



## Optimization of Teak Wood Furniture Production Using Linear Programming Method at Sumenep East Java Indonesia

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### Abstract

3R Furniture company produces some products, i.e., doors, chairs, cabinets, tables, and frames. This company has some problems with maximizing production and minimizing the cost of production. The 3R furniture company has not managed demand properly because it has been unable to synchronize its available resources with fulfilling consumer demand. This study aims to determine the number of products produced by the "3R" Furniture Company by utilizing available resources and finding the maximum profit obtained by the "3R" Furniture Company in Sumenep Regency. This research was conducted at the "3R" Furniture Company in Sumenep Regency, especially on Kangean Island. Linear programming is an operational research model usually used to solve optimization problems. The simplex method is a method that can be used in linear programming, which serves to find optimal solutions. This research aims to optimize the benefits of 3R Furniture company. The respondents comprised 4 people, one business owner and three labor representatives from the "3R" Furniture business. The results showed that the number of products produced to obtain maximum profit was 30 units of tables by utilizing existing resources. The maximum gain from creating a table is Rp. 20999.998.

## INTRODUCTION

In Kangean Island, the furniture company, namely 3R Furniture, processed wood products into doors, chairs, cabinets, tables, and frames. The wood used as the primary material for production is teak wood. The company was founded on a land area of 900 M2 in 2005. The owner of this industry is Mr. Abdurrahman, who has pioneered and developed this industry until now. This company has some problems maximizing the benefit and minimizing the production cost. In determining the amount of production, a plan is needed. In furniture companies 3R, the capacity of production decisions still does not consider labor capacity and material availability.

For example, the company cannot produce certain types because the raw materials are unavailable and are still waiting for delivery. Because the company uses a piece-rate system, the results obtained are different for each worker in terms of products produced and time. The availability of company resources at the 3R furniture company is a problem in production planning, which influences the expected profit and is hard to estimate. The 3R furniture company has not managed demand properly because it has been unable to synchronize its available resources with fulfilling consumer demand. The optimization of the production process cannot be achieved, and profits cannot be predicted correctly and precisely.

Production is the creation of products (goods/services). It also can be interpreted as an activity or process of transforming inputs into outputs. Operational management is a process or action of making products by transforming inputs into results. Production and operations management can also be defined as managing and coordinating various resources' effective and efficient use to create products or improve their value [1]. The Linear Programming method is an option that will determine the amount of production of each furniture product so that the production process can be optimized precisely and adequately. Several previous studies have discussed the implementation of this linear programming[2], [3], [12], [13], [4]–[11].

Applying this linear programming also determines how many units must be produced by the 3R furniture industry located in Kangean. This furniture industry has several cabinets with the same primary raw material: teak wood. The products include Decorative Cabinets, Tulet Hanging Cabinets, Chairs, Doors, Windows, Frames, and Tables. These seven products are the most often ordered from customers in large or small quantities. Based on the problems above, research is necessary to optimize the furniture products' production process to obtain maximum profit.

## METHOD

In this study, data analysis uses a linear programming model simplex method. The simplex method is one of the solutions of linear programming in which the solution is by using an iteration path, namely determining the possible point of the goal to be achieved with the help of a table until the optimal solution is obtained. The simplex method begins with one feasible point test to determine whether the objective function has achieved optimal results or has not achieved optimal results. When the results obtained from one possible point have not reached optimal results, proceed with the next feasible point, and so on, until the objective function accepts optimal results if there is one[12].

The simplex method is a calculation using an iteration path. Before performing iteration calculations, change the general form of linear programming to a standard format. Changing the common form begins by changing the equation of the constraint function and adding the initial basis variable to each of the existing constraint functions. The initial basis variable indicates that the activity has not been carried out on the precious resource. Even though it is an equation, the constraint function in the general form must be changed first [14]–[17].

Some things must be considered before changing the general form of simplex into the standard form, namely:

- 1) The inequality with the form  $\leq$  in the general structure of the constraint function is first converted into equation  $=$  by adding one slack variable.
- 2) Change the inequality in general form  $\geq$  into equation  $=$  on the constraint function by subtracting one surplus variable.
- 3) Constraint function with equation  $=$  in general form plus artificial variable (artificial variable).

Iterative calculations using the simplex method must be made in tabular form so that the general form converted into standard form is entered into the simplex table in Table 1 [11].

Table 1. Simplex Table

Base Variable	$x_1$	$x_2$	...	$x_n$	$S_1$	$S_2$	...	$S_n$	NK
$Z$	$-c_1$	$-c_2$	...	$-c_n$	0	0	0	0	0
$S_1$	$a_{11}$	$a_{12}$	...	$a_{1n}$	1	0	0	0	$b_1$
$S_2$	$a_{21}$	$a_{22}$	...	$a_{2n}$	0	1	0	0	$b_2$
...	...	...	...	...	...	...	...	...	...
$S_n$	$a_{n1}$	$a_{n2}$	...	$a_{nn}$	...	...	...	1	$b_n$

$Z$  = objective function

$C_n$  = coefficient value from objective decision variable  $x_n$

$x_n$  = decision variable to-n

$S_n$  = slack variable to-n

$a_{(mn)}$  = resource requirements m for every  $x_n$

$b_m$  = total resources

$n$  = total decision variable from 1, 2, ... ,  $n$

$m$  = total of types of resources used from 1, 2..  $m$

Paying attention to the steps in solving the simplex method is necessary. These steps are [18]–[20]:

- 1) Changing the objective function with constraints: after all the objective functions are changed, the objective function is changed to an implicit part,
- 2) Arrange the equations into tabular form.
- 3) Selecting a key column, the key column to be determined is seen from the objective function line with the smallest negative value.
- 4) Selecting the key row, the key row is determined by looking at the smallest ratio value. The ratio value is obtained by dividing the right and key column values.
- 5) Changing the value of the key row, the value of the key row is changed by dividing all the values in the key row by the key number. Then there will be an exit variable and an incoming variable.
- 6) Change the values in the key row with the formula New row = old row – (coefficient per key column \* key row value)

Continue to improve the steps above until optimal results are found. Optimal results will be obtained when the values in the objective function are all positive.

## RESULT AND DISCUSSION

### Production Optimization System Analysis in 3R Furniture

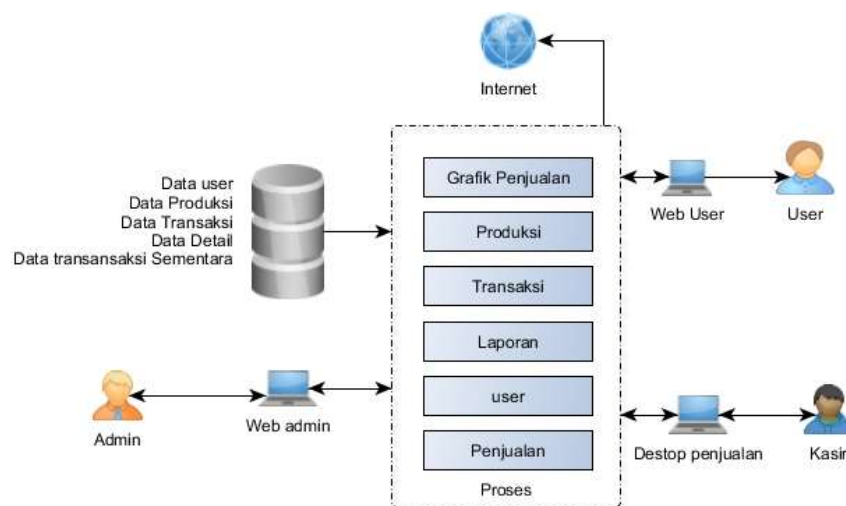


Figure 1. Flowchart System of 3R Furniture

Figure 1 is a diagram or Flow chart system of 3R furniture where there is some data with different needs or users. The admin can manage all the data. The user only sees the graph, and the cashier can make sales. For production, 3R Furniture Company faces some constraints. They are raw materials and operational costs. Data processing using the linear programming simplex method

assisted by WINQSB software shows the results of production optimization obtained by 3R Furniture Company. Based on the production optimization process results, the optimal solution combines products, resource status, and sensitivity analysis.

Then, based on the production data provided by 3R Furniture, some products are released by 3R furniture such as Wardrobe, Cupboard, Chairs, Door, Table, windows, etc. Furthermore, those items have different costs, production times, and profits.

### Research Design

The production capacity data, amount of raw material inventory, the composition of materials for production, and processing time of each product have been obtained in data collection. Furthermore, these data will be used to create a mathematical model in the form of a linear program that will be completed with the help of the WINQSB program so that output will be produced that provides optimal information and sensitivity analysis from the existing system discussion.

Table 2. Production Types

Production Types	Wardrobe $X_1$	Cupboard $X_2$	Chairs $X_3$	Doors $X_4$	Window $X_5$	Frame $X_6$	Table $X_7$
Production Cost/units (Thousand)	1500	750	800	300	100	300	150
Raw Materials/units (Thousand)	2050	1700	1500	800	150	750	500
Packaging Cost/units (Thousand)	600	600	200	200	100	150	150
Selling Price/unit (Thousand)	8050	3500	2700	1700	400	1300	1500

Table 3. Working Hours

Products	Time Estimation of Production per 1 unit (hour/unit)
Wardrobe	56
Cupboard	32
Chairs	56
Door	8
Window	1
Frame	4
Table	8

Table 4. Raw Materials (wood)

Products	Raw Materials (sheet)
Wardrobe	20
Cupboard	17
Chairs	8
Door	3
Window	1.5
Frame	7.5
Table	1.5

Based on the Data above, the Mathematic model will be implemented in a linear program. Then, supporting WINQSB, the solution will be found.

### 1. Decision Variable

A decision variable is a variable that explains the decisions made entirely. The decision Variable will determine the number of wardrobes, cupboards, Chairs, Doors, Tables, windows, frames, and tables that must be produced. Based on the Field research, the variable of decision is as follows:

- a.  $X_1 = \text{Wardrobe}$
- b.  $X_2 = \text{Cupboard}$
- c.  $X_3 = \text{Chairs}$
- d.  $X_4 = \text{Door}$
- e.  $X_5 = \text{Window}$
- f.  $X_6 = \text{Frame}$
- g.  $X_7 = \text{Table}$

### 2. Objectives Function

The objective function is a function of the decision variable to be maximized or minimized. Assist in making the objective function in Table 5, namely the product production table. The objective function is as follows.

$$Z_{max} = 3900X_1 + 450X_2 + 200X_3 + 400X_4 + 50X_5 + 100X_6 + 700X_7$$

### 3. Constraint Function

The Constraint Function consists of the Raw Materials availability table, working hours table, and Raw Materials use table. The Constraint Function is as follows:

- a) Raw Materials Constraints

$$20X_1 + 17X_2 + 8X_3 + 3X_4 + 1.5X_5 + 7.5X_6 + 1.5X_7 \leq 1755$$

- b) Working Hours Constraints

$$56X_1 + 32X_2 + 56X_3 + 8X_4 + 1X_5 + 4X_6 + 8X_7 \leq 240$$

Constraints indicate the capacity of the supply of wood raw materials and working hours for production, raw materials as many as (1755 sheets) and working hours (240 hours). The complete formulation model for the problem of the optimum production amount to get the optimal production amount of the product produced at the 3R Furniture Company with the simplex method is as follows:

#### 1) Replacing of Objectives Function to Constraints Function

- Objectives Function:

$$Z_{max} = -3900X_1 - 450X_2 - 200X_3 - 400X_4 - 50X_5 - 100X_6 - 700X_7$$

- Constraints Function:

$$20X_1 + 17X_2 + 8X_3 + 3X_4 + 1.5X_5 + 7.5X_6 + 1.5X_7 + S_1 \leq 1755$$

$$56X_1 + 32X_2 + 56X_3 + 8X_4 + 1X_5 + 4X_6 + 8X_7 + S_2 \leq 240$$

## 2) Arranging Equation into the table

Table 5. Arranging of Equation

NB	X <sub>1</sub>	X <sub>2</sub>	X <sub>3</sub>	X <sub>4</sub>	X <sub>5</sub>	X <sub>6</sub>	X <sub>7</sub>	S <sub>1</sub>	S <sub>2</sub>	NK
Z	-3900	-450	-200	-400	-50	-100	-700	0	0	0
S <sub>1</sub>	20	17	8	3	1.5	7.5	1.5	1	0	1755
S <sub>2</sub>	56	32	56	8	1	4	8	0	1	240

## 3) Determining of Pivot Columns

Pivot Columns is a column with a row value Z, which is negative for the biggest number.

Table 6. Determining of Key Columns

NB	X <sub>1</sub>	X <sub>2</sub>	X <sub>3</sub>	X <sub>4</sub>	X <sub>5</sub>	X <sub>6</sub>	X <sub>7</sub>	S <sub>1</sub>	S <sub>2</sub>	RE
Z	-3900	-450	-200	-400	-50	-100	-700	0	0	0
S <sub>1</sub>	20	17	8	3	1.5	7.5	1.5	1	0	1755
S <sub>2</sub>	56	32	56	8	1	4	8	0	1	240

## 4) Determining Pivot Row

The smallest index is for determining the Pivot row

$$\text{Index} = \frac{\text{Right element}}{\text{Pivot column element}}$$

Table 7. Determining of Key Row

NB	X <sub>1</sub>	X <sub>2</sub>	X <sub>3</sub>	X <sub>4</sub>	X <sub>5</sub>	X <sub>6</sub>	X <sub>7</sub>	S <sub>1</sub>	S <sub>2</sub>	RE
Z	-3900	-450	-200	-400	-50	-100	-700	0	0	0
S <sub>1</sub>	20	17	8	3	1.5	7.5	1.5	1	0	1755
S <sub>2</sub>	56	32	56	8	1	4	8	0	1	240

## 5) Determining of new Pivot row element

Current Pivot row = Pivot row / Pivot number

Table 8. Determining of new pivot row value

NB	X <sub>1</sub>	X <sub>2</sub>	X <sub>3</sub>	X <sub>4</sub>	X <sub>5</sub>	X <sub>6</sub>	X <sub>7</sub>	S <sub>1</sub>	S <sub>2</sub>	NK
Z										
S <sub>1</sub>										
X <sub>1</sub>	1	$\frac{4}{7}$	1	$\frac{1}{7}$	$\frac{1}{56}$	$\frac{1}{14}$	$\frac{1}{7}$	0	$\frac{1}{56}$	$\frac{30}{7}$

## 6) Replacing the Pivot row element

Current Row = old row – (Pivot column element \* New Pivot row )

$$\begin{array}{r}
 Z \quad (-3900 \quad -450 \quad -200 \quad -400 \quad -50 \quad -100 \quad -700 \quad 0 \quad 0 \quad 0) \\
 -3900 \left( \begin{array}{cccccccccc} 1 & \frac{4}{7} & 1 & \frac{1}{7} & \frac{1}{56} & \frac{1}{14} & \frac{1}{7} & 0 & \frac{1}{56} & \frac{30}{7} \end{array} \right) - \\
 \hline
 \begin{array}{cccccccccc} 0 & -\frac{3}{7} & 3700 & -\frac{6}{7} & -\frac{5}{14} & -\frac{3}{7} & -\frac{6}{7} & 0 & \frac{9}{14} & 15600 \end{array} \\
 \\
 S_1 \quad (20 \quad 17 \quad 8 \quad 3 \quad 1.5 \quad 7.5 \quad 1.5 \quad 1 \quad 0 \quad 87) \\
 -20 \left( \begin{array}{cccccccccc} 1 & \frac{4}{7} & 1 & \frac{1}{7} & \frac{1}{56} & \frac{1}{14} & \frac{1}{7} & 0 & \frac{1}{56} & \frac{30}{7} \end{array} \right) - \\
 \hline
 \begin{array}{cccccccccc} 0 & \frac{39}{7} & -12 & \frac{1}{7} & \frac{8}{7} & \frac{85}{7} & -\frac{19}{14} & 0 & -\frac{5}{14} & \frac{11685}{7} \end{array}
 \end{array}$$

Table 9. Iteration table 1

NB	X <sub>1</sub>	X <sub>2</sub>	X <sub>3</sub>	X <sub>4</sub>	X <sub>5</sub>	X <sub>6</sub>	X <sub>7</sub>	S <sub>1</sub>	S <sub>2</sub>	NK
Z	0	$\frac{12450}{7}$	3700	$\frac{1100}{7}$	$\frac{275}{14}$	$\frac{1250}{7}$	$-\frac{1000}{7}$	0	$\frac{975}{14}$	$\frac{117000}{7}$
S <sub>1</sub>	0	$\frac{39}{7}$	-12	$\frac{1}{7}$	$\frac{8}{7}$	$\frac{85}{7}$	$-\frac{19}{14}$	0	$-\frac{5}{14}$	$\frac{11685}{7}$
X <sub>1</sub>	1	$\frac{4}{7}$	1	$\frac{1}{7}$	$\frac{1}{56}$	$\frac{1}{14}$	$\frac{1}{7}$	0	$\frac{1}{56}$	$\frac{30}{7}$

Table 10. Iteration Table 2

NB	X <sub>1</sub>	X <sub>2</sub>	X <sub>3</sub>	X <sub>4</sub>	X <sub>5</sub>	X <sub>6</sub>	X <sub>7</sub>	S <sub>1</sub>	S <sub>2</sub>	NK
Z	1000	2350	4700	300	37.5	250	0	0	87.5	20999.998
S <sub>1</sub>	$\frac{19}{2}$	11	$-\frac{5}{2}$	$\frac{3}{2}$	$\frac{1313}{1000}$	$\frac{27}{4}$	0	1	$-\frac{3}{16}$	1710
X <sub>7</sub>	7	4	7	1	$\frac{1}{8}$	$\frac{1}{2}$	1	0	$\frac{1}{8}$	30

Perhitungan persamaan kedalam tabel

Baris	X1	X2	X3	X4	X5	X6	X7	S1	S2	S3	S4	S5	S6	S7
S1	20.00	17.00	8.000	3.000	1.500	7.500	1.500	1.000	0.000	0.000	0.000	0.000	0.000	1710
S2	50.00	32.00	50.00	8.000	1.000	4.000	8.000	0.000	1.000	0.000	0.000	0.000	0.000	162.0
S3	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000
S4	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000
S5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000
S6	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000
S7	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Zj-Cj	-3900	-450.0	-200.0	-400.0	-50.00	-100.0	-700.0	0.000	0.000	0.000	0.000	0.000	0.000	0.000

S[1]=1755.00  
 S[2]=240.000  
 S[3]=0.000000  
 S[4]=0.000000  
 S[5]=0.000000  
 S[6]=0.000000  
 S[7]=0.000000  
 Maks(Z) = 0.0

Figure 2. Simplex Table

Figure 3. Iteration Table 1

Figure 4. Iteration Table 2

The calculation of profit optimization with the simplex method obtained maximum results, namely profits obtained by using all available production time and labor to produce tables ( $X_7$ ), namely a total of 30 units of tables, resulting in a gain of Rp. 20999.998. Based on these results, it can be seen that the linear programming method can be used in profit optimization. These results are related to research that uses the linear programming method to solve optimization cases.

In this study, the validation was carried out by testing. This test is done by involving calculations. This test aims to measure the level of truth of the calculation results of the system made. The test method is by performing calculations with different inputs or case studies, and the accounting results will be matched with data from the case studies. The test table can be seen in

Table 11. System Result Testing

No	Case Study	System Result Testing	Case Study Optimization Result	Accordance
1	$Z = 30X_1 + 40X_2$ Constrain : $3X_1 + 4X_2 \leq 120$ $X_2 \leq 20$ $2X_1 + 2X_2 \leq 40$	$Z_{max} = 800$	$Z_{max} = 800$	equal
2	$Z = 5X_1 + 3X_2$ Constrain : $2X_1 \leq 8$ $X_2 \leq 15$ $6X_1 + 5X_2 \leq 30$	$Z_{max} = 27\frac{1}{2}$	$Z_{max} = 27\frac{1}{2}$	equal

No	Case Study	System Result Testing	Case Study Optimization Result	Accordance
3	$Z = 60X_1 + 80X_2$ Constrain : $2X_1 + 2X_2 \leq 16$ $3X_1 + 5X_2 \leq 30$ $2X_1 + 3X_2 \leq 36$ $Z_{max} = 540$	$Z_{max} = 540$	$Z_{max} = 540$	equal
4	$Z = 8X_1 + 6X_2$ Constrain : $4X_1 + 2X_2 \leq 60$ $2X_1 + 4X_2 \leq 48$	$Z_{max} = 132$	$Z_{max} = 132$	equal
5	$Z = 15X_1 + 18X_2 + 12X_3$ Constrain : $10X_1 + 12X_2 + 8X_3 \leq 120$ $18X_1 + 15X_2 + 6X_3 \leq 135$ $12X_1 + 16X_2 + 6X_3 \leq 150$	$Z_{max} = 180$	$Z_{max} = 180$	equal
6	$Z = 8X_1 + 9X_2 + 4X_3$ Constrain : $X_1 + X_2 + 2X_3 \leq 2$ $2X_1 + 3X_2 + 4X_3 \leq 3$ $7X_1 + 6X_2 + 2X_3 \leq 8$	$Z_{max} = 31/3$	$Z_{max} = 31/3$	equal
7	$Z = 30.000X_1 + 50.000X_2$ Constrain : $2X_1 \leq 8$ $3X_2 \leq 15$ $6X_1 + 5X_2 \leq 30$	$Z_{max} = 275000$	$Z_{max} = 275000$	equal
8	$Z = 5X_1 + 4X_2$ Constrain : $6X_1 + 4X_2 \leq 24$ $X_1 + 2X_2 \leq 6$ $-X_1 + X_2 \leq 1$ $X_2 \leq 2$	$Z_{max} = 21$	$Z_{max} = 21$	equal
9	$Z = 60X_1 + 30X_2 + 20X_3$ Constrain : $8X_1 + 6X_2 + X_3 \leq 48$ $4X_1 + 2X_2 + 1.5X_3 \leq 20$ $2X_1 + 1.5X_2 + 0.5X_3 \leq 8$ $X_2 \leq 5$	$Z_{max} = 280$	$Z_{max} = 280$	equal
10	$Z = 180X_1 + 170X_2$ Constrain : $40X_1 + 20X_2 \leq 100$ $48X_1 + 24X_2 \leq 120$	$Z_{max} = 850$	$Z_{max} = 850$	equal

Based on the test results in Table 10, it can be concluded that as many as 10 data samples produce accuracy values according to the following calculations: Accuracy element counting =  $10/10 \times 100 = 100\%$ . So, based on the results of tests carried out on the system with as much as 10 data, the accuracy value obtained is 100% accurate, which shows that the optimization system is functioning correctly.

## CONCLUSION

Based on the findings and results, several conclusions can be drawn that the mathematical model for optimizing cost production in 3R Furniture consists of the objective and constraint functions. The objective function is maximizing the sum of the multiplication between the contributions of production costs with the decision variables of each style on each machine. The constraints function is the constraints of working hours, demand, and use of wood. The working hours constraints for each device must be less than 24 hours, the demand constraints for each style produced on the seven machines are at least the same or more than the order, and the wood capacity constraints indicate that the seven types made in each production must less than or equal to the production capacity for each exhibition, and the decision variable must be non-negative. The working hours constraint for each machine must be less than 24 hours, and the demand constraints for each style produced on the seven machines are at least the same or more than the order. The wood capacity constraints indicate that the seven types made in each production must be less than or equal to the production capacity for each show, and the decision variable must be non-negative.

This study also concluded that the cost of producing 3R furniture by the 3R Furniture Company is optimal. It can be shown by the calculation of the program that I made that fulfills the objective and constraint functions. In other words, the result obtained is the optimal value. In addition, because the profit from the calculation carried out by the 3R Furniture Company is Rp. 20,999,998.00 from the table production carried out by the 3R Furniture Company, it can be concluded that the table production profit by the 3R Furniture Company is optimal.

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