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Research paper

Decision support system fuzzy goal programming model to optimize benefits of SME furniture

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Abstract

SME Furniture currently has not done an optimal analysis of production amount. The amount of production is based solely on the needs of the consumer, resulting in improper production costs. This study aims to determine the optimal amount of production of each product using Fuzzy Goal Programming (FGP) model. In obtaining optimal benefits consider the cost of labor costs and raw material costs. Fuzzy goal programming model is used for decision making in determining the amount of production on each product type. The analysis has done by maximizing profits and minimize labor, raw materials and working time. The results of this study indicate that the fuzzy goal programming model can optimize the clothing in furniture SMEs by 30%.

Keywords: *Fuzzy Goal Programming; Furniture; SME; Optimal; Production.*

1. Introduction

Pasuruan Regency is one of the center of furniture SMEs in East Java, Indonesia. Based on existing data, many SMEs have not conducted production analysis to optimize profits appropriately. One of the study cases for SMEs was UD. Wijaya Pasuruan. This SME produces teak furniture with kinds of products such as cabinets, sideboard, cots, and desk chairs. So far the number of SME products every month, based only on the previous year's production and consumer demand only. SMEs have not done production planning to determine the optimal amount of production from each product type. Based on this, SMEs require production planning to obtain optimal production amount.
Production planning is a plan used to determine the type and quantity of products produced by a company in the future. Production planning is also part of the company's operational planning and should consider the optimization of production so that it can achieve optimal production with the lowest cost level for the production process implementation [1]. Production planning as a process for producing goods at a certain period as predicted or scheduled through the organization of labor resources, raw materials, machinery and other equipment [2 - 4]. One method that can be used for optimal production planning is goal programming. This method is a method that can be used to maximize the purpose function with certain constraints [5], [6].
Goal Programming (GP) is also used for multi-purpose problem solving through deviation variables, goal programming automatically captures information about the relative achievement of the objectives. The optimum given solution can be limited to a compatible solution by combining desired performance measures [7]. GP is able to resolve conflicting aspects of elements in production planning. These aspects include consumers, products, and manufacturing processes. However, the goal programming method is not suitable for data consisting of uncertainty and qualitative criteria. The GP method is only used for definite quantitative problems; it can't be used for range sizes. The existence of indicators or variables in the production process of furniture SMEs consisting of uncertainty and qualitative criteria it is necessary to solve problems with Fuzzy Goal Programming (FGP) method [8 - 10]. This research combines fuzzy method with goal programming or called fuzzy goal programming.
The purpose of this study is to use FGP to maximize revenue by minimizing labor costs, raw material costs, and time off work, constrained by available constraints or resources. The Fuzzy method in this study is used to accommodate the disguised nature of qualitative criteria. Excess Fuzzy is capable of handling data that contains uncertainty and inaccuracy, has excellent performance, the decision-making process is more flexible [11], [12]. Fuzzy integration methods with other methods can also contribute to optimal decision-making and decision-making strategies more efficiently [13 - 16]. The fuzzy goal programming approach is also to handle inaccurate data input Inaccuracy, allow a trade-off between conflicting objectives in process decision making [17], solve multiobjective goal programming problem [18], multiple priorities with optimization method [19], determine production plans for decision-making [20], [21]. Based on the above background, this research uses fuzzy goal programming method to determine the optimal production and profit for SME furniture.

2. Research method

The research steps there are several stages. The first stage is the identification of the problem of production management is not optimal in SME Furniture, followed by data collection of production costs and data processing. The second stage is to create an optimal profitability model and then analyze the model simulation results to obtain an optimal advantage.

2.1. Data collection

This stage of data collection that support the achievement of the goal. Production data are expected to provide information to optimize resources. SME furniture in the production activities resulting in the type of product as a research variable that is: x_1 = the cabinets 1 door, x_2 = the cabinets 2 doors, x_3 = the cabinet 3 doors, x_4 = 1 meter sideboard, x_5 = 1.5 meter sideboard, x_6 = 2 meter sideboard, x_7 = 1.2 meter bed, x_8 = 1.4 meter bed, x_9 = 1.6 meter bed and x_{10} = table chair [22].

2.2. Data analysis

The stage of forming the model determines the decision variables namely the types of products produced by SMEs Furniture, a kind of teak furniture products. Determination of purpose model functions is income maximization, minimization of raw material cost, labor cost minimization and minimization of work time. Determination of constraint functions are constraints relating to the raw materials required per unit of product and availability of raw materials.
The formation of the Fuzzy Goal Programming (FGP) model is determined by the solution of the LP model is established, then expressed in the fuzzy membership function. Data analysis to find an optimal model solution and fuzzy membership degree by using POM / QM Win. This optimal model solution is documented as a basis for conducting sensitivity analysis [13].
Sensitivity analysis is needed to determine the lower limit and upper limit of the raw material supply for each type of product. The model of this optimal solution will change in case of changes to the availability of resources or raw materials. The decision variable is the type of furniture product to be produced is $x = (x_1, x_2..., x_n)$.

2.2.1. Goals function

Goals function in this model [11] is:

1) The revenue function will be maximized

$$P(x) = c_1X_1 + c_2X_2 + \ldots + c_jX_j + \ldots + c_nX_n$$

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

c_j = price per product j, for j = 1,2,…, n).

2) The time function of the work will be minimized

$$M(x) = p_1X_1 + p_2X_2 + \ldots + p_jX_j + \ldots + p_nX_n$$

$$M(x) = \sum_{j=1}^{n} p_j x_j \quad (2)$$

p_j = production time per product j, for j = 1,2,…, n.

3) Function of raw material cost to be minimized

$$B(x) = q_1X_1 + q_2X_2 + \ldots + q_jX_j + \ldots + q_nX_n$$

$$B(x) = \sum_{j=1}^{n} q_j x_j \quad (3)$$

q_j = cost of raw materials per product j, for j = 1,2,…, n.

4) Function of labor costs to be minimized

$$T(x) = r_1X_1 + r_2X_2 + \ldots + r_jX_j + \ldots + r_nX_n$$

$$T(x) = \sum_{j=1}^{n} r_j x_j \quad (4)$$

r_j = labor costs produce per product j, for j = 1,2,…, n.

5) The profit function will be maximized. The function of this profit is the function of revenue minus the function of the cost of raw materials and labor costs.

$$Z(x) = (c_1-q_1-r_1)\, X_1 + (c_2-q_2-r_2)\, X_2 + \ldots + (c_n-q_n-r_n)\, X_n \quad (5)$$

2.2.2. Function constraints

The form of constraints relating to the availability of resources or raw materials of furniture is:
a. Raw material of furniture
The total stock i raw material is the amount of raw material i for production per product j is a_{ij}, then:

$$a_{11}x_1 + a_{12}x_2 + \ldots + a_{1i}x_i + \ldots + a_{1n}x_n < b_1 \quad (6)$$

$$a_{21}x_1 + a_{22}x_2 + \ldots + a_{2i}x_i + \ldots + a_{2n}x_n < b_2 \quad (7)$$

$$a_{j1}x_1 + a_{j2}x_2 + \ldots + a_{ji}x_i + \ldots + a_{jn}x_n < b_j \quad (8)$$

$$a_{m1}x_1 + a_{m2}x_2 + \ldots + a_{mi}x_i + \ldots + a_{mn}x_n < b_m \quad (9)$$

b. Standard constraints in the model
The standard constraints in the model are non-negative constraints:

$$X_j > 0 \quad (10)$$

2.2.3. Model FGP

FGP model, it is necessary to find the LP solution for each purpose function [12]:

a) The lowest profit to be gained is $\overline{Z}$, fuzzy membership:

$$\mu_Z(x) = \begin{cases} 1 \; ; Z(x) \geq Z^* \\ \frac{Z(x)-\overline{Z}}{Z^*-\overline{Z}} \; ; \overline{Z} \leq Z(x) \leq Z^* \\ 0 \; ; Z(x) \leq \overline{Z} \end{cases} \quad (11)$$

b) Highest time of work used is $\overline{M}$, fuzzy membership:

$$\mu_M(x) = \begin{cases} 1 \; ; M(x) \leq M^* \\ \frac{\overline{M}-M(x)}{\overline{M}-M^*} \; ; M^* \leq M(x) \leq \overline{M} \\ 0 \; ; M(x) \geq \overline{M} \end{cases} \quad (12)$$

c) The highest cost of raw materials is $\overline{B}$, fuzzy membership:

$$\mu_B(x) = \begin{cases} 1 \; ; B(x) \leq B^* \\ \frac{\overline{B}-B(x)}{\overline{B}-B^*} \; ; B^* \leq B(x) \leq \overline{B} \\ 0 \; ; B(x) \geq \overline{B} \end{cases} \quad (13)$$

d) The highest labor costs is $\overline{T}$, fuzzy membership:

$$\mu_T(x) = \begin{cases} 1 \; ; T(x) \leq T^* \\ \frac{\overline{T}-T(x)}{\overline{T}-T^*} \; ; T^* \leq T(x) \leq \overline{T} \\ 0 \; ; T(x) \geq \overline{T} \end{cases} \quad (14)$$

Based on equations (11), (12), (13), (14) it is made in the form of fuzzy linear programing membership as shown in Figure.1.

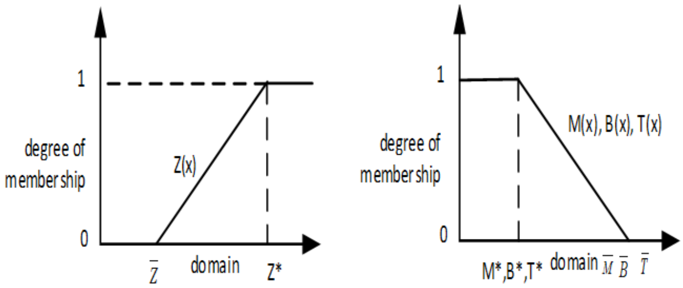

Fig. 1: Fuzzy Linear Programming Membership.

So the fuzzy goal programming model is Max λ [14],[15].
With constraints:

$$\frac{Z(x)-\overline{Z}}{Z^{*}-\overline{Z}} \geq \lambda \quad (15)$$

$$\frac{\overline{M}-M(x)}{\overline{M}-M^{*}} \geq \lambda \quad (16)$$

$$\frac{\overline{B}-B(x)}{\overline{B}-B^{*}} \geq \lambda \quad (17)$$

$$\frac{\overline{T}-T(x)}{\overline{T}-T^{*}} \geq \lambda \quad (18)$$

$a_{11}x_1 + a_{12}x_2 + \ldots + a_{1i}x_i + \ldots + a_{1n}x_n < b_1$

$a_{21}x_1 + a_{22}x_2 + \ldots + a_{2i}x_i + \ldots + a_{2n}x_n < b_2$

$\vdots \; \vdots$

$a_{m1}x_1 + a_{m2}x_2 + \ldots + a_{mi}x_i + \ldots + a_{mn}x_n < b_m$ (19)

$x_j > 0$ (20)

3. Result and discussion

The raw materials used to make one unit of each product (variable, x_i), consist of wood material, putty, glue, varnish, nails, bamboo and fixtures. The cost of purchasing raw materials and labor costs in the manufacture of products as in Table 1:

Table 1: Raw Materials and Costs

Materials	Variable									
	x_1	x_2	x_3	x_4	x_5	x_6	x_7	x_8	x_9	x_{10}
Wood (m^3)	0.25	0.37	0.5	0.24	0.36	0.42	0.21	0.26	0.31	0.5
Putty (Kg)	0.6	0.8	1.1	0.7	1.1	1.3	0.4	0.6	0.8	1.2
Glue (L)	0.25	0.27	0.3	0.3	0.32	0.34	0.1	0.13	0.15	0.4
Varnish (kg)	4	5	6	4	5	6	3	4	5	6
Nail (kg)	0.4	0.5	0.6	0.4	0.5	0.6	0.4	0.5	0.6	0.6
Bamboo (m^3)	0.001	0.002	0.002	0.001	0.002	0.002	0.001	0.001	0.001	0.002
Equipment (set)	1	1	1	1	1	1	1	1	1	0
Raw Material Costs (Rp)	1277600	1831220	2417400	1270000	1828820	2141440	994000	1242580	1490200	2314600
Labor Costs (Rp)	225000	240000	260000	375000	450000	525000	180000	220000	240000	340000

3.1. Function goals

Sales price data per unit as a function of income will be maximized are:

a) Maximize Revenue:

Max P = $2600000x_1 + 340000x_2 + 4200000x_3 + 2800000x_4 + 3500000x_5 + 4100000x_6 + 2100000x_7 + 2500000x_8 + 3000000x_9 + 3900000x_{10}$

b) Minimize time of work:

Min M = $0.7x_1 + 0.6x_2 + 0.5x_3 + 0.4x_4 + 0.3x_5 + 0.25x_6 + 0.7x_7 + 0.65x_8 + 0.6x_9 + 0.3x_{10}$

c) Minimize the cost of raw materials:

Min B = $1277600x_1 + 1831220x_2 + 2417400x_3 + 1270000x_4 + 1828820x_5 + 2141440x_6 + 994000x_7 + 1242580x_8 + 1490200x_9 + 2314600x_{10}$

d) Minimization of Labor Costs:

Min T = $225000x_1 + 240000x_2 + 260000x_3 + 375000x_4 + 450000x_5 + 525000x_6 + 180000x_7 + 220000x_8 + 240000x_9 + 340000x_{10}$

e) Maximize profit:

Max Z = $1000000x_1 + 1300000x_2 + 1500000x_3 + 1100000x_4 + 1200000x_5 + 1450000x_6 + 900000x_7 + 1000000x_8 + 1200000x_9 + 1250000x_{10}$

The profit function is the revenue minus the cost of raw materials and labor costs so that the function of profit maximization objectives.

3.2. Forms of constraints

Based on Table 1 and the availability of raw materials every month, it can be obtained the form of constraints of each raw material:

1) Wood

a) Cupboard: $0.25x_1 + 0.37x_2 + 0.5x_3 < 60$

b) Sideboard: $0.24x4 + 0.36x5 + 0.42x6 < 50$

c) Bed: $0.21x7 + 0.26x8 + 0.31x9 < 40$

d) Table chairs: $0.5x10 < 25$

2) Putty

$0.6x_1 + 0.8x_2 + 1.1x_3 + 0.7x_4 + 1.1x_5 + 1.3x_6 + 0.4x_7 + 0.6x_8 + 0.8x_9 + 1.2x_{10} < 400$

3) Glue

$0.25x_1 + 0.27x_2 + 0.3x_3 + 0.3x_4 + 0.32x_5 + 0.34x_6 + 0.1x_7 + 0.13x_8 + 0.15x_9 + 0.4x_{10} < 100$

4) Varnish

$4x_1 + 5x_2 + 6x_3 + 4x_4 + 5x_5 + 6x_6 + 3x_7 + 4x_8 + 5x_9 + 6x_{10} < 2.400$

5) Nail

$0.4x_1 + 0.5x_2 + 0.6x_3 + 0.4x_4 + 0.5x_5 + 0.6x_6 + 0.4x_7 + 0.5x_8 + 0.6x_9 + 0.6x_{10} < 255$

6) Bamboo

$0.001x_1 + 0.002x_2 + 0.002x_3 + 0.001x_4 + 0.002x_5 + 0.002x_6 + 0.001x_7 + 0.001x_8 + 0.001x_9 + 0.002x_{10} < 8$

7) Equipment

$x_1 < 10$, $x_2 < 12$, $x_3 < 15$, $x_4 < 11$, $x_5 < 15$, $x_6 < 20$, $x_7 < 10$, $x_8 < 11$, $x_9 < 11$

8) Time of work

Time of person hours per month = 8 (hour/day) x 24 (day/month) x 30 (person) = 5760 hour person/month.

$0{,}7x_1 + 0{,}6x_2 + 0{,}5x_3 + 0{,}4x_4 + 0{,}3x_5 + 0{,}25x_6 + 0{,}7x_7 + 0{,}65x_8 + 0{,}6x_9 + 0{,}3x_{10} < 5760$

9) The minimum amount of wood to produce

Average production data within 1 month should be provided the amount of wood 24 m^3.

$0.25x_1 + 0.37x_2 + 0.5x_3 + 0.24x_4 + 0.36x_5 + 0.42x_6 + 0.21x_7 + 0.26x_8 + 0.31x_9 + 0.5x_{10} > 24$

10) Non negative

$x_1, x_2, x_3, x_4, x_5, x_6, x_7, x_8, x_9, x_{10} > 0$

3.3. Fuzzy membership functions of each purpose function

If the decision maker wants to determine a particular policy that relates to the four objectives to be achieved, then the allowable value interval as a restriction on the fuzzy membership function is limited by the optimal solution for each of those objective functions, can be expressed in the form: Z* = 202900000, M*=14.36, B*=151425600, T*=14400000, maka $\overline{Z} \leq Z^*$, $\overline{M} \geq M^*$, $\overline{B} \geq B^*$, $\overline{T} \geq T^*$ so based on the form of a fuzzy membership function can be expressed:

$$\mu_Z(x) = \begin{cases} 0 \; ; Z(x) \leq \overline{Z} \\ \frac{Z(x)-\overline{Z}}{202900000-\overline{Z}} \; ; \overline{Z} \leq Z(x) \leq 202900000 \\ 1 \; ; Z(x) \geq 202900000 \end{cases}$$

$$\mu_M(x) = \begin{cases} 1 \; ; M(x) \leq 14.36 \\ \frac{\overline{M}-M(x)}{\overline{M}-14.36} \; ; 14.36 \leq M(x) \leq \overline{M} \\ 0 \; ; M(x) \geq \overline{M} \end{cases}$$

$$\mu_B(x) = \begin{cases} 1 \; ; B(x) \leq 151425600 \\ \frac{\overline{B}-B(x)}{\overline{B}-151425600} \; ; 151425600 \leq B(x) \leq \overline{B} \\ 0 \; ; B(x) \geq \overline{B} \end{cases}$$

$$\mu_T(x) = \begin{cases} 1 \; ; T(x) \leq 14400000 \\ \frac{\overline{T}-T(x)}{\overline{T}-14400000} \; ; 14400000 \leq T(x) \leq \overline{T} \\ 0 \; ; T(x) \geq \overline{T} \end{cases}$$

Based on the four function objectives then the fuzzy membership is shown from the linear programming as in figure 2.

3.4. Decision support system based on FGP model

In this section, the decision maker can determine the preference or constraint of his or her desire for each objective function, as part of the decision support system (DSS) in the production decision to be taken. In this FGP model which is an optimization model analysis of solutions in the DSS, decision makers can determine how much profit to achieve and how much time the work, raw material costs, labor costs that can be used, to further obtain the desired model solution. A sensitivity analysis is also undertaken in the DSS to see changes in the availability of resources in relation to the desired optimal conditions.

3.5. FGP model solutions

Initially given the opportunity to the decision maker to determine his desire to achieve the purpose function. The data analysis describes the decision maker's desire to determine the optimal value. Creating a fuzzy goal programming model that can be solved in the form of linear programming. Based on models and constraints for $\overline{Z}$ =0.3Z*, $\overline{M}$ =1.25M*, $\overline{B}$ = 1.25B*, $\overline{T}$ = 1.25T*, then the FGP model can be known maxλ. The amount of profit at least 30% of minimal profits ($\overline{Z}$) = 60870000, multiplication of work at most 1.25 multiplication maximum work time ($\overline{M}$) = 17.95, cost of raw materials at most 1.25 multiplication the maximum material cost ($\overline{B}$) = 189282000, labor costs at most 1.25 multiplication the maximum labor cost ($\overline{T}$) = 18000000.

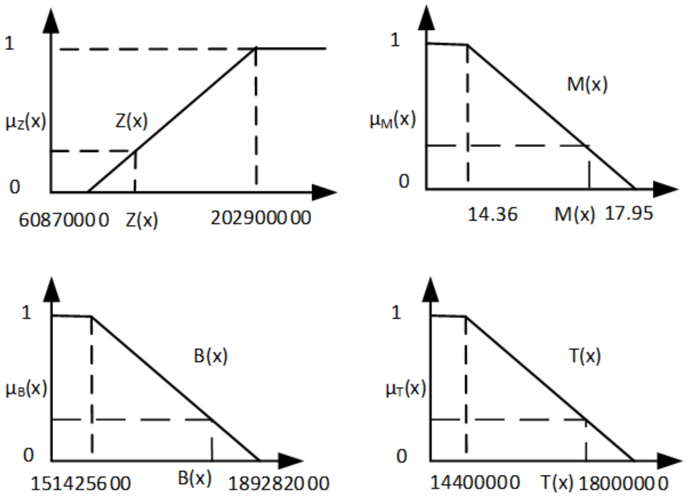

Fig. 2: Membership Fuzzy.

Then the existing constraint form in the LP model increases the constraints of the objective function that is:

a) The constraint form of profit maximization purpose function

$$\frac{Z(x)-\overline{Z}}{202{,}900{,}000-\overline{Z}} \geq \lambda$$

$2600000x_1 + 3400000x_2 + 4200000x_3 + 2800000x_4 + 3500000x_5 + 4100000x_6 + 2100000x_7 + 2500000x_8 + 3000000x_9 + 3900000x_{10} - 142030000\lambda > 60870000$

b) The form of constraints of the objective function of minimizing the working time

$$\frac{\overline{M}-M(x)}{\overline{M}-14{,}36} \geq \lambda$$

$0.7x_1 + 0.6x_2 + 0.5x_3 + 0.4x_4 + 0.3x_5 + 0.25x_6 + 0.7x_7 + 0.65x_8 + 0.6x_9 + 0.3x_{10} + 3.59\,\lambda < 17.95$

c) The constraints of the objective function of material cost minimization

$$\frac{\overline{B}-B(x)}{\overline{B}-151.425.600} \geq \lambda$$

$1277600x_1 + 1831220x_2 + 2417400x_3 + 1270000x_4 + 1828820x_5 + 2141440x_6 + 994000x_7 + 1242580x_8 + 1490200x_9 + 2314600x_{10} + 37856400\,\lambda < 189282000$

d) The form of constraints of the objective function of labor cost minimization

$$\frac{\overline{T}-T(x)}{\overline{T}-14.400.000} \geq \lambda$$

$225000x_1 + 240000x_2 + 260000x_3 + 375000x_4 + 450000x_5 + 525000x_6 + 180000x_7 + 220000x_8 + 240000x_9 + 340000x_{10} + 3600000\lambda < 18000000$

Based on the results of linear programming settlement using QMWin for profit maximization purpose obtained FGP model solution in the following Table 2:

Table 2: FGP Model Solutions

Variable	(a)	(b)	(c)	(d)	Value
(x_1)	10	0	0	0	0
(x_2)	12	0	0	0	0
(x_3)	15	0	0	15	3.83
(x_4)	11	0	0	0	0
(x_5)	15	0	0	0	0
(x_6)	20	20	0	0	2.96
(x_7)	10	0	0	0	0
(x_8)	11	0	0	0	0
(x_9)	11	0	0	0	0
(x_{10})	50	31.2	48	33	50
Solution Model (Rp)	(Z*) 202900000	(M*) 14.36 days	(B*) 151425600	(T*) 14400000	(λ) 0.08

Table Descriptions : (a) Profit maximization purpose function value, (b) Minimization value of work time, (c) Minimization raw material costs value, (d) Minimization labor cost value.

If the values of x_1, x_2, ..., x_{10} are substituted for each function the objectives will be obtained by the amount of profit, the time of the work, the cost of the raw material, and the labor cost of the profit Z(x) = 72537000, time of work M(x) = 17.66 day, raw material cost B(x) = 179887754 and labor costs T(x) = 17703000, with membership value λ :

$$\mu_Z(x) = \frac{Z(x) - \overline{Z}}{Z^* - \overline{Z}} = \frac{72537000 - 60870000}{202900000 - 60870000} = 0.08$$

$$\mu_M(x) = \frac{\overline{M} - M(x)}{\overline{M} - M^*} = \frac{17.95 - 17.66}{17.95 - 14.36} = 0.08$$

$$\mu_B(x) = \frac{\overline{B} - B(x)}{\overline{B} - B^*} = \frac{189282000 - 179887754}{189282000 - 151425600} = 0.24$$

$$\mu_T(x) = \frac{\overline{T} - T(x)}{\overline{T} - T^*} = \frac{18000000 - 17703000}{18000000 - 14400000} = 0.08$$

The desire of the decision maker to be achieved with the result given is at the desired value ie the least profit which is wanted ($\overline{Z}$) 60870000, it exceeds the profit of Z (x) 72537000, time of the most work can be used ($\overline{M}$) 17.95 days, it turns out that used only M (x) 17.66 days, the cost of the most raw material that can be used ($\overline{B}$)189282000 apparently used only B (x) 179887754, and most labor cost that can be used ($\overline{T}$) 18000000 turns that used only T (x) 17703000.

3.6. Sensitivity model

Sensitivity analysis in the research is conducted on the availability of available timber resources. Value of wood resource availability to maintain optimal condition at 12.43 - 29.31 m^3. The availability of wood resources is changed beyond this hose, then the optimum conditions will also change. The need for wood that must be provided at least for teak wood raw material every month for production activities to achieve optimal conditions should be provided the amount of wood by 15.58 m^3.

4. Conclusion

Based on the research results can be concluded that the fuzzy goal programming model can be used to determine the optimal profit value in production management. The result of the objective function is limited by the function of resource constraints, then the amount of wood that must be provided for SME furniture minimal amounted to 15.58 m^3 / month. The value of Fuzzy membership (λ) of 0.24 shows that the optimal profit can be achieved at a minimum of 30%. The result of sensitivity analysis gives a limit of change of each resource availability in maintaining an optimal solution of the wood raw material type of table chair product is limited 12.43 – 29.31 m^3.

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