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APPLICATION OF THE GOAL PROGRAMMING METHOD AND SENSITIVITY ANALYSIS IN OPTIMIZING BREAD PRODUCTION PLANNING

Zuhri *[1]
STIM Sukma Medan, Indonesia
zuhrimuin63@gmail.com

Sri Rafiqoh
Politeknik Tanjungbalai, Indonesia
fiqoh.fiqoh@gmail.com

Hery Saputra
Universitas Jabal Ghafur, Indonesia
Herysaputra346@gmail.com

Abstract

Umama Bakery's bread production process is considered less than optimal because the production quantity for each flavor variant is unlimited, resulting in insufficient raw materials at certain times. In addition, the order production process requires a long total completion time (makespan), resulting in delays in production completion (mean tardines). The aim of this research is to optimize total completion time, average delay time, use of raw materials used and optimize production income. This research uses the Goal Programming model with the Branch and Bound method. The results of the analysis using the Goal Programming model with the Branch and Bound method obtained an optimal solution, namely excess total completion time (makespan) of 36 minutes, excess average delay time (mean tardines) of 6 minutes, excess raw materials in raw materials. material availability is all zero, and sales revenue shortfall is zero. The results of the sensitivity analysis show that bread production at the Umama Bakery factory will remain optimal if there are changes in the availability of production completion time, delays in production time, and the availability of raw materials during these changes. variables are still within tolerance limits.

Keywords: Goal Programming; optimization, sensitivity analysis.

INTRODUCTION

Etymologically, "business" refers to a situation where a person or group of individuals is involved in work that generates money(Boutillier & Uzunidis, 2020; Fuerst & Luetge, 2023). In general, business is described as an activity carried out by all humans to obtain money, risk, or income to fulfill their needs and desires by managing economic resources successfully and efficiently (Dolnicar et al., 2005, 2015; Lancia & Serafini, 2018). The growth of the business world accompanied by intense competition

[1] Correspondence author

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The growth of the business world accompanied by intense competition has given rise to various problems which also have an impact on the company's ability to operate. In conditions like this, many small bread production businesses have to struggle hard to continue carrying out their production business activities. Therefore, every business entity needs good planning for the development of the business it runs. In running a business, especially in the production sector, a company must be able to maximize the use of production factors such as production equipment, labor , raw materials in order obtained maximum results (Esmaeilian et al., 2016)

High competition between entrepreneurs in running their business. This means that entrepreneurs must be able to formulate the right strategy so that their business continues to run well and smoothly. One of the small and medium industrial companies is Umama Bakery. This business operates in the bread for making industry in Bengkalis Regency. Umama Bakery produces 5 types of bread, namely chicken sandwiches, sausage sandwiches, cheese sandwiches, pizza roll bread, banana sandwiches that 2 types of brownies, namely afifa brownies and cup brownies. In running its business, Umama Bakery experiences obstacles in obtaining maximum profits. This is due to a lack of ability to determine optimal production quantities. To overcome this problem, Umama Bakery needs a method to get a solution, namely by using the Branch and Bound Integer programming method.

Linear programming is a solution method in mathematics that has an objective function that must be maximized or minimized within the limits of available resources. Linear programming can be solved in various ways, including graphical methods and the simplex methods. The simplex method can be used if there are many variables and constraints (Brahmana & Sinaga, 2013; Matousek & Gärtner, 2007; Rao & Walsh, 1986). Integer linear programming is one of the most effective ways to solve optimization problems (Dolnicar et al., 2005; Lancia & Serafini, 2018). In integer linear programming there are several ways of solving problems to obtain integer solutions, namely the cutting plane method and the branch and bound method. The branch and limit method is generally considered a more effective approach than the cutting plane method in solving integer linear programming problems (Álvarez-Miranda et al., 2024; Li et al., 2024; Liu & Urgo, 2024; Sudoso, 2024). Therefore, in this research to solve optimization problems, researchers used the Branch and Bound method. The Branch and Bound method is a method for producing optimal solutions to linear programs that produce integer decision variables. This method limits the optimal solution that will produce a number 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. Integer programming is a linear programming problem whose optimal solution must produce whole numbers, not fractions (Buzzi et al., 2024; Hackenberg & Sevinc, 2024; Kong et al., 2024; Kor et al., 2024)

The Branch and Bound algorithm is carried out repeatedly to form a search tree structure where the limiting process is carried out by setting boundaries to find the optimal solution (Ambarsari et al., 2024; Angmalisang & Anam, 2024, 2024; Putra et al., 2024).

The advantage of this algorithm lies in its higher accuracy compared to other methods, because it often produces more than one optimal solution. The branching root that has an integer value and meets the specified optimal boundary criteria is the best solution selected (Moslem et al., 2024; Yang et al., 2024; Zamani et al., 2024). Research conducted by (Polasi & Shalini, 2024; Prathyusha et al., 2024; Sarkar & Srivastava, 2024; Tayyebi et al., 2024) used the goal programming method to optimize the number of chip production at PT. Casava chips aim to meet consumer demand, maximize sales revenue, to minimize production costs, but the research no production time planning was carried out. Apart from that, research conducted by [10] using the Branch and Bound method can optimize profits in spring bed production with QM for Windows V5 software. However, this research cannot plan changes in production quantity for each type of spring bed if there is a shortage of raw materials. So analysis is necessary

RESEARCH METHOD

This research is quantitative research with a case study of the Umama Bakery factory. This research conducted a literature study sourced from books, journals its other related articles. The data used in this research is primary data by direct review and interviews. The steps in analyzing research data include: 1. Searching journals and references 2. Identifying problems by conducting interviews and reviewing directly 3. Collecting data Data obtained from direct observation they are : a. Bread production time data b. Umama Bakery Umama Income Data c. Data on raw material usage and availability of raw materials 4. Process the data obtained using a goal programming model using the branch and bound method with the help of Lingo 18.0 software 5. Sensitivity analysis is carried out

RESULT AND DISCUSSION

Decision Variables

The decision variable in solving production optimization problems is based on the type of bread produced by the Umama Bakery factory. The variables used include: $x1$=Bread with chocolate variant; $x2$=Bread with chocolate peanut variety; $x3$= Bread with mocha variant; $x4$= Bread with jam variant; $x5$= Bread with striped variant

Objective Function

The objective functions in this research are optimizing makespan, optimizing mean tardines, optimizing income and optimizing use of raw materials. Research data obtained from the factory can be seen in Tables 1 to Table 3.

Table 1. SUmmary of Production Time Data

Product	The number of products produced in each production (pcs / day)	Time's required (minutes)	Time restrictions are required for each package	Makespan for each packaging (minutes)	Average delay per packet (minutes)
x_1	475	106,9	0,225	0,240	0,015
x_2	227	51	0,225	0,240	0,015
x_3	150	33,75	0,225	0,240	0,015
x_4	121	27,2	0,225	0,240	0,015
x_5	225	50,6	0,225	0,240	0,015

Table 2. SUmamary of income data

Product	Selling price	income/day
x_1	2000	
x_2	2000	
x_3	2000	4.800.000
x_4	2000	
x_5	2000	

Table 3. Summary of Data on use of raw materials and availability of raw materials

Bread raw materials	x_1	x_2	x_3	x_4	x_5	Availability of bread raw materials per production (gr)
Flour	41,66	41,66	41,66	41,66	41,66	100.000
SKM	1,0416	1,0416	1,0416	1,0416	1,0416	2500
Mineral water	20,833	20,833	20,833	20,833	20,833	50.000
Cake softener	0,2083	0,2083	0,2083	0,2083	0,2083	500
Butter	5,5	5,5	10	5,5	5,5	15.000
Salt	0,416	0,416	0,416	0,416	0,416	1000
Sugar	7,7	7,7	11	7,7	7,7	20.000
Bread yeast	0,416	0,416	0,416	0,416	0,416	1000
Chocolate	10	8	-	-	15	20.000
Peanut	-	3,3	-	-	-	1500
Mocha Paste	-	-	3,33	-	-	1000

Jam	-	-	-	4	-	1000

Based on the data in Table 1, Table 2, and Table 3, the objective function of the goal programming model is obtained, namely:

$$Min = \sum_{a=1}^{4} z_a$$

Where is

$$\sum_{a=1}^{4} z_a = d_i^+ + d_2^+ + d_3^- + \sum_{i=4}^{15} d_i^+$$

Minimizing Z is minimizing positive deviation or positive deviation on excess makespan or total completion time, positive deviation or positive deviation on excess average delay or production time delay, negative deviation or negative deviation on factory revenue shortfall, and positive deviation or deviation
positive on excess raw materials

Constraint Function

The constraint function in this research consists of planning constraints, delay meaning constraints, income constraints and raw material constraints. Function constraints with objective programming models implemented using LINGO18.0 to determine the optimal solution. Based on the Goal Programming model above, the optimal solution presented in subproblem 1 is obtained, namely: branching. Then the variable $x1$ is branched into two sub-questions, namely sub-question 2 and sub-question 3. For sub-question 1, the limit $x1 \leq 912$ is added and for sub-question 2, the limit $x1 \geq 913$ is added. Then look for the solution to each branching problem for variable $x1$. so that the solutions $x1 \leq 912$ and $x1 \geq 913$ produce integer values. In subproblem 2 there is no longer a branch because the objective function crosses the boundary of the objective function or z value in subproblem 1, while subproblem 3 produces another branch because the value is not yet an integer value. The variable $x2$ branches into two sub-questions, namely sub-question 4 and sub-question 5, each of which is given the constraints $x2 \leq 454$ and $x2 \geq 455$. Then look for solutions to each problem. The branching of variable $x2$ can be seen in Figure 1

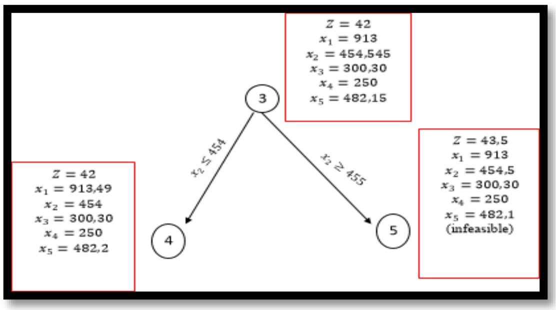

Figure 1. Tree Branching and Tied Branching Methode

Based on Figure 1, the solutions obtained $x2 \leq 454$ and $x2 \geq 455$ have produced integer values. In subproblem 4, the branching is carried out again because the value $x3$ is not yet an integer value, while subproblem 5 no longer produces a branching because the objective function is greater than the value of subproblem 1. Variable $x3$ branches into two subproblems, namely subproblem 6 and subproblem 7, each of which is given a limit. $x3 \leq 300$ and $x3 \geq 301$. Then find the solution to each problem. The branching of variable $x3$ can be seen in Figure 2.

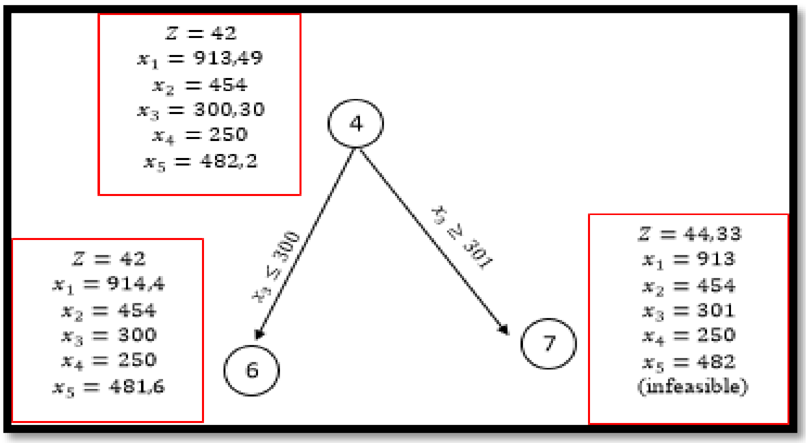

Figure 2. Branching Tree Branch and Bound Method

Based on Figure 2, subproblems with limits $x3 \leq 300$ and $x3 \geq 301$ produce integer values. In subproblem 6, the branching is carried out again because the value $x5$ is not yet an integer value, while subproblem 7 no longer produces a branching because the objective function exceeds the limit value of subproblem 1. Variable $x5$ branches into two subproblems, namely subproblem 8 and subproblem 9, each of which is limited $x5 \leq 481$and$x5 \geq 482$. Then look for solutions to each problem.

After branching 4 times, the optimal solution of the branch and bound algorithm is found in subproblem 8 for the objective function of minimizing production time, maximizing income, and minimizing use of raw materials. Because all variables in subproblem 8 have integer values and subproblem 9 has a value greater than the z value in subproblem 1, the branching process is not continued or stopped. The optimal solution can be presented again, namely:

Z=42, x_1=915, x_2=454,
x_3=300, x_4=250, x_5=481

Sensitivity Analysis

After getting the optimal solution, the next step is to carry out a sensitivity analysis of the coefficients of the objective function and constraint function [5]. The purpose of this sensitivity analysis is to help the Umama Bakery Factory make better decisions so that optimal planning can be obtained in its bread sales business.

Table 4. Optimal Solution using Lingo18.0

Variable	value	Reduced cost
x_1	915	0,255
x_2	454	0,255
x_3	300	0,255
x_4	250	4,255
x_5	481	0,255

Cost reduction refers to the change in the optimal value of the objective function when products that should not be produced are still produced. If a product has a cost reduction greater than zero, this indicates that the product is not profitable. However, if the cost reduction value is equal to zero, this indicates that the product is profitable to produce. In Table 4, it can be seen that the Reduced Cost value for each variable is greater than 0, this indicates that the product is not profitable to produce.

Change of objective function Sensitivity analysis is to find out how large the value or amount of change is still allowed, so that it does not affect the results of the optimal product combination . From the calculation results under optimal conditions, it is known that there are limits if there is a change in the value of each bread produced by Umama Bakery.

Table 5. Changes in objective function coefficient values

Variable	Coeficient	Allowable increase	Allowable reduction
d_1^+	1	8332.271	1
d_2^+	1	133316.3	1
d_3^-	1	INFINITY	0.9998725
d_4^+	1	INFINITY	1
d_5^+	1	INFINITY	1
d_6^+	1	INFINITY	1
d_7^+	1	INFINITY	1
d_8^+	1	INFINITY	1
d_9^+	1	INFINITY	1
d_{10}^+	1	INFINITY	1
d_{11}^+	1	INFINITY	1
d_{12}^+	1	INFINITY	1
d_{13}^+	1	INFINITY	1
d_{14}^+	1	INFINITY	1
d_{15}^+	1	INFINITY	1

Furthermore, Table 5 provides the range of changes in objective function coefficients that illustrates the permitted increases and permitted decreases for changes in objective function coefficients such as +decrease. The permitted amount is 0.9998725 and the permitted increase is unlimited, d+ the reduction permit is 1 and the additional permit is unlimited up to d+ where the decrease permit is 1 and the addition permit is unlimited.

Changes to the constraint function

Multiple analysis is carried out to evaluate the assessment of the availability of available raw materials and evaluate decisions in the production process by paying attention to slack/surplus and double value. The double values represent the change that would occur in the constraint function if each constraint were changed by one unit. If the slack/surplus is greater than zero and the double value is equal to zero then the constraint is classified as an excessive constraint (D. Handayani et al., 2021; Kong et al., 2024; Prathyusha et al., 2024). In table 6, it can be seen that the RHS shows changes in the constraint function at the umama Bakery factory.

Table6. Summary of Changes in Boundary Function Values

Line	Coeficient	Allowable increas	Allowable reduction
2	540	36	INFINITY
3	30	6	INFINITY
4	4800000	76.80123	300000
5	100000	INFINITY	16
6	2500	INFINITY	0.16
7	50000	INFINITY	0.8
8	500	INFINITY	0.8
9	15000	INFINITY	1800
10	1000	INFINITY	1.6
11	20000	INFINITY	529.0090
12	1000	INFINITY	1.6
13	20000	4563.677	2412.094
14	1500	2151.448	1500
15	1000	533.8182	803.2273
16	1000	1216.981	964.8376

Table 6 shows how much capacity to increase or decrease for each constraint without changing the optimal solution obtained. It can be seen that the existing Makespan can be increased to 36 minutes and the allowable decrease is infinite, meanardines can be increased by 6 minutes and the allowable decrease is infinite, in factory income the allowable increase is 76.80123 and the allowable decrease is 300,000, and for all materials Existing raw materials can be added to infinity, meaning that the existing raw materials are excess raw materials, while in the reduction column the allowable reduction value for wheat flour raw materials is 16 grams, SKM raw materials is 0.16 grams, water is 0.8 grams. , raw materials for softener 0.8 grams, raw materials for butter 1800 grams, raw materials for salt 1.6 grams, raw materials for sugar 529 grams, raw materials for yeast 1.6 grams, raw materials for chocolate 2412 grams, raw materials for nuts 1500 grams, mocha raw materials were 803.2 grams and jam raw materials were 964.8 grams. Changes in the composition of raw materials will affect the optimal level of production combination, but the solution obtained is still feasible because the results of changes in raw materials are still more than zero.

CONCLUSION

Based on the results and analysis of this research, it can be concluded that the Goal Programming model is used to optimize bread production at Umama Bakery by considering the function of factory constraints and objectives. The analysis results use the Branchand method Bound shows that the optimal solution includes increasing production completion time by 36 minutes, average production time delay of 6 minutes, raw material availability reaching zero, and sales revenue remaining stable. In addition, the results of the sensitivity analysis show that bread production at the Umama Bakery factory remains optimal even though there are changes in the coefficients of the objective function and constraint function, as long as the predetermined upper and lower limits are adhered to.

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