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Development of Multi-Criteria Decision-Making Model in the Packaged Beverage Industry to Minimize Production Costs and Maximize Machine Utility using the Step Method

Puryani[1], Sutrisno[2]
[1, 2] Universitas Pembangunan Nasional Veteran Yogyakarta

Abstract
The packaged beverage industry has grown rapidly. Now a packaged beverage industry has emerged with various brands. The emergence of many competitors, requires the packaged beverage industry to implement a strategy to survive and win the competition. One of these strategies is to make savings and maximize the use of resources. The savings made are contradictory problems with maximizing the use of resources, this is due to the use of resources, for example, the use of machines will require operational costs, even though the industry must make savings.The problem above is a multi-criteria decision making problem. Multi-criteria decision-making problems are characterized by conflicting goals on a problem to be resolved. The meaning of conflicting goals is that optimizing the value of one objective function will reduce the level of optimality of the other objective functions. One of the savings in an industry is to minimize production costs, while maximizing the use of resources, one of which can be done by maximizing machine utility. To increase the competitiveness of the packaged beverage industry, it is necessary to minimize production costs while maximizing machine utility. This can be done if the company's management implements policies to optimally achieve the two contradictory company goals. Optimization of contradictory or conflicting company goals is a multi-criteria decision-making problem. To facilitate company management in making decisions on conflicting company goals, it is necessary to develop a multi-criteria decision-making model. In this study, a multi-criteria decision-making model will be developed to optimize two conflicting objectives, namely minimizing production costs and maximizing machine utility, with limitations in the form of company resources to achieve these goals. To optimize the multi-criteria decision-making model developed using the step method. The advantage of this method when compared to other multi-criteria decision-making techniques is the iteration in determining the value of the trade-off (simultaneous search for optimal values of two conflicting objective functions). If the determination of the value of the trade-off in an iteration does not satisfy the decision maker, then the alternative value of the trade-off can be found by doing the next iteration. Optimization of the multi-criteria decision-making model will result in minimal production costs and maximum machine utility. The multi-criteria decision-making model that was developed also resulted in a production plan that was in accordance with the number of consumer demands. In addition, the production planning carried out will also be in accordance with the capacity of the warehouse, because the model developed takes into account the capacity of the warehouse.

Keywords: multi-criteria decision making, step method, minimizing production costs, maximizing machine utility

INTRODUCTION

Today's packaged beverage industry has grown rapidly. A new packaged beverage industry with various brands has emerged in the market to enliven the competition. The emergence of many competitors, requires the packaged beverage industry to implement a strategy to survive and win the competition. One of these strategies is to make savings and maximize the use ofresources.

The savings made in an industry can be contradictory to maximizing the use of resources. This is because the use of resources in an industry, for example the use of machines will require operational costs, even though an industry must make savings.
The problem of saving in an industry that is contradictory to maximizing the use of resources is included in the category of multi-criteria decision-making problems. Multi-criteria decision-making problems are characterized by conflicting goals on a problem to be resolved. The meaning of

Corresponding author:
sutrisno@upnyk.ac.id
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conflicting goals is that optimizing the value of one objective function will reduce the level of optimality of the other objective functions.

One of the savings in an industry is to minimize production costs, while maximizing the use of resources, one of which can be done by maximizing machine utility. To increase the competitiveness of a packaged beverage industry, it is necessary to minimize production costs while simultaneously maximizing the utility of the machines they have. To minimize production costs while maximizing machine utility, the company's management must carry out a policy to optimally achieve the two contradictory company goals. Optimization of contradictory or conflicting company goals is a multi-criteria decision-making problem. To facilitate company management in making decisions on conflicting company goals, it is necessary to develop a multi-criteria decision-making model.

In this study, a multi-criteria decision-making model will be developed to optimize two conflicting goals in the packaged beverage industry, namely minimizing production costs and maximizing machine utility, with limitations in the form of company resources to achieve these goals. To optimize the multi-criteria decision-making model developed, it will be carried out using the step method. The advantage of this method when compared to other multi-criteria decision-making techniques is the iteration in determining the value of the trade-off (simultaneous search for optimal values of two conflicting objective functions). If the determination of the value of the trade-off in an iteration does not satisfy the decision maker, then the alternative value of the trade-off can be found by doing the next iteration.

Optimization of the multi-criteria decision-making model will result in minimal production costs and maximum machine utility. The multi-criteria decision-making model that was developed also resulted in a production plan that was in accordance with the number of consumer demands. In addition, the production planning carried out will also be in accordance with the capacity of the warehouse, because the model developed takes into account the capacity of the warehouse.

Formulation of the problem
The formulation of the problem in this study is how to develop a multi-criteria decision-making model in the packaged beverage industry to minimize production costs and maximize machine utility?

Research Purposes
The purpose of this study is to develop a multi-criteria decision-making model in the packaged beverage industry to minimize production costs and maximize machine utility using the step method.

LITERATURE REVIEW

Decision Making
Basically, humans are decision-making creatures, the ability which is a special gift that is not given by God to other creatures on earth. Philosophers and great thinkers such as Aristotle and Plato have since thousands of years ago studied human capacity in the decision-making process (Rohayani, 2013).

Rational decision makers apply a systematic and scientific procedure in making decisions. The procedure follows the stages (Balteiroet et.al, 2017) as follows: (i) Identifying decision situations related to the problem to be solved, (ii) Clarifying the goals desired by decision makers, (iii) Generating various alternatives to achieve goals. the desired goal, (iv) Obtaining the right solution from the model and evaluating it based on the established assessment criteria, (v) Selecting and recommending the implementation of alternative decision solutions into real problems.

Multi Criteria Decision Making
Multi-criteria decision making (Multiple Criteria Decision Making) is a method of alternative selection process to obtain the optimal solution from several alternative decisions by taking into account more than one criterion or objectives that are in conflicting situations. This paradigm is different from the

traditional perspective on the problem of finding the optimal solution for a decision. Complex decision problems are modeled only as simple problems from a single-objective decision optimization model. So that there is an excessive simplification of the problem reality, in the end the decision solution fails to find a solution to the actual problem. This means that the single-approach optimization model approach fails to accommodate "heterogeneity", the dynamics and conditions of the conflicting criteria (Huang et.al., 2011).

Siet et.al., (2016) divides the scientific taxonomy of multi-criteria decision making into 2 different approaches, namely: Multiple Objective Decision Making (MODM) and Multiple Attribute Decision Making (MADM). Each has characters, attributes, and properties, as well as applications for solving a variety of different decision problems.

MODM Approach
The MODM approach is concerned with solving optimization models that have multiple objectives and conflicting objectives. The existence of an "optimal" solution or trade-off for this multiple objective will be a differentiator from classical single-objective optimization approaches such as linear programming. In the MODM method, the decision activity which is defined as the searched decision variable (continuous variable) is not determined beforehand. The objective function is more than two objectives that must be optimized simultaneously and the decision system constraint is formed from this variable (Cinelli et. al, 2014).

Multi-criteria decision-making techniques that can be used to solve MODM problems include single objective approach, unifying objective function approach (global criterion method, minimum deviation method, utility function method, and compromise constraint method), goal programming, interactive approach (step method and game theoretical technique), and compromise programming.

MADM Approach
Methodologically the difference between the MADM method in its use is based on the way of aggregating the selection criteria (Jiang et.al., 2009), namely: (i) a synthesis approach that forms a single criterion function from various comparable criteria (agrigation complete transitive); (ii) an "outranking" approach, by accepting rankings in separate aggregation criteria (agnation partiale); (iii) Approach with local and interactive judgment (aggregation locale / iterative).

The approach to aggregating criteria functions raises different views among multi-criteria researchers, namely between the "ecole americain" approach (such as the AHP method, MAUT, and others) which represents the synthesis approach and the "ecole francophone" approach which represents the partial aggregation approach, namely the outranking method. for example the ELECTRE method, PROMETHE and others). (Handayani and Wakhidah, 2012).

Step Method
The Step Method is one of the solving methods in the interactive approach. Interactive approach is a method of solving multi-objective problems where an optimization implementer can interact with decision makers at the management level to determine the solution desired by management. (Indrianti and Sutrisno, 2014).

The step method was invented by Benayoun, de Montgolfier, Tergny and Laritchev (1971). This method involves a sequential exploration of directed solutions based on the decision maker's response to the questions provided by the algorithm. Each iteration consists of two phases, namely the calculation phase and the decision-making phase.

RESEARCH METHODOLOGY

The research steps taken can be seen in the following research framework.

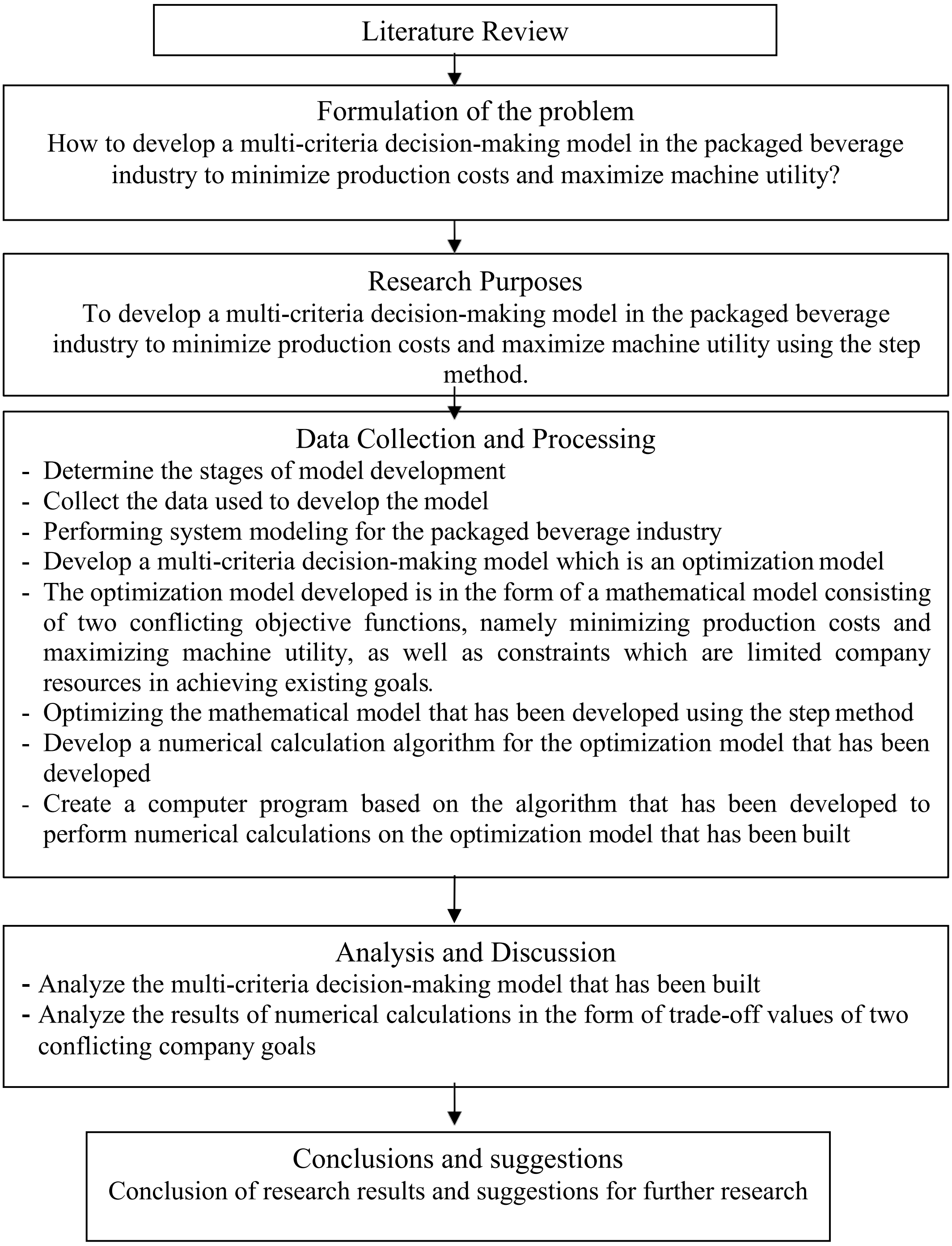

Figure 1. Research Framework

FINDING AND DISCUSSION

Data Collection

This research was conducted at the X Packaged Beverage Company. The data needed to build a multi-criteria decision-making model at Packaged Beverage Company X are data on the production process time, data on demand for beverage products at Packaged Beverage Company X every week in Agustus, September, and Oktober 2021, data on the cost of production needs for determine the production cost of each type of beverage in cartons, the availability of working hours at the X Packaging Beverage Company in one week, the availability of capacity in the warehouse.

Data Processing

The data that has been collected will then be used to build a multi-criteria decision-making model at Packaged Beverage Company X. The collected data will be used to determine the objective and constraint functions of the multi-criteria decision-making model that is built complete with parameters, constants, and variables from the model developed. build the model..

The data that has been collected will then be tested for adequacy and data uniformity tests. Furthermore, data processing will be carried out by calculating the standard time of the production process, calculating the production cost of packaged drinks, forecasting the number of product requests, determining the master production schedule, and calculating the capacity of the production process. The data processing carried out will produce parameters, constants, and research variables that will be used to build a mathematical model which is a multi-criteria decision-making model.

Development of a Multi-Criteria Decision Making Model

The multi-criteria decision-making model developed is a mathematical model that contains two conflicting objective functions, namely the minimization of production costs and the maximization of machine utility, with a problem constraint in the form of the X Packaged Beverage Company's limitations in achieving the two conflicting company goals. The stages of developing a multi-criteria decision-making model which is a mathematical model are determining the decision variables, determining the objective function-objective function, and determining the problem constraint. Furthermore, the multi-criteria decision-making model that was built will be optimized using the step method to produce weekly production plans from August 2021 to October 2021.

Determine the decision variable

The decision variable here is the number of products at the X Packaged Beverage Company that must be produced so that the required production costs are minimal and the machine utility used is maximized. The decision variables in this study are

X_1 = number of Apple Green Tea products produced per week (cartons)
X_2 = number of Original Green Tea products produced per week (cartons)
X_3 = number of Tamarind products produced per week (cartons)
X_4 = number of Bio Sari Kelapa products produced per week (cartons)
X_5 = number of Bio Teler products produced per week (cartons)
X_6 = number of Bio Klamud products produced per week (cartons)
X_7 = number of Kopyor Strawberry products produced per week (cartons)
X_8 = number of Kopyor Mangga products produced per week (cartons)

Determine the objective function

The mathematical model of this multi-criteria decision-making model consists of two conflicting objective functions, namely minimizing production costs and maximizing machine utility. The formulation for the objective function of minimizing production costs is:

$$Min. Z_1 = 6.675X_1 + 6.421X_2 + 6.705X_3 + 12.082X_4 + 11.877X_5 + 12.119X_6 + 12.313X_7 + 11.823X_8$$

Formulation of maximizing machine utility in the boiling processis:

$Max.\ Z_2 =$

$$\frac{\begin{bmatrix} \left(\left(\left(\frac{4{,}32X_1}{1000}\right)\right)\times 13{,}749\right)+\left(\left(\left(\frac{4{,}32X_2}{1000}\right)\right)\times 13{,}805\right) \\ +\left(\left(\left(\frac{4{,}32X_3}{1000}\right)\right)\times 14{,}468\right)+\left(\left(\left(\frac{4{,}32X_4}{1000}\right)\right)\times 16{,}804\right) \\ +\left(\left(\left(\frac{4{,}32X_5}{1000}\right)\right)\times 17{,}197\right)+\left(\left(\left(\frac{4{,}32X_6}{1000}\right)\right)\times 17{,}048\right) \\ +\left(\left(\left(\frac{4{,}32X_7}{1000}\right)\right)\times 13{,}229\right)+\left(\left(\left(\frac{4{,}32X_8}{1000}\right)\right)\times 13{,}000\right) \end{bmatrix}}{8.000}$$

The formula for maximizing machine utility in the cup pouring process is

$$Max.Z_3 = \frac{\begin{bmatrix} 0{,}062X_1 + 0{,}062X_2 + 0{,}062X_3 + 0{,}062X_4 \\ +0{,}062X_5 + 0{,}062X_6 + 0{,}062X_7 + 0{,}062X_8 \end{bmatrix}}{8.000}$$

The formula for maximizing machine utility in the carton packaging process is

$$Max.Z_4 = \frac{\begin{bmatrix} 0{,}711X_1 + 0{,}711X_2 + 0{,}711X_3 + 0{,}711X_4 \\ +0{,}711X_5 + 0{,}711X_6 + 0{,}711X_7 + 0{,}711X_8 \end{bmatrix}}{56.000}$$

IV.2.1.3. Determine the constraint function

a. The formulation for the capacity constraint function of machine working hours in the boiling process is

$$\left(\left(\left(\frac{4{,}32X_1}{1000}\right)\right)\times 13{,}749\right)+\left(\left(\left(\frac{4{,}32X_2}{1000}\right)\right)\times 13{,}805\right)$$
$$+\left(\left(\left(\frac{4{,}32X_3}{1000}\right)\right)\times 14{,}468\right)+\left(\left(\left(\frac{4{,}32X_4}{1000}\right)\right)\times 16{,}804\right)$$
$$+\left(\left(\left(\frac{4{,}32X_5}{1000}\right)\right)\times 17{,}197\right)+\left(\left(\left(\frac{4{,}32X_6}{1000}\right)\right)\times 17{,}048\right)$$
$$+\left(\left(\left(\frac{4{,}32X_7}{1000}\right)\right)\times 13{,}229\right)+\left(\left(\left(\frac{4{,}32X_8}{1000}\right)\right)\times 13{,}000\right)$$
$$\leq 8.000$$

b. The formulation for the capacity constraint function of machine working hours in the boiling process is

$$0{,}062X_1 + 0{,}062X_2 + 0{,}062X_3 + 0{,}062X_4 + 0{,}062X_5 + 0{,}062X_6$$
$$+0{,}062X_7 + 0{,}062X_8 \leq 8.000$$

c. The formulation for the constraint function of the availability of human working hours in the carton packaging process is

$$0{,}711X_1 + 0{,}711X_2 + 0{,}711X_3 + 0{,}711X_4 + 0{,}711X_5 + 0{,}711X_6$$
$$+ 0{,}711X_7 + 0{,}711X_8 \leq 56.000$$

d. The formulation of the minimal production constraint function is

$$X_1 \geq 21.376 - (0 - 0)$$
$$X_2 \geq 2.462 - (0 - 0)$$
$$X_3 \geq 1.664 - (0 - 0)$$
$$X_4 \geq 1.928 - (0 - 0)$$
$$X_5 \geq 548 - (0 - 0)$$

$X_6 \geq 764 - (0 - 0)$

$X_7 \geq 326 - (0 - 0)$

$$X_8 \geq 222 - (0 - 0)$$

e. The formulation of warehouse capacity is

$$X_1 + X_2 + X_3 + X_4 + X_5 + X_6 + X_7 + X_8 \leq 35.154$$

IV.2.2. Optimization of Multi-Criteria Decision Making Model Production Planning Second Week of August 2021

a. Determine the ideal solution for each objective function

The multi-criteria decision-making model developed is determined by the ideal value of each objective function using the LINGO software. The ideal value of each objective function is $Z_1^* = Z_1\ minimal$ = Rp215.350.800 with $X^{1*} = (21.376, 2.462, 1.664, 1.928, 548, 764, 326, 222)$, $Z_2^* = Z_2\ maksimal$ = 0,290924 with $X^{2*} = (21.376, 2.546, 1.851, 2.083, 5.787, 925, 352, 231)$, $Z_3^* = Z_3\ maksimal$ = 0,272444 with $X^{3*} = (21.376, 2.462, 7.528, 1.928, 548, 764, 326, 222)$, $Z_4^* = Z_4\ maksimal$ = 0,446330 with $X^{4*} = (21.376, 2.462, 7.528, 1.928, 548, 764, 326, 222)$.

b. Create a pay-off table

Table 1. *Pay-off* Table

	X1*	X2*	X3*	X4*
Z1	Rp215.350.800	Rp283.620.537	Rp254.671.210	Rp254.671.210
- Z1	**-Rp215.350.800**	-Rp283.620.537	-Rp254.671.210	-Rp254.671.210
Z2	0,232092	**0,290924**	0,277304	0,277304
Z3	0,226998	0,272420	**0,272444**	0,272436
Z4	0,371878	0,446292	0,446318	**0,446330**

c. Mathematical model of model optimization using step method

$$\alpha_1 = \frac{-215.350.800 - (-283.620.537)}{-215.350.800} \cdot \frac{1}{\sqrt{6.675^2 + 6.421^2 + 6.705^2 + 12.082^2 + 11.877^2 + 12.119^2 + 12.313^2 + 11.823^2}}$$

= -1,08 . 10^{-5}

$$\alpha_2 = \frac{0,290924 - (0,232092)}{0,290924} \cdot \frac{1}{\sqrt{(7,4.10^{-6})^2 + (7,4.10^{-6})^2 + (8.10^{-6})^2 + (9.10^{-6})^2 + (9.10^{-6})^2 + (9.10^{-6})^2 + (7.10^{-6})^2 + (7.10^{-6})^2}}$$

= 9.016,8

$$\alpha_3 = \frac{0,272444 - (0,226998)}{0,272444} \cdot \frac{1}{\sqrt{(8.10^{-6})^2 + (8.10^{-6})^2 + (8.10^{-6})^2 + (8.10^{-6})^2 + (8.10^{-6})^2 + (8.10^{-6})^2 + (8.10^{-6})^2 + (8.10^{-6})^2}}$$

= 7373,6

$$\alpha_4 = \frac{0,446330 - (0,371818)}{0,446330} \cdot \frac{1}{\sqrt{(1.10^{-5})^2 + (1.10^{-5})^2 + (1.10^{-5})^2 + (1.10^{-5})^2 + (1.10^{-5})^2 + (1.10^{-5})^2 + (1.10^{-5})^2 + (1.10^{-5})^2}}$$

= 5.902,4

$$\pi_1 = \frac{-0,000108}{-0,0000108 + 9.016,8 + 7.373,6 + 5.902,4} = -5.10^{-10}$$

$$\pi_2 = \frac{9.016{,}8}{-0{,}0000108 + 9.016{,}8 + 7.373{,}6 + 5.902{,}4} = 0{,}4$$

$$\pi_3 = \frac{7.373{,}6}{-0{,}0000108 + 9.016{,}8 + 7.373{,}6 + 5.902{,}4} = 0{,}33$$

$$\pi_2 = \frac{5.902{,}4}{-0{,}0000108 + 9.016{,}8 + 7.373{,}6 + 5.902{,}4} = 0{,}26$$

Solve the following mathematical model:
Maximise z = y
Subject to

$$\left(\left(\left(\frac{4{,}32X_1}{1000}\right)\right) \times 13{,}749\right) + \left(\left(\left(\frac{4{,}32X_2}{1000}\right)\right) \times 13{,}805\right) + \left(\left(\left(\frac{4{,}32X_3}{1000}\right)\right) \times 14{,}468\right) + \left(\left(\left(\frac{4{,}32X_4}{1000}\right)\right) \times 16{,}804\right) + \left(\left(\left(\frac{4{,}32X_5}{1000}\right)\right) \times 17{,}197\right) + \left(\left(\left(\frac{4{,}32X_6}{1000}\right)\right) \times 17{,}048\right) + \left(\left(\left(\frac{4{,}32X_7}{1000}\right)\right) \times 13{,}229\right) + \left(\left(\left(\frac{4{,}32X_8}{1000}\right)\right) \times 13{,}000\right) \le 8.000$$

$$0{,}062X_1 + 0{,}062X_2 + 0{,}062X_3 + 0{,}062X_4 + 0{,}062X_5 + 0{,}062X_6 + 0{,}062X_7 + 0{,}062X_8 \le 8.000$$

$$0{,}711X_1 + 0{,}711X_2 + 0{,}711X_3 + 0{,}711X_4 + 0{,}711X_5 + 0{,}711X_6 + 0{,}711X_7 + 0{,}711X_8 \le 56.000$$

$$X_1 \ge 21.376 - (0 - 0)$$
$$X_2 \ge 2.462 - (0 - 0)$$
$$X_3 \ge 1.664 - (0 - 0)$$
$$X_4 \ge 1.928 - (0 - 0)$$
$$X_5 \ge 548 - (0 - 0)$$
$$X_6 \ge 764 - (0 - 0)$$
$$X_7 \ge 326 - (0 - 0)$$
$$X_8 \ge 222 - (0 - 0)$$
$$X_1 + X_2 + X_3 + X_4 + X_5 + X_6 + X_7 + X_8 \le 35.154$$

$$y \ge \left[\begin{matrix}-215.350.800 - (6.675X_1 + 6.421X_2 + 6.705X_3 + 12.082X_4 + 11.877X_5 + \\ 12.119X_6 + 12.313X_7 + 11.823X_8\end{matrix}\right]$$

$$y \ge \left[\begin{matrix}0{,}290924 - (7{,}4.10^{-6}X_1 + 7{,}4.10^{-6}X_2 + 8.10^{-6}X_3 + 9.10^{-6}X_4 + 9.10^{-6}X_5 + \\ 9.10^{-6}X_6 + 7.10^{-6}X_7 + 7.10^{-6}X_8\end{matrix}\right]$$

$$y \ge \left[\begin{matrix}0{,}272444 - (8.10^{-6}X_1 + 8.10^{-6}X_2 + 8.10^{-6}X_3 + 8.10^{-6}X_4 + 8.10^{-6}X_5 + \\ 8.10^{-6}X_6 + 8.10^{-6}X_7 + 8.10^{-6}X_8\end{matrix}\right]$$

$$y \ge \left[\begin{matrix}0{,}446330 - (1.10^{-5}X_1 + 1.10^{-5}X_2 + 1.10^{-5}X_3 + 1.10^{-5}X_4 + 1.10^{-5}X_5 + \\ 1.10^{-5}X_6 + 1.10^{-5}X_7 + 1.10^{-5}X_8\end{matrix}\right]$$

With the help of the LINGO software, a solution is obtained:

$$Z^* = -215.350.800 \text{ dengan}$$
$$X^* = (21.376, 2.582, 7.407, 1.928, 548, 764, 326, 222)$$

So the compromise solution (trade-off) is

$Z_1 = Rp254.630.420$

$Z_2 = 0{,}277221$

$Z_3 = 0{,}272436$

$Z_4 = 0{,}446318$

RESULT ANALYSIS

Based on the results of the optimization of the multi-criteria decision-making model using the step method for production planning for the 2nd week of August 2021, the results are number of Apple Green Tea products produced per week is 21.376 cartons, number of Original Green Tea products produced per week is 2.582 cartons, number of Tamarind products produced per week is 7.407 cartons, number of Bio Sari Kelapa products produced per week is 1.928 cartons, number of Bio Teler products produced per week is 548 cartons, number of Bio Klamud products produced per week is 764 cartons, number of Kopyor Strawberry products produced per week is 326 cartons, number of Kopyor Mangga products produced per week is 222 cartons. The minimum production cost achieved in the 2nd week of August 2021 is $Rp254.630.420$. The machine utility at the boiling, cup pouring, and carton packing work stations in a row is 0,2777221, 0,272436, 0,446318. The amount of production does not exceed the capacity of the existing warehouse, so it will minimize the cost of maintaining goods before being distributed to consumers.

CONCLUSION

This research has succeeded in developing a multi-criteria decision-making model. To optimize the multi-criteria decision-making model developed using the step method. The optimization results have resulted in a weekly production plan that minimizes production costs and maximizes machine utility. The resulting production plan will also be quite precise with the weekly product demand. Likewise, the weekly production plan will also be in accordance with the warehouse capacity, so that it will minimize the cost of maintaining the product before it reaches the consumer.

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