

Optimization of Fabric Production through Linear Programming to Maximize Profit of a Textile Industry

R A Harianto¹, Supriyanto² and R Wijayaningsih³

^{1,2,3}Universitas Bhayangkara Jakarta Raya, Indonesia

¹haribast@gmail.com

Abstract. This study aims at maximizing a business profit in a textile industry. By using a descriptive quantitative approach, the study was conducted in the district of Cikokol, Tangerang, Indonesia by collecting data from a textile company producing yarn and woven fabrics for the years 2016 until 2017. The data was analyzed by using linear programming to maximize a business profit. In its daily process, the company faced many problems or constrains in its production planning. Uncertain demand fluctuation has caused shortage or overproduction. Other problems are the constrain of raw materials, machine working hour, labour working hour, spindle hour per unit, loom hour per unit, and demand of products. The result of the study showed that the total profit earned by the company to produce 6.67 dozen (80 pcs) of T/C woven fabric is US\$ 133.400. On the other hand, total profit to produce 6.67 dozen (80 pcs) of cotton fabric is US\$ 100.050, with the assumption that the profit is in accordance with fixed objective and constrain function.

1. Introduction

The textile and textile product (TPT) manufactured in textile industry in Banten Province is one of the main sources of country's national income, besides accommodating large number of workers. In the year 2014, total number of workers employed in this sector reached up to 1.2 million people, which spread over 2,651 textile companies in Indonesia. West Java Province is the largest producer of textile products in Indonesia, consisting of 1.496 companies (56.43%), followed by DKI Jakarta with 456 companies (17.30%) and Central Java with 381 companies (13.37%). The rests are spread over Sumatra, Yogyakarta, East Java, Bali, and Sulawesi. One of the problems arising from the existence of TPT is the impact of emerging creativity and innovation in the Digital Economy Era that lead to the increased of competitiveness among producers, not only in the domestic market but also foreign markets. One of the most popular scientific advancements is linear programming, which is also applicable for textile industry [7]. The linear programming is used to optimize the production of woven fabrics in order to obtain maximum profit. Based on the case study conducted in PT. Argo Pantes, the linear programming technique with simplex model was applied in order to optimize woven fabric production with the aim at maximizing business profit. [4]

2. Research Method

The descriptive quantitative approach of linear programming was applied to maximize profit.[1]. The study was conducted in the district of Cikokol, Tangerang by collecting data from textile industry for the years 2016 until 2017.

3. Problem And Equations In Linear Programming

Linear programming was developed for the first time by George B. Dantzig in 1951. It is a problem-solving method dealing with the use of multiple resources/commodities/factors/products to produce various products. In addition, each unit of the products can provide a maximum benefit. By utilizing linear algebraic theories, several techniques or procedures can be developed [9]. Thus, without having to re-explore the theories; the techniques or procedures can be used to solve the problems that involve the combination of aforementioned resources and products [10]. By employing this method, the potential maximum benefits could be determined. In the textile industry, the linear programming method has been widely applied. For instances, plant operations analysis, production planning, fiber mixing in spinning process, sales-production coordination, marketing strategy, research activities and so forth [2].

In this paper, a brief concept of linear programming and its application in optimizing the production of woven fabric in the company will be described. The formulation of the linear programming problem can be arranged in the form of the following mathematical model. If the factory plans to produce F_1 type of fabric products as much as X_1 units and F_2 as much as X_2 units, then the benefits that can be obtained are:

$$Z = C_1X_1 + C_2X_2 + \dots + C_nX_n \dots\dots\dots (1)$$

Equation (1) is called objective function. Furthermore, producing F_1 fabric as much as X_1 units requires $a_{11}X_1$ spindle-hour and $a_{21}X_1$ loom-hour. Similarly, producing F_2 fabrics as much as X_2 units requires $a_{12}X_2$ spindle-hour and $a_{22}X_2$ loom-hour. Hence, to produce the two kinds of fabric [2], the followings are needed:

- Spindle-hour: $a_{11}X_1 + a_{12}X_2$, and
- Loom-Hour : $a_{21}X_1 + a_{22}X_2$

Since the available capacity of spindle-hour is b_1 and the available capacity of the loom-hour is b_2 , then the usage of the spindle-hour and loom-hour should not exceed the available capacity [5], So that,

- $a_{11}X_1 + a_{12}X_2 \leq b_1 \dots\dots\dots (2)$
- $a_{21}X_1 + a_{22}X_2 \leq b_2 \dots\dots\dots (3)$

Equations (2) and (3) are called the constraint function. In more details, this issue is illustrated in Table 1.

Table 1. Linear programming problems for two types of products¹

Resources	T/C woven fabric F_1	Cotton Fabric F_2	Available Capacity
Fabrics production (unit)	X_1	X_2	
Spindle hour per unit	a_{11}	a_{12}	b_1
Loom hour per unit	a_{21}	a_{22}	b_2
Profit per unit (\$)	C_1	C_2	

Based on Table 1, then the problem formulation can be arranged as follows:

- Maximize: $Z = C_1X_1 + C_2X_2 \dots\dots\dots (4)$
- Constraint Function: $a_{11}X_1 + a_{12}X_2 \leq b_1 \dots\dots (5)$
- $a_{21}X_1 + a_{22}X_2 \leq b_2 \dots\dots (6)$
- $X_1, X_2 \geq 0 \dots\dots\dots (7)$

The main purpose of the problem formulation mentioned above is to determine the prices of X_1, X_2, \dots, X_n while a_{ij}, b_i , and C_j are constants, respectively [6].

4. Problem Solving Method

To solve problems with the linear programming, many methods have been developed. One of the popular methods is the simplex method. Solving the problem with simplex method is to use simple formulas through iteration (repetition/replication steps) by using matrix tables. Thus, the maximum results can be obtained in step by step approach.

5. Result And Discussion

Currently, PT. Argo Pantes produces two types of product. They are T/C woven fabrics and 100% cotton woven fabrics. The two products can provide a net profit of \$20 and \$15 per unit, respectively. The spindle hour per unit (in spinning process) to produce T/C woven fabric is 100; whereas to produce 100% cotton fabrics is needed 50 spindle hour per unit. In addition, the loom hour per unit of producing T/C woven fabric is 20; and 25 loom hour per unit is needed to produce 100% cotton woven fabrics. The results of the study show that total available capacity of the plant is 1000 with 300 total capacity of the loom hour. By using the linear programming, the optimum combination of fabrics to be produced by the factory is presented in Table 2.

Table 2. Data for the problem solving by linear programming²

Resources	Product		Capacity
	T/C Woven Fabric	Cotton Woven Fabric	
Spindle hour per unit	100	50	1.000
Loom hour per unit	20	25	300
Profit per unit (\$)	20	15	

Based on Table 2, the problem can be formulated as follows:

Maximize: $Z = 20X_1 + 15X_2$ (8)
 Constrain Function : $100X_1 + 50X_2 \leq 1000$ (9)
 $20X_1 + 25 X_2 \leq 300$ (10)

5.1 Optimization by Using Simplex Method

The constraint function in the formulation of the above problem contains a sign of inequality. Thus, it must be first changed into a form of equation by adding "slack variable" X_3 and X_4 . So that, the new formulations of the problem are as follows:

$Z - 20X_1 - 15X_2 = 0$ (11)
 $100X_1 + 50X_2 + X_3 = 1000$ (12)
 $20X_1 + 25X_2 + X_4 = 300$ (13)

In the next step, the problem formulation as in equations (11), (12), and (13) will be analyzed by using the simplex algorithm by following the steps as below:

Step 1

Create table 3 and determine X and Z coefficients of the constraint functions and objective functions.

Table 3. Solutions of simplex method in the initial conditions

			1	2	3	4	0
Base Variable	Z	X ₁	X ₂	X ₃	X ₄	RK	
0	Z	1	-20	-15	0	0	0
1	X ₃	0	100	50	1	0	1000
2	X ₄	0	20	25	0	1	300

Variables X_3 and X_4 are slack variables of the initial conditions, which are also considered as a base variable, while X_1 and X_2 are called as non-base variables.

Step 2

At row (0), select the cell with the lowest negative price. This price is obtained in line (0) and column (1) or in cell (01). Since the price is obtained in column (1), then $F = 1$. $F = 1$ is the column for the variable X_1 . Thus, X_1 could be a new base variable (will become base variable).

Step 3

Consider the RK column or column (0) of the newly selected column (1), then choose the smallest positive price of the prices comparison in column (0) divided by the price in column (1). The result of this comparison is as follows:

Row (1): $\frac{1000}{100} = 10$

Row (2): $\frac{300}{20} = 15$

The smallest value is in row (1), so $r = 1$ in row $r = 1$ is a row in X_3 . Thus, the X_3 must leave the row.

Step 4

For row (1) or $r = 1$, the prices are as follows:

Column (1): $a_{11} = 100$ $a'_{rk} = a_{11} = 100$, and then $a_{11} = 100 / 100 = 1$ as a new value
 Column (2): $a_{12} = 50$ $a'_{12} = 50 / 100 = \frac{1}{2}$
 Column (3): $a_{13} = 1$ $a'_{13} = 1 / 100$
 Column (4): $a_{14} = 0$ $a'_{14} = 0 / 100 = 0$
 Column (0): $a_{10} = 1000$, and then $a'_{10} = 1000 (1000 / 100) = 10$

For the other rows (i.e., row (0) and row (2)), each is obtained through the following procedure:

For line (0)

Column (1): $a_{01} = -20$ $a_{11} = 1$ $a_{01} = 0$

Column (2): $a_{02} = -15$ $a_{01} = -20$ $a_{12} = \frac{1}{2}$ then, $a'_{02} = -5$

In the same procedure,

Column (3): $a'_{03} = 0 - (1/100)(-20) = 1/5$

Column (4): $a'_{04} = 0$

Column (5): $a'_{00} = 200$

For Line (2)

Column (1): $a'_{21} = 20 - 1(20) = 0$

Column (2): $a'_{22} = 15$

Column (3): $a'_{23} = -1/5$

Column (4): $a'_{24} = 1$

Column (0): $a'_{20} = 300 - (10)(20) = 100$

Furthermore, fill up the cells in row (0) and row (2) with new values calculated above and the results are as listed in Table 4.

Table 4. Solutions with simplex method in the first iteration

No	Base Variable						RK
		Z	X ₁	X ₂	X ₃	X ₄	
0	Z	1	0	-5	1/5	0	200
1	X ₁	0	1	1/2	1/100	0	10
2	X ₄	0	0	15	-1/5	1	100

The results of the table above shows that row (0) still contain a negative value. Thus, the next calculation is back to Step 2.

Step 2

The smallest negative value in row (0) is in cell (02), thus, F = 2. This means that X₂ will enter the row variable.

Step 3

The comparison of cells in column (0) with column (2) yields the smallest ratio in cell (22) or in row (2). So that, r = 2. Therefore, the variable X₄ will be leaving the base.

Step 4

The new results are listed in Table 5.

Table 5. Solutions with simplex method on the second iteration

No	Base variable						RK
		Z	X ₁	X ₂	X ₃	X ₄	
0	Z	1	0	0	2/15	1/3	233,450
1	X ₁	0	1	0	1/60	1/30	6,67
2	X ₂	0	0	1	-1/75	1/15	6,67

Note : volume in unit x 1000

Step 2

Based on Table 5, row (0) has no longer a negative cell value. The next step is to proceed with step 5.

Step 5

The optimum production quantity of T/C woven fabric of 6.67 dozen (cell contents 10) and 100% cotton woven fabrics is 6.67 dozen listed in the table (content of cell 20). The maximum profit earned is \$233,330.

5.2 Conclusions

Conclusion can be drawn from Table 5 linear programming solution with simplex method that:

1. The production of polyester cotton (T / C) mixed woven fabrics reaches an optimum is 6.67 dozen with profit : US\$ 133.400,-
2. The Production of woven fabric for 100% cotton type reaches an optimum is 6.67 dozen. With Profit: US\$ 100.050,-
3. Maximum profit or business profit can be achieved for \$ 233, 450, -

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