the optimal solution to the problem.

Goal programming is a technique to solve the problem of multi-objective decision making in finding a set of satisfying solutions. The goal programming was first introduced by Charnes and Cooper [1], and further developed by Lee [2], Ignizio [3], Romero [4], Tamiz et al. [5], and others Li [6], and Chang [7]. The aim of goal programming is to minimize deviations in achieving the goals.

The goal programming method is one of the mathematical models of the extension of linear programming that can be used in production planning to solve multi-objective problems [4]. In linear programming, the objective function is maximized or minimized so that all management objectives are formulated into one objective function. The system used can be optimal conditions for one goal by ignoring other goals. In contrast to linear programming, the objective function of the goal programming method is to minimize the deviation from each goal to be achieved so that the results achieved are optimal without neglecting other goals. Furthermore, multiple aspiration levels can be assigned to the objective function of goal programming problem. Then the effort is to select an appropriate aspiration level for an objective function that minimizes the deviations between the achievement of goal and the aspiration level [8].

Many research on the goal programming method for solving optimization problems have been carried out. Among them, this method is used for production planning modelling, such as in bakery production research using the goal programming method with five decision variables and three objective constraints [9]. As a result, the goal programming method can solve optimization problems that have several objective functions. This method is also used in bakery production planning with five decision variables and three objective constraints [10]. The same application is carried out on small-scale companies by taking three decision variables and three objective constraints [11]. Optimal use of raw materials in a bakery by making three decision variables and three constraints of objectives was successful thanks to the application of the goal programming method [12].

Rotte Bakery is one of the companies in Pekanbaru City which is engaged in the food industry and produces various types of bread. Rotte Bakery has fulfilled the needs of the people of Pekanbaru City for bread since 2016. The research at Rotte Bakery was carried out using the pre-emptive goal programming method to take an optimal decision in production planning. This is done so that every existing demand can be met by determining production targets so that the amount produced can meet market demand right on target in the midst of many products or competitors circulating in the market, so that maximum profit is obtained.

In this paper, the LINGO 11.0 application is used to calculate the pre-emptive goal programming method. This research is limited by the factors of production of raw materials, production profits, the amount of production, and production costs. In section two, the goal programming method is described and in section three, the discussion of production planning problems using the pre-emptive goal programming method is explained. Then in section four, it is continued by explaining the conclusions from the discussion of this working paper.

## 2. RESEARCH METHODS

Goal programming is an extension of linear programming so that all assumptions, notations, mathematical model formulations, model formulation procedures, and solutions are not much different. The main difference lies in the structure and use of the objective function. In linear programming, there is only one objective function, while in goal programming, there are several combinations of objective functions, each having a variable deviation [13] dan [14].

The deviation variable serves to express the objective function in the form of a goal constraint and then find a solution by minimizing the number of deviations from the objective function [15] dan [16]. The positive deviation variable $d_i^+$ is the achievement above the $b_i$ target and the negative deviation variable $d_i^-$ is the achievement below the $b_i$target. The inclusion of the deviation variable can be seen in Table 1.

**Table 1. Deviation variable inclusion**

| No. | Objective function constraint | Deviation variable in objective function | Undesirable deviation variable |
|---|---|---|---|
| 1 | $f_i(x) = b_i$ | $f_i(x) + d_i^- - d_i^+ = b_i$ | $d_i^- + d_i^+$ |
| 2 | $f_i(x) \geq b_i$ | $f_i(x) + d_i^- - d_i^+ = b_i$ | $d_i^-$ |
| 3 | $f_i(x) \leq b_i$ | $f_i(x) + d_i^- - d_i^+ = b_i$ | $d_i^+$ |

Based on Table 1, if $f_i(x) = b_i$, then $d_i^-$ and $d_i^+$ will be minimized with the aim that there is no deviation in the target so that the target is exactly according to the desired $b_i$. If $f_i(x) \geq b_i$ then the desired goal is to maximize so that $d_i^-$ will be minimized with the aim that there is no deviation from the target $d_i^-$, with the desired target not being less than $b_i$. Likewise, if $f_i(x) \leq b_i$ then the desired goal is minimization so that $d_i^+$ will be minimized with the aim of avoiding deviations, namely excess of target $d_i^+$ with the desired target not being more than $b_i$. The pre-emptive goal programming method is one method for completing the goal programming as a basis for decision making to analyse solutions of a problem involving many goals based on priorities so that optimal alternative solutions are obtained.

The notation used to identify the priority of these goals is $p_i$ for $i = 1, 2, \ldots, m$, where $m$ is the number of goals arranged in a sequence. These priority factors have the following relationship:

$$p_1 >>> p_2 >>> \cdots >>> p_m.$$

The form >>> above has the meaning "much more important than". This is to state the order of priority of the goals to be achieved, where $p_1$ has a higher priority that must be achieved first before proceeding to the next priority. Deviations that exist in the higher priority must be minimized first prior to the deviation of the lowest priority.

The general form of the pre-emptive goal program method is

$$\min z = \sum_{i=1}^{m} p_i(d_i^+ + d_i^-) \quad \text{for } i = 1, 2, \ldots, m \tag{1}$$

subject to

$$\left.\begin{aligned} a_{11}x_1 + a_{12}x_2 + \cdots + a_{1n}x_n + d_1^- - d_1^+ &= b_1 \\ a_{21}x_1 + a_{22}x_2 + \cdots + a_{2n}x_n + d_2^- - d_2^+ &= b_2 \\ &\vdots \\ a_{m1}x_1 + a_{m2}x_2 + \cdots + a_{mn}x_n + d_m^- - d_m^+ &= b_m \end{aligned}\right\} \tag{2}$$

$$x_j, d_i^-, d_i^+ \geq 0 \text{ for } i = 1, 2, \ldots, m, j = 1,2, \ldots, n, \tag{3}$$

where

$a_{ij}$ := decision variable coefficient coefficient in $i$th constraint, $i = 1, 2, \ldots, m$, $j = 1, 2, \ldots, n$,
$x_j$ := linear programming decision variable, $j = 1, 2, \ldots, n$,
$b_i$ := constraint function value, $i = 1, 2, \ldots, m$,
$d_1^+$ := positive deviation variable, $i = 1, 2, \ldots, m$,
$d_1^-$ := negative deviation variable, $i = 1, 2, \ldots, m$,
$p_i$ := priority factor in $i$th goal, $i = 1, 2, \ldots, m$,
$n$ := number of decision variables,
$m$ := number of constraints.

## 3. RESULTS AND DISCUSSION

The initial step of the production planning formulation model is to collect all data related to the goals to be achieved in production planning. The data used in this study is data obtained from interviews regarding data on the amount of production, production costs, availability of raw materials, and profits. Furthermore, the problem is modelled using the pre-emptive goal programming form by determining the decision variables, constraint functions, and objective functions to be solved. The decision variables in this problem are five types of best-seller bread denoted in the form of notation $x_j$ with $j = 1, 2, 3, 4, 5$. Decision variables are

$x_1 :=$ The number of white bread produced in one month,
$x_2 :=$ The number of white wheat bread produced in one month,
$x_3 :=$ Number of productions of mini fit-O bread in one month,
$x_4 :=$ Number of productions of special chocolate bread in one month,
$x_5 :=$ The number of donuts produced in one month.

The next step is to model the objective and constraint functions mathematically to obtain optimal results in the form of deviation values by adding priority to the constraint functions. The objective function of this problem is for the deviation variables to be minimized, according to the priority level that has been determined by the management of Rotte Bakery so that it can be modelled as follows:

$$\left.\begin{array}{r} p_1 := \min(d_1^-) \\ p_2 := \min(d_2^+) \\ p_3 := \min(d_3^+ + d_4^+ + d_5^+ + d_6^+ + d_7^+) \\ p_4 := \min\begin{pmatrix} d_8^+ + d_9^+ + d_{10}^+ + d_{11}^+ + d_{12}^+ + d_{13}^+ + d_{14}^+ + d_1^+ + d_{16}^+ \\ +d_{17}^+ + d_{18}^+ + d_{19}^+ + d_{20}^+ \end{pmatrix} \end{array}\right\} . \tag{4}$$

Substituting **Equation (4)** into **Equation (1)** gives the general form of pre-emptive goal programming objective function for this problem as follows:

$$\min z = \sum_{i=1}^{4} p_j(\, d_i^+ + \, d_i^-) \quad \text{for} \;\; i = 1, 2, \dots, 20$$

The constraint functions that become the restriction in the production of Rotte Bakery bread are the raw material of bread, production profits, production costs, and the amount of production for each product with the following constraints formulation:

(i) Priority 1 ($p_1$)
In priority 1, there exists one goal, i.e., Goal 1. The goal to be achieved is to minimize the lack of the production profit target shown in **Table 2**, with the deviation variable to be minimized is $d_1^-$.

**Table 2. Data of profit for each type of bread**

| No | Type of bread | Selling price (Rp) | Profit (Rp) | Profit target (Rp) |
|---|---|---|---|---|
| 1 | White bread | 11,500 | 5,967 | |
| 2 | White wheat bread | 14,000 | 5,956 | |
| 3 | Mini fit-O bread | 2,500 | 1,336 | 48,000,000 |
| 4 | Special chocolate bread | 3,000 | 1,721 | |
| 5 | Donuts | 3,500 | 1,155 | |

*Source*: Rotte Bakery in Pekanbaru City

(ii) Priority 2 ($p_2$)
In priority 2, there is one goal, namely Goal 2. The goal to be achieved is to minimize the excess of the production cost target, as shown in **Table 3**, with the deviation variable to be minimized is $d_2^+$.

**Table 3. Data of production cost for each type of bread**

| No. | Type of bread | Production cost (Rp) | Target of production cost (Rp) |
|---|---|---|---|
| 1 | White bread | 5,533 | |
| 2 | White wheat bread | 8,044 | |
| 3 | Mini fit-O bread | 1,164 | 52,000,000 |
| 4 | Special chocolate bread | 1,279 | |
| 5 | Donuts | 2,345 | |

*Source*: Rotte Bakery in Pekanbaru City

(iii) Priority 3 ($p_3$)
In priority 3, there are 5 goals, namely Goal 3, Goal 4, Goal 5, Goal 6, and Goal 7. The goal to be achieved is to minimize the excess of the target amount of production shown in **Table 4**. The deviation variables that will be minimized are $d_3^+, d_4^+, d_5^+, d_6^+, d_7^+$.

**Table 4. Data of target amount of production for each type of bread**

| No. | Type of bread | Amount of production (unit) |
|---|---|---|
| 1 | White bread | 903 |
| 2 | White wheat bread | 582 |
| 3 | Mini fit-O bread | 13,539 |
| 4 | Special chocolate bread | 7,2057 |
| 5 | Donuts | 7,4817 |

*Source*: Rotte Bakery in Pekanbaru City

(iv) Priority 4 ($p_4$)
In priority, 4 there are 13 goals, namely Goal 8, Goal 9, ⋯, Goal 20. The goal to be achieved is to minimize the excess of the raw material availability target, as shown in **Table 5**. The deviation variables to be minimized are $d_8^+, d_9^+, \dots, d_{20}^+$.

**Table 5. Ingredients for each unit type of bread**

| No. | Ingredient (in gram) | Type of bread | | | | | Stock (in gram) |
|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | |
| 1 | Flour | 250 | 200 | 15 | 15 | 25 | 84,500 |
| 2 | Baking powder | 4 | 4 | 0.2 | 0.2 | 0.3 | 12,500 |
| 3 | Cake emulsifier | 1 | 1 | 0.1 | 0.1 | 0.1 | 4,300 |
| 4 | Egg | 0 | 0 | 2 | 2 | 2 | 56,450 |
| 5 | Sugar | 15 | 0 | 3 | 3 | 4 | 106,000 |
| 6 | Butter | 15 | 15 | 3 | 3 | 3 | 107,000 |
| 7 | Wheat | 0 | 50 | 0 | 0 | 0 | 29,100 |
| 8 | Coffee | 0 | 0 | 0.5 | 0 | 0 | 6,770 |
| 9 | Chocolate filling | 0 | 0 | 0 | 5 | 0 | 36,100 |
| 10 | Chocolate sprinkles | 0 | 0 | 0 | 15 | 0 | 108,075 |
| 11 | Chocolate toping | 0 | 0 | 0 | 0 | 5 | 37,500 |
| 12 | Milk powder | 5 | 0 | 0.5 | 0.5 | 1 | 22,400 |
| 13 | Water | 125 | 150 | 7 | 7 | 9 | 413,000 |

Based on **Table 2**, **Table 3**, **Table 4** and **Table 5**, a mathematical model is obtained using the pre-emptive goal programming method as follows:

$$\min z = p_1(\, d_1^-) + p_2(d_2^+) + p_3(d_3^+ + d_4^+ + d_5^+ + d_6^+ + d_7^+) + p_4(d_8^+ + d_9^+$$
$$+d_{10}^+ + d_{11}^+ + d_{12}^+ + +d_{13}^+ + d_{14}^+ + d_{15}^+ + d_{16}^+ + d_{17}^+ + d_{18}^+ + d_{19}^+ + d_{20}^+)$$

$$5{,}967\,x_1 + 5{,}956x_2 + 1{,}336x_3 + 1{,}721x_4 + 1{,}155x_5 + d_1^- - d_1^+ = 48{,}000{,}000,$$
$$5{,}533\,x_1 + 8{,}044x_2 + 1{,}164x_3 + 1{,}279x_4 + 2{,}345x_5 + d_2^- - d_2^+ = 52{,}000{,}000,$$
$$x_1 + d_3^- - d_3^+ = 903,$$
$$x_2 + d_4^- - d_4^+ = 582,$$
$$x_3 + d_5^- - d_5^+ = 13{,}539,$$
$$x_4 + d_6^- - d_6^+ = 7{,}205,$$
$$x_5 + d_7^- - d_7^+ = 7{,}481,$$
$$250x_1 + 200x_2 + 15x_3 + 15x_4 + 25x_5 + d_8^- - d_8^+ = 845{,}000,$$
$$4x_1 + 4x_2 + 0.2x_3 + 0.2x_4 + 0.3x_5 + d_9^- - d_9^+ = 12{,}500,$$
$$x_1 + x_2 + 0.1x_3 + 0.1x_4 + 0.1x_5 + d_{10}^- - d_{10}^+ = 4{,}300,$$
$$2x_3 + 2x_4 + 2x_5 + d_{11}^- - d_{11}^+ = 56{,}450,$$
$$15x_1 + 3x_3 + 3x_4 + 4x_5 + d_{12}^- - d_{12}^+ = 106{,}000,$$
$$15\,x_1 + 5x_2 + 3x_3 + 3x_4 + 3x_5 + d_{13}^- - d_{13}^+ = 107{,}000,$$
$$50x_2 + d_{14}^- - d_{14}^+ = 29.100,$$
$$0.5x_3 + d_{15}^- - d_{15}^+ = 6{,}770,$$
$$5x_4 + d_{16}^- - d_{16}^+ = 36{,}100,$$
$$15x_4 + d_{17}^- - d_{17}^+ = 108{,}075,$$
$$5\,x_5 + d_{18}^- - d_{18}^+ = 37{,}500,$$
$$5x_1 + 0.5x_3 + 0.5x_4 + x_5 + d_{19}^- - d_{19}^+ = 22{,}400$$
$$125x_1 + 150x_2 + 7x_3 + 7x_4 + 9x_5 + d_{20}^- - d_{20}^+ = 413{,}00,$$
$$x_1, x_2, x_3, x_4, x_5\; d_i^-, d_i^+ \geq 0 \text{ untuk } i = 1,2,\dots,20,$$

Based on the calculations using the LINGO 11.0 application, production planning with the pre-emptive goal programming method provides the optimal production planning recommendations to get effective and efficient production at the Rotte Bakery Company by taking into account the order of priority. These results can be seen in **Table 6**.

**Table 6. Optimal production planning based on LINGO 11.0 output**

| Priority | Goal | $d_i^+$ | $d_i^-$ | Target | Optimal | Description |
|---|---|---|---|---|---|---|
| 1 | Goal 1 | 0 | 0 | 48,000,000 | 48,000,000 | Satisfied |
| 2 | Goal 2 | 0 | 0 | 52,000,000 | 52,000,000 | Satisfied |
| 3 | Goal 3 | 63.68 | 0 | 903 | 966.68 | |
| | Goal 4 | 0 | 46.75 | 582 | 535.25 | |
| | Goal 5 | 0 | 0 | 13,539 | 13,539.00 | Not satisfied |
| | Goal 6 | 0 | 0 | 7,205 | 7,205.00 | |
| | Goal 7 | 0 | 73.22 | 7,481 | 7,407.78 | |
| 4 | Goal 8 | 73.61 | 0 | 845,000 | 845,073.61 | |
| | Goal 9 | 0 | 121.16 | 12,500 | 12,378.84 | |
| | Goal 10 | 17.10 | 0 | 4,300 | 4,317.10 | |
| | Goal 11 | 0 | 146.44 | 56,450 | 56,303.56 | |
| | Goal 12 | 363.28 | 0 | 106,000 | 106,363.28 | |
| | Goal 13 | 0 | 15.77 | 107,000 | 106,984.23 | |
| | Goal 14 | 0 | 2,337.58 | 29,100 | 26,762.42 | Not satisfied |
| | Goal 15 | 0 | 0.5 | 6,770 | 6,769.50 | |
| | Goal 16 | 0 | 75 | 36,100 | 3,525.00 | |
| | Goal 17 | 0 | 0 | 108,075 | 108,075.00 | |
| | Goal 18 | 0 | 461.10 | 37,500 | 37,038.90 | |
| | Goal 19 | 213.17 | 0 | 22,400 | 22,613.17 | |
| | Goal 20 | 0 | 0 | 413,000 | 413,000.00 | |

Based on **Table 6**, it can be seen that the conditions of priority 1 and priority 2 are met because there are no deviations for Goal 1 and Goal 2. In priority 3, the conditions are not met, this is due to efforts to achieve the goals of fulfilling Goal 3, Goal 4, and Goal 7 deviation from the target occurs. In priority 4, conditions are not met, this is due to efforts to achieve the goals of fulfilling Goal 8, Goal 9, Goal 10, Goal 11, Goal 12, Goal 13, Goal 14, Goal 15, Goal 16, Goal 18, and Goal 19 deviation from the target occurs.

By using the pre-emptive goal programming method, it provides an overview of planning the availability of production raw materials to Rotte Bakery to minimize the surplus and lacks of the availability of raw materials during the production process. The output results obtained suggest the availability of flour as much as 845,073.61 grams, the availability of baking powder as much as 12,378.84 grams, the availability of cake emulsifier as much as 4,317.10 grams, the availability of eggs as much as 5,6303.56 grains, the availability of sugar as much as 106,363.28 grams, the availability of sugar as much as 106,363.28 grams, butter as much as 106,984.23 grams, the availability of wheat as much as 26,762, 42 grams, the availability of coffee as much as 6,769.50 grams, the availability of chocolate filling as much as 3,525 grams, the availability of chocolate sprinkles as much as 108,075 grams, the availability of chocolate toppings as much as 37,038.90 grams, the availability of milk powder as much as 22,613 ,17 grams, and the availability of water as much as 413,000 litres. The results of planning the optimal amount of production are presented in **Table 7**.

**Table 7. Optimal number of bread produced**

| No. | Decision variable | Value |
|---|---|---|
| 1 | $x_1$ | 967 |
| 2 | $x_2$ | 535 |
| 3 | $x_3$ | 13,539 |
| 4 | $x_4$ | 7,205 |
| 5 | $x_5$ | 7,408 |

From the output, it is suggested to produce 967 units of white bread, 535 units of white wheat bread, 13,539 units of mini fit-O bread, 7,205 units of special chocolate bread, and 7,408 units of donuts. The amount of production explains that the mini fit-O bread and special chocolate bread are on target. White bread experienced an increase in the amount of production from the target, while white wheat bread and donuts experienced a reduction in the amount of production from the target.

**Table 8. Percentage After Implementing Pre-Emptive Goal Programming Method**

| Priority | Goal | Original value | Optimal | Percentage |
|---|---|---|---|---|
| 1 | Goal 1 | 48,000,000 | 48,000,000 | 0.00% |
| 2 | Goal 2 | 52.000.000 | 52,000,000 | 0.00% |
| 3 | Goal 3 | 903 | 966.68 | 6.59% |
| | Goal 4 | 582 | 535.25 | 8.03% |
| | Goal 5 | 13,539 | 13,539.00 | 0.00% |
| | Goal 6 | 7,205 | 7,205.00 | 0.00% |
| | Goal 7 | 7,481 | 7,407.78 | 0.98% |
| 4 | Goal 8 | 845,000 | 845,073.61 | 0.01% |
| | Goal 9 | 12,500 | 12,378.84 | 0.97% |
| | Goal 10 | 4,300 | 4,317.10 | 0.40% |
| | Goal 11 | 56,450 | 56,303.56 | 0.26% |
| | Goal 12 | 106,000 | 106,363.28 | 0.34% |
| | Goal 13 | 107,000 | 106,984.23 | 0.01% |
| | Goal 14 | 29,100 | 26,762.42 | 8.03% |
| | Goal 15 | 6,770 | 6,769.50 | 0.01% |
| | Goal 16 | 36,100 | 36,025.00 | 0.21% |
| | Goal 17 | 108,075 | 108,075.00 | 0.00% |
| | Goal 18 | 37,500 | 37,038.90 | 1.23% |
| | Goal 19 | 22,400 | 22,613.17 | 0.94% |
| | Goal 20 | 413,000 | 413,000.00 | 0.00% |

**Table 8** shows the calculation of the percentage change in production planning after using the pre-emptive goal programming method from the percentage to the goal and changes to the right-hand side of the 20 goal constraints which have been grouped into four priorities. By making changes, with increasing and decreasing limits suggested by the pre-emptive goal programming method so that the percentage is minimized to 0% to obtain an optimal solution.

The results obtained will be compared with manual production planning. The differences in manual production planning using the pre-emptive goal program method are as follows:

(i) Optimization Results of Manual Production Planning

(a) Production planning in achieving the goal in stages where the next month's production volume planning uses the previous month's data, and profits are obtained based on product sales for that month.

(b) Production planning for the 4 predetermined objectives is less efficient because there are still deviations that occur so that several objectives have not been met. This can be seen in Table.

(c) Production achievement is focused on production profits, namely the following month's production profit increased by 10% from the previous month's production profit.

(ii) Optimization results of production planning using the pre-emptive goal programming method

(a) Production planning can achieve various objectives by considering other objectives simultaneously. This can describe the estimated amount of production to be produced by considering the availability of raw materials, production costs, and profit targets.

(b) The description of the production planning for the four objectives has been optimal using the pre-emptive goal program method and assisted by LINGO 11.0.

## 4. CONCLUSIONS

The goal programming method is an extension of linear programming. There are differences in results between production planning using the pre-emptive goal program method and manual production planning. In the problem of production planning which is applied based on objectives and planning, it aims to determine optimal production planning by maximizing the objective function. Production planning using the pre-emptive goal program method using the LINGO 11.0 application can be an alternative to solving a production planning problem based on the priority order of many goals by minimizing deviations that will occur from the desired target. Thus, the optimization of production planning using the LINGO 11.0 application with the goal program method is more efficient than manual production planning applied by the Rotte Bakery Company. For future works, it might be worth to take into account the times series data in the optimization model of production planning.

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