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The Use Of Sensitivity Analysis To Find Maximum Profit In The Production Of Msme Angga Furniture Using The Simplex Method

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Abstract: At time progresses, business competition becomes increasingly fierce. This also result in MSME (Micro,small dan Medium Enterprises) from various cities competing fiercely. There are many MSME that have emerged, one of which is Angga Furniture MSME which operates in the furniture sector. The aim of this research is to determine the maximum profit obtained using the Simplex Method and continue with Sensitivity Analysis to see to what extent the objective function coefficients and constants on the right side of the constraint function can change without affecting the optimal solution. Based on calculation using the Simple Method, a maximum sales profit of IDR 2.830.000 is obtained if production is increased for 10 baby swings, 9 capsule chairs and 2 room deviders. Furthermore, using Sensitivity Analysis calculations, the maximum sales profit is IDR 2.454.000 and the maximum sales profit is IDR 4.396.000.

Keywords: Maximum, Optimization, Profit, Sensitivity Analysis, Simplex Method

1. Introduction

The more the times develop, the competition in the business world is getting tighter, this is due to the large number of similar MSMEs (Micro, Small and Medium Enterprises) competition. This, of course, makes every MSME must be able to regulate the quality of the products they market. Every MSME that creates a product must have quality and every product created by the company must have a brand. In Indonesia, there are various types of MSME sectors, one of which is MSMEs engaged in furniture or furniture. The furniture industry is an industry that processes raw materials or semi-finished materials including rattan, wood, and other natural materials into finished goods products that can be called furniture that has added value and higher benefits. The development of rattan crafts is not only available in the final product made of rattan, but in various products produced such as furniture, interior decoration and souvenirs are often combined with other raw materials.

The problem related to the process of maximizing profits and minimizing costs is called optimization. The determination of the amount of production to obtain a maximum profit can be solved by using a linear program model with the simplex method. In addition to finding the optimal solution, an analysis is often carried out to find out what changes occur in the coefficient of the objective function and the right segment constant in the constraint function. The analysis is called sensitivity analysis. Sensitivity analysis is an analysis carried out to determine production parameters to changes in the performance of the production system in generating profits. In addition, sensitivity analysis can also explain the extent to which the coefficients of the objective function and the right segment constant of the constraint function can change without affecting the optimal function.

So far, the production of Angga Furniture's MSMEs is not in accordance with the expected target so that it cannot generate optimal profits. This problem requires a model to get maximum profit, namely by using the simplex method and followed by sensitivity analysis to determine the range of changes in the coefficients of the objective function and the constant of the right segment of the constraint function in the previously obtained simplex model. Based on the description above, the author is interested in conducting research on sensitivity analysis to seek maximum profits in the production of Angga Furniture MSMEs. In this study, the author took 5 variables, namely baby swing (x_1), capsule chair (x_2), flower pot (x_3), room divider (x_4), and serving hood (x_5).

2. Methods

2.1 Simplex Method

The simplex method is one of the optimal solution determination techniques used in linear programming. The simplex method is an algorithmic procedure used to calculate and store a large number of numbers in the current iterations and make decisions on the next iteration. Iteration is the same calculation process and is carried out repeatedly or several times until optimal results are obtained (Surachman, 2015). According to Suyitno (2017), the outline of the steps to determine the completion of linear program optimization using the Simplex Method in the form of n variables and m constraints is as follows:

1. Change the equation in the story question to the form of a mathematical model. Make sure the problem meets the requirements of the linear program, such as limits, objectives, and alternative actions.

2. Next, change the form of inequality into a standard form of linear program so that calculations can be carried out using the simplex method by giving rise to additional variables such as tightening variables, pseudo-variables, and artificial variables.

3. Arrange the initial program in a simplex table with all the values of the base variable being zero.

4. The first step to do the calculation using simplex is to conduct a program optimization test by investigating the value of $C_j - Z_j$. The value of Z is obtained from the sum of the multiplication between the coefficient of the base variable and the efficiency of the decision variable. If the problem is maximum, the program is said to be not optimal if there is still a value While if the problem is minimal, the program is said to be not optimal if there is still a value $C_j - Z_j \leq 0. C_j - Z_j \geq 0$.

5. If the program is not optimal, then select the key column element with the rules are as follows:

    - Define the key columns by selecting the smallest negative value for the maximize problem and the largest positive value for the minimize problem. $C_j - Z_j C_j - Z_j$
    - Calculate the value divided by the corresponding key columns.b_i
    - Determine the key row by looking at the value divided by the smallest key column by fixing negative, zero, and undefined results.b_i
    - Changing the key element to a value of 1.
    - Calculating the value of Z is done by adding the multiplication between and the corresponding base variableb_i
    - Construct a new simplex table by replacing the base variable on the key row and replacing it with the variable in the key column. Next, fix all the elements in the table using the following transform formula:

      For a key line that is now a new base variable using the formula

      $$\text{new key row} = \frac{\text{old key row}}{\text{key figure}}$$

      For other lines,

      $$\text{New value} = \text{Old value } (-\text{Entering variable} \times \text{ key field})$$

6. Next, steps such as step four can be done as another first step to complete the table. If it turns out that there are still those who have not met the optimal requirements, then the steps can be taken again as above. While if has been met, then a conclusion can be drawn on the table obtained. With the optimal value is at the value of Z and the value of the optimal decision variable is in the column b_i.

a. Sensitivity Analysis

According to Amiruddin, sensitivity analysis is an action that needs to be taken to find out the possible consequences of changes in the function of the purpose and value of the right segment of the constraint function can be predicted and anticipated in advance. Sensitivity analysis is an analysis that is carried out to observe changes that occur in the coefficient of the objective function and the constraint function, sensitivity analysis explains the extent to which the coefficient of the objective function and the function of the constraint can change without affecting the optimal solution (Siswanto, 2006). In principle, there are several changes that may occur and can be answered through sensitivity analysis, namely changes in the coefficient of objective functions either in the basic (base) or non-base coefficient and its effect on variables, changes in constraints either in capacity or coefficients, new decision variables and the addition of new constraints or constraints.

Sensitivity analysis in cases of 2 variables can be solved by the graphical method, while in cases of more than 2 variables can be solved by the simplex method:

1. Change in the function coefficient of the purpose of the base variable

Based on the optimal table above, it can be seen that the variable to determine the range of change in the coefficient of the purpose function of the base variable, the following formula is used:

$$\hat{C}_j = C_b \ \hat{Y}_j - C_j \tag{1}$$

The optimal table conditions remain optimal if $\hat{C}_j \geq 0$

C_b= coefficient of the objective function of the base variable in the optimal table

$\hat{Y}_j$= dual variable of the result variable/slack variable

$\hat{C}_j$= indicates a new value or value in the optimal table

C_j= coefficient on the objective function

2. Change of the constant of the Right Segment of the constraint function

   The change in the right-hand constant of the constraint function in the optimal table can be determined by investigating the change of the new right-field constant in the optimal table, or formulated as:

$$\hat{b}_i = B^{-1} b_i \tag{2}$$

B^{-1}= matrix below the initial base variable in the optimal table

$\hat{b}_i$ = indicates a new value or value in the optimal table .

b. Matrix

Matrix arrays are rectangular arrays of numbers. The numbers in the order are called entries in the matrix. The size of the matrix varies in size. The size of the matrix is explained by stating the number of rows (horizontal lines) and the number of columns (vertical lines) contained in the matrix. In the matrix, it is explained that the matrix has row 2 and column 2, while in the matrix it is explained that the matrix has row 2 and column 3. $M_{2\times2}M_{2\times3}$The arithmetic operations that are commonly performed on matrices are the addition and multiplication operations of two matrices, as well as the multiplication of the matrix by scalars.

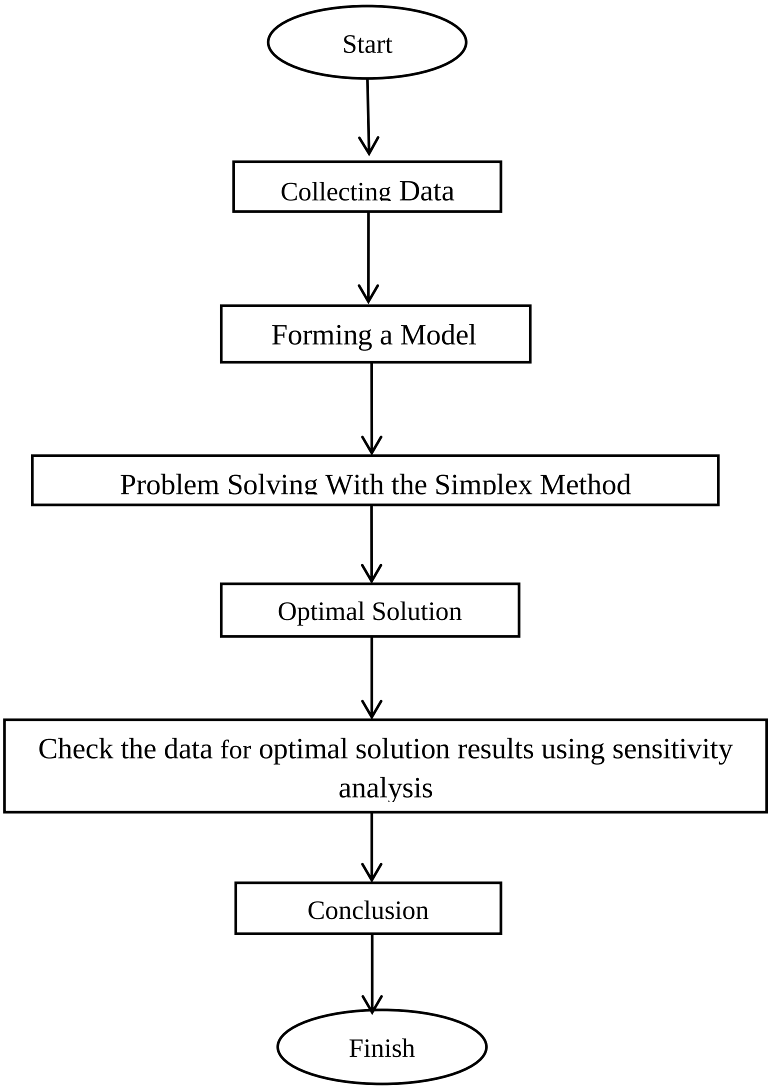

Figure 1. Sensitivity Analysis Flowchart

3. Results and Discussion

3.1 Solving with the Simplex Method

In this study, data collection was taken through direct interviews with MSME owners Angga Furniture. The data taken is daily data on the amount of raw material inventory, selling price, production cost, and profit from each variable in sales in one production time which can be seen in the following table:

Table 1.
Availability of Raw Materials for One-Time Production

Constraints	x_1	x_2	x_3	x_4	x_5	Stock in stock (kg)
Rattan	9	24	12	9	0	324
Pitrich	1	4	0	2	1	50
Rattan sago	1	1	1	0,5	0,5	20
Paku	0,8	0,5	0,25	0,2	0,05	20
Straps	0,1	0,2	0,05	0,05	0,05	10
Cat	0,25	0,5	0,25	0,2	0,05	20

Table 2.
Advantages of One-Time Production Sales

Variabel	Kind of Variable	Selling price	Production costs	Advantages
x_1	Baby swing	IDR 250,000	IDR 167,000	IDR 83,000
x_2	Capsule seat	IDR 600,000	IDR 400,000	IDR 200,000
x_3	Flower pots	IDR 90,000	IDR 60,000	IDR 30,000
x_4	Room divider	IDR 300,000	IDR 200,000	IDR 100,000
x_5	Serving Lids	IDR 150,000	IDR 100,000	IDR 50,000

Based on Table 2, the following constraint functions are obtained.

$$\begin{aligned} 9x_1 + 24x_2 + 12x_3 + 9x_4 &\leq 324 \\ x_1 + 4x_2 + 2x_4 + x_5 &\leq 50 \\ x_1 + x_2 + x_3 + 0,5x_4 + 0,5x_5 &\leq 20 \\ 0,8x_1 + 0,5x_2 + 0,25x_3 + 0,2x_4 + 0,05x_5 &\leq 20 \\ 0,1x_1 + 0,2x_2 + 0,05x_3 + 0,05x_4 + 0,05x_5 &\leq 10 \\ 0,25x_1 + 0,5x_2 + 0,25x_3 + 0,2x_4 + 0,05x_5 &\leq 20 \end{aligned} \tag{3}$$

From equation 3, it is known that all constraint functions have a sign, so the Slack variable is added to the constraint function. So the constraint function is obtained as follows.≤

$$9x_1 + 24x_2 + 12x_3 + 9x_4 + S_1 = 324$$

$$x_1 + 4x_2 + 2x_4 + x_5 + S_2 = 50$$

$$x_1 + x_2 + x_3 + 0{,}5x_4 + 0{,}5x_5 + S_3 = 20 \qquad (4)$$

$$0{,}8x_1 + 0{,}5x_2 + 0{,}25x_3 + 0{,}2x_4 + 0{,}05x_5 + S_4 = 20$$

$$0{,}1x_1 + 0{,}2x_2 + 0{,}05x_3 + 0{,}05x_4 + 0{,}05x_5 + S_5 = 10$$

$$0{,}25x_1 + 0{,}5x_2 + 0{,}25x_3 + 0{,}2x_4 + 0{,}05x_5 + S_6 = 20$$

Based on table 4, the function of the purpose is obtained, namely:

$$Maks\ Z = 83.000x_1 + 200.000x_2 + 30.000x_3 + 100.000x_4 + 50.000x_5 + 0S_1 + 0S_2 + 0S_3 + 0S_4 + 0S_5 + 0S_6 \qquad (5)$$

In equation 5, there is a variable S where the variable S *is* added because for the constraint function the sign ≤ must be added the variable S (slack variable). Based on Table 2 and Table 3, an Initial Table is formed to obtain maximum profit using the Simplex Table Method as shown in Table 3 below:

Table 3.
Initial table

CB	C_j	83.000	200.000	30.000	100.000	50.000	0	0	0	0	0	0	b_i	R_i
	Basis	$x1$	$x2$	$x3$	$x4$	$x5$	$S1$	$S2$	$S3$	$S4$	$S5$	$S6$		
0	s1	9	24	12	9	0	1	0	0	0	0	0	324	324/24= 13,5
0	$s2$	1	4	0	2	1	0	1	0	0	0	0	50	50/44= 12,5
0	$S3$	1	1	1	0,5	0,5	0	0	1	0	0	0	20	20/1=20
0	$S4$	0,8	0,5	0,25	0,2	0,05	0	0	0	1	0	0	20	20/0,5=40
0	$S5$	0,1	0,2	0,05	0,05	0,05	0	0	0	0	1	0	10	10/0,2=50
0	$S6$	0,25	0,5	0,25	0,2	0,05	0	0	0	0	0	1	20	20/0,5=40
	Zj	0	0	0	0	0	0	0	0	0	0	0	0	
	Cj – Zj	83.000	200.000	30.000	100.000	50.000	0	0	0	0	0	0		

=key column =key row =key number

From the key line we must change the number on that key line to obtain a new number on the key line seen in Table 5 below:

Table 4.
Finding New Numbers on Key Numbers

Old key line	1	4	0	2	1	0	1	0	0	0	0	50
Key numbers	4	4	4	4	4	4	4	4	4	4	4	4
New figures x_2	0.25	1	0	0.5	0.25	0	0.25	0	0	0	0	12,5

The new number of the key row is moved to the new key row in the iteration table 1 As for the empty row, i.e. the non-key row, it is determined by,

(New numbers on non-key lines) = (old numbers on non-key lines) - {New numbers on the key line × The number of the cross of the key column with the row being searched }

The results of the first, second, third, and seventh non-key rows are moved to Table 6 of the Table of Iteration 1. Before forming IterationTable 1, first determine the values of the Zj row and the Cj – Zj row. After the value on the Zj line is obtained, the next step is to subtract the Cj line by the Zj line. So Table 5 of Table 1 is formed which can be seen in the following table:

Table 5.
Table of Iteration 1 (Final Table of Table of Iteration 1)

CB	C_j	83.000	200.000	30.000	100.000	50.000	0	0	0	0	0	0	b_i	R_i
	Basis	$x1$	x_2	$x3$	$x4$	$x5$	$S1$	$S2$	$S3$	$S4$	$S5$	$S6$		
0	S1	3	0	12	-3	-6	1	-6	0	0	0	0	24	8
200.000	$x2$	0,25	1	0	0,5	0,25	0	0.25	0	0	0	0	12,5	50
0	$S3$	0,75	0	1	0	0,25	0	-0.25	1	0	0	0	7,5	10
0	$S4$	0,675	0	0.25	-0,05	-0,075	0	-0.125	0	1	0	0	13,75	20,37
0	$S5$	0,05	0	0.05	-0,05	0	0	-0.05	0	0	1	0	7,5	150
0	$S6$	0,125	0	0.25	-0,05	-0,075	0	-0.125	0	0	0	1	13,75	110
	Zj	50.000	200.000	0	100.000	50.000	0	50.000	0	0	0	0	2.500.000	
	Cj – Zj	33.000	0	30.000	0	0	0	-50.000	0	0	0	0		

=key column =key row =key number

Based on Table 5, the result of the value of Cj - Zj is still positive, so the value is still not maximum, so it is continued to the next Iteration Table in the same way when creating the Iteration Table 1. After searching for several Iteration Tables, the optimal final results can be found in the following 4th Iteration Table:

Table 6.

Iteration Table 4 (Final Result of Iteration Table 4)

CB	C_j	83.000	200.000	30.000	100.000	50.000	0	0	0	0	0	0	b_i
	Basis	$x1$	$x2$	$x3$	$x4$	$x5$	$S1$	$S2$	$S3$	$S4$	$S5$	$S6$	
83.000	$x1$	1	0	1,3333	0	0,3333	0	-0,3333	1,3333	0	0	0	10
200.000	$x2$	0	1	1	0	-1	0,1667	-0,5	-1	0	0	0	9
100.000	$x4$	0	0	-2,6667	1	2,3333	-0,3333	1,6667	1,3333	0	0	0	2
0	$S4$	0	0	-0,7833	0	-0,1833	-0,0167	0,1833	-0,8333	1	0	0	7,1
0	$S5$	0	0	-0,15	0	0,1	-0,0167	0,05	0	0	1	0	7,1
0	$S6$	0	0	-0,05	0	0	-0,0167	0	-0,1	0	0	1	12,6
	Z_j	83.000	200.000	44.000	100.000	61.000	0	39.000	44.000	0	0	0	2.830.000
	Cj − Zj	0	0	-14.000	0	-11.000	0	-39,000.0	-44,000	0	0	0	

Because the value in the column in Iteration 4 is already zero or negative, the solution is optimal and the calculation is stopped by performing four iterations. The results of the completion of the variable values obtained and the value of $C_j - Z_j x_1 = 10, x_2 = 5, x_4 = 10 Z = 2.830.000$.

3.2 Solution with Sensitivity Analysis

After the optimal solution is obtained, then sensitivity analysis is carried out to the coefficient of the objective function and the constant of the right segment of the constraint function. To complete sensitivity analysis, it can be done with several methods, one of which is the simplex method. From the above results, it shows the range of changes in the coefficient of the objective function and the constant of the right segment of the constraint function and for simplicity it can be seen in table 7 and table 8 as follows:

1). Range of Change coefficient of purpose function (C_j)

Table 7.
Range of Change in Purpose Function (in rupiah units)

Objective Function Coefficient	Range of changes	Objective Function Coefficient	Range of changes
C_1	$[50.000, 200.000]$	C_4	$[77.000, 100.000]$
C_2	$[200.000, 244.000]$	C_5	$[-\infty, 61.000]$
C_3	$[-\infty, 44.000]$		

Table 6 shows the results of the sensitivity analysis of the production of Angga Furniture MSMEs, in the table the ranges of changes in the coefficient of the purpose function are produced. Changes in the coefficient of the purpose function are related to changes in the selling price owned by MSMEs. In the above problems, namely:

C_1 = Baby Swing Selling Price (x_1)

C_2 = Capsule Seat Selling Price (x_2)

C_3 = Flower pot selling price (x_3)

C_4 = Selling Price of Room Dividers (x_4)

C_5 = The Selling Price of Scarves (x_5)

The range of changes that can be made to the coefficient of the objective function is the first of the baby swing profit (the minimum profit obtained is Rp.50,000.00 and the maximum is up to Rp.200,000.00 which means the highest profit is Rp.200,000.00. Furthermore, the minimum profit () capsule seat obtained is Rp. 200,000.00 and the maximum is Rp. 244,000.00. Furthermore, the flower pot (the maximum profit obtained is Rp.44,000.00. Furthermore, the room divider (the minimum profit obtained is Rp. and the maximum is Rp.100,000.00. Furthermore, the serving hood (the maximum profit obtained is Rp.61,000.00. x_1)x_2x_3)x_4) 77.000,00x_5)

2) The change range of the constant of the right segment of the constraint function (b_i)

Table 8.
Range of Change of the Constant of the Right Segment of the Constraint Function

Right Segment Constant Constraint Function	**Range of changes**	**Right segment constant of constraint function**	**Range of changes**
b_1	[270,330]	b_4	$[13, \infty]$
b_2	[49,68]	b_5	$[3, \infty]$
b_3	[18,29]	b_6	$[7, \infty]$

Table 8 shows the results of the sensitivity analysis of the production of Angga Furniture MSMEs, in the table the ranges of constant changes in the right segment of the constraint function. The constant change in the right segment of the constraint function is related to the change in raw materials owned by the company. In the above problems, namely:

b_1 = Rattan Raw Material

b_2 = Pittric Raw Material

b_3 = Raw Material of Rattan Sago

b_4 = Nail Raw Material

b_5 = Strap-On Raw Material

b_6 = Paint Raw Material

The range of changes that can be made to the constant of the right segment of the constraint function is the first in the rattan raw materials used (what is meant is the minimum rattan raw material used by the company in the production of Angga Furniture MSMEs as much as 270 kg and a maximum of 330 kg. Furthermore, the minimum raw materials used by the company are 49 kg and a maximum of 68 kg. Furthermore, the raw materials for sago rattan used as raw materials for sago rattan are the minimum used by the company, which is 18 kg and a maximum of 29 kg. Furthermore, the minimum nail raw materials used by the company are 13 kg and there is no limit to the maximum. Furthermore, the minimum strap-on material used by the company is 3 kg and there is no limit to the maximum. And then on the paint raw materials used (so the minimum paint raw material used by the company is 7 kg and there is no limit to the maximum. $b_1[270,330]$, b_2 $[49,68]$, b_3 $[18,29]$, b_4 $[13,\infty]$, b_5 $[3,\infty]$, b_6 $[7,\infty]$.

3). Proof if one of the coefficients of the destination function changes (above and below the range)

In Table 8 it can be seen that the value can change to the extent that . If the value changes to 250,000 (above the range) then the optimal solution changes. It can be seen in the following Figure 2 : $x_1 50.000 \leq x_1 \leq 200.000 x_1$

	X1	X2	X3	X4	X5		RHS	Dual
Maximize	250000	200000	30000	100000	50000			
Constraint 1	9	24	12	9	0	<=	324	0
Constraint 2	1	4	0	2	1	<=	50	0
Constraint 3	1	1	1	.5	.5	<=	20	250000
Constraint 4	.8	.5	.25	.2	.05	<=	20	0
Constraint 5	.1	.2	.05	.05	.05	<=	10	0
Constraint 6	.25	.5	.25	.2	.05	<=	20	0
Solution->	20	0	0	0	0		5000000	

FIGURE 2. Table of Value Change x_1 Above the Range

Furthermore, if the value changes to 45,000 (below the range) then the optimal solution also changes. It can be seen in the following Figure 3: x_1

	X1	X2	X3	X4	X5		RHS	Dual
Maximize	45000	200000	30000	100000	50000			
Constraint 1	9	24	12	9	0	<=	324	0
Constraint 2	1	4	0	2	1	<=	50	42500
Constraint 3	1	1	1	.5	.5	<=	20	30000
Constraint 4	.8	.5	.25	.2	.05	<=	20	0
Constraint 5	.1	.2	.05	.05	.05	<=	10	0
Constraint 6	.25	.5	.25	.2	.05	<=	20	0
Solution->	0	1.5	7.5	22	0		2725000	

FIGURE 3. Table of Value Change x_1 Under Range

From the explanation above, it can be concluded that the minimum profit and maximum profit that can be obtained are:

$$Z_{min} = 50.000(10) + 200.000(9) + 30.000(0 + 77.000(2) + 50.000(0)$$

$$= 500.000 + 1.800.000 + 154.000$$

$$= 2.454.000$$

$$Z_{max} = 200.000(10) + 244.000(9) + 44.000(0) + 100.000(2) + 61.000(0)$$

$$= 2.000.000 + 2.196.000 + 200.000$$

$$= 4.396.000$$

Based on the results of the Sensitivity Analysis on the sales of MSMEs Angga Furniture, the minimum sales profit was obtained which was Rp.2,454,000.00 and the maximum sales profit was Rp.4,396,000.00.

4. Conclusion

Based on the results of the research that has been carried out and the results of analysis and discussion, conclusions can be drawn, namely as follows

1. The results of profit optimization using the simplex method in the production of Angga Furniture MSMEs obtained a maximum completion of Z = 2,830,000 which occurred during the Baby Swing (unit, Capsule Chair (unit and room divider $x_1) = 10x_2) = 9(x_4) = 2$ unit.
2. The results of sensitivity analysis on the range of changes in the coefficient of the objective function and the constant of the right segment of the constraint function obtained a minimum sales profit of Rp.2,454,000.00 and a maximum sales profit of Rp.4,396,000.00.

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