Analyzing Textile Industry by Linear Programming

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Abstract
In this paper, we are trying to optimize the production in the Textile industry with linear programming. To achieve this goal, we need to have a detailed understanding of the various demand factors in the production process, including the capital, production consumption, and quantity of raw materials. With the production data collected from the textile industry, we tested the linear programming model. The result has proven that such a strategy can optimize production methods and maximize profit.

Keywords: *Manufacturing, Linear Programming, Textile*

1. Introduction

1.1 What is our focus?

As research has been done by our group on dozens of industries around the world, the researcher finally decide that the textile industry is worth being and has the potential to be analyzed with the method of linear programming for the purpose of maximizing profit. The market value of this industry shows a trend of constantly increasing during the past 5 years regardless of the impact of the Covid-19 pandemic. At the same time, the global textile market size was around 1000.3 billion USD in 2020, which was approximately the GDP (gross) of the whole country of Indonesia in the same year [1]. These stunning data indicate the immovable demand and massive scale of the textile industry, which certainly was the reason why we chose it to be our analytic target.

1.2 Features of the industry

The textile industry is a very simple and traditional industry with low-cost materials and simple procedures. From the several steps from buying raw materials to selling cloth, the researcher wants to focus on the section of production with fewer inputs and outputs with more stable prices, which is the non-woven fabric industry.

1.3 Capacity of using linear programming

As we previously stated, there are only a few inputs and outputs for the non-woven fabric industry while all of them are having relatively stable prices. With these features, it is relatively easy to set the variables and build mathematical models for linear programming because there are both clearly defined objective functions to optimize and easily identified constraints to be applied.

1.4 Necessity of using linear programming

According to the survey on the textile industry made by Statista, there were 160 thousand manufacturers in EU28 countries in 2019. Other surveys showed that there are 3384 million people in the labor force of the textile industry globally. These data reveal an extremely competitive market that any mistakes made by the managers could cause severe loss of the companies. Under this situation, the optimization strategy calculated by linear programming provides managers better solutions to gain more profit and run the companies more properly.

2. Literature Review

2.1 Textile industry

The textile industry is essentially concerned with

Y. Jiang et al. (Eds.): ICEDBC 2022, AEBMR 225, pp. 1459–1463, 2022.
https://doi.org/10.2991/978-94-6463-036-7_216

planning, generation, and dispersion of yarn, cloth, and clothing. The crude fabric may be natural or manufactured utilizing items of the chemical industry due to the legislative trade motivating forces and opportunity of universal exchanging environment. Within a long time in the past, there has been a critical increase in material projects. The four central generation stages in the material industry are yarn formation, fabric formation, wet processing, and fabrication [2].

2.2 Linear programming

Linear programming (LP) is a mathematical technique for analyzing optimum decisions subject to certain constraints in the linear inequalities. Numerically, it applies to optimization problems that certain factors can represent. Linear programming may hence be a strategy to choose the ideal combination of components (inputs) to deliver a given yield or the perfect variety of items (outputs) to be created by a given plant and gear (inputs) [3,4].

2.2.1 Advantages of Linear Programming

- Quality Decision: The manager can select the best arrangement with the assistance of LP by assessing the cost and profit of different alternatives.
- Maximization of Resources: LP gives a database for optimum allocation of scarce resources.
- Complex Problem: The technique can solve the complex problem we encounter in real life, helping in solving multi-dimensional issues.
- Multiple Constraint: This procedure is more appropriate to solve numerous constraints issues, helping make alterations according to changing conditions.
- Simplicity: Direct programming model can be fathomed with the assistance of a straightforward and straight strategy called simplex.
- Multipurpose: This procedure can solve different real-life problems.

2.2.2 Limitations of Linear Programming

- It isn't simple to characterize a particular objective function. This strategy expects certainty, but the firm might not know the values of objectives and constraints beforehand in a few circumstances.
- Even if a particular objective function is laid down, it may not be easy to discover different mechanical, monetary, and other limitations.
- It is conceivable that the imperatives may not be straightforwardly expressible as linear inequalities.
- It expects parameters that are steady; meanwhile, it isn't so in real life.
- There is no confirmation that the value we are going to get will be an integer. For instance, linear programming arrangement might result in 4.2 machines which are not conceivable in real life.
- Linear programming tackles a single objective; it cannot bargain with different goals. In real life, choice producers at times experience a problem with clashing targets.
- The LP method is based on the presumption of constant returns. In reality, there are either lessening or expanding that a firm encounters in production.
- Linear programming is only utilizable when the firm can represent constraints and objectives in linear equations.

3. Materials and Methods

Data for the study is obtained from another paper investigating this company [1] as well as from the company's website. Data were obtained on the unit cost of each aspect of the production of the 5 products of the company.

3.1. Model Formulation

The objective of this study is to maximize profit.

Where Ci represents the profit derived from the sales of the products (i = 1,2,3,4,5) and Xi represents the number of units produced for each of the products (i = 1,2,3,4,5)

$$Z = C1X1 + C2X2 + C3X3 + C4X4 + C5X5 \quad (1)$$

Subject to

$$a11x1 + a12x2 + a13x3 + a14x4 + a15X5 \leq b1 \quad (2)$$

$$a21x1 + a22x2 + a23x3 + a24x4 + a25X5 \leq b2 \quad (3)$$

$$a31x1 + a32x2 + a33x3 + a34x4 + a35X5 \leq b3 \quad (4)$$

$$aj1x1 + aj2x2 + aj3x3 + aj4x4 + aj5X5 \leq bj \quad (5)$$

$$Non - Negativity = X1, X2, X3, X4, X5 \geq 0 \quad (6)$$

The model can be written in the Canonical form

$$Z = \sum cjxj \quad (7)$$

$$j = 1,2 \ldots .5 \quad (8)$$

Subject to

$$\sum aijxj \leq bi \tag{9}$$

$$j = 1,2 \ldots .5 \tag{10}$$

j = number of units of yarn,fabric,CM, knit garment,woven garment

i = units of materials to be used

bi = budget limit of each aspect of production

3.1.1. Linear programming model of the company

Maximize

$$Z = C1X1 + C2X2 + C3X3 + C4X4 + C5X5 \tag{11}$$

Maximize

$$Z = 10.92X1 + 4.59X2 + 3.57X3 + 3.45X4 + 21.21X5 \tag{12}$$

Subject to:

$$50.94\,X1 + 20.18\,X2 + 15.96\,X3 + 14.94\,X4 + 73.54\,X5 \leq 175.56\ (raw\ material\ cost\ constraint) \tag{13}$$

$$4.37\,X1 + 2.14\,X2 + 1.43\,X3 + 1.84\,X4 + 18.39\,X5 \leq 28.17\ (labour\ cost\ constraint) \tag{14}$$

$$17.46\,X1 + 8.26\,X2 + 6.43\,X3 + 6.21\,X4 + 49.50\,X5 \leq 87.86\ (overhead\ cost\ constraint)$$

$$X1, X2, X3, X4, X5 \geq 0 \tag{15}$$

3.1.2 production constraint

Sometimes after the maximization calculation, only one or two products are being produced. Although the profit is maximized, this is not an ideal case in reality because of the following reasons:

(1) Product diversity is ignored

(2) Customer need is not fully satisfied

(3) Workers employed for producing other products may become jobless.

(4) The resources like machines and raw materials used in the production of other products cannot be effectively utilized or they may remain underutilized.

(5) Production of these products goes beyond the market demand, so they cannot be completely sold out.

Therefore, some extra constraints should be set to ensure product diversity. Either by setting an upper limit for the 'very profitable' products, or setting a lower limit for the 'less profitable' products:

$$Xn < k\%(X1 + X2 + X3 + X4 + X5) \tag{16}$$

or

$$Xn > k\%(X1 + X2 + X3 + X4 + X5) \tag{17}$$

$$where\ 0 < k < 100 \tag{18}$$

3.2. Techniques for model solution

The model is solved by using a linear programming problem solver in Matlab.

3.3Models under different extra constraints

Model 1 is the original one whose aim is to find the composition which obtains the most profit without any extra constraints. It is shown in the following picture. And the first five numbers in the picture are X1 to X5, the rest are slack variables in Matlab which could be ignored.

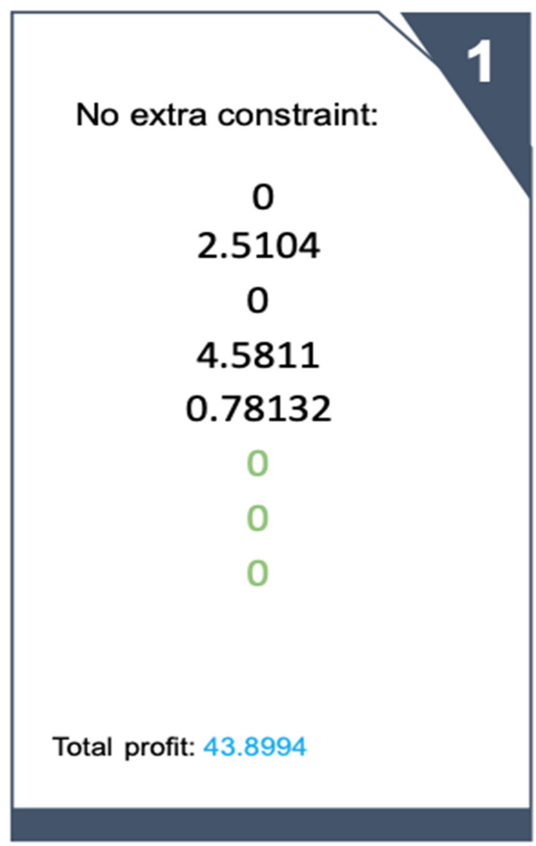

Figure 1 Via Model 1, the maximization of profit is found which is 43.8994

As we mentioned in 3.2, profit is not the only factor we will consider in production. In Model 1, since the quantity of the first and third kind of product is 0, which is not the ideal composition we wish to find, we limit the production of X4 to less than 80% of total production and we find there is no difference. In addition, we limit the production of X4 to less than 60% of the total and there is still no difference. In model 3, we limit the production of X4 to less than 40% of the total.

Figure 2 In Model 3, we find that X1 is not zero anymore and X3 is still zero.

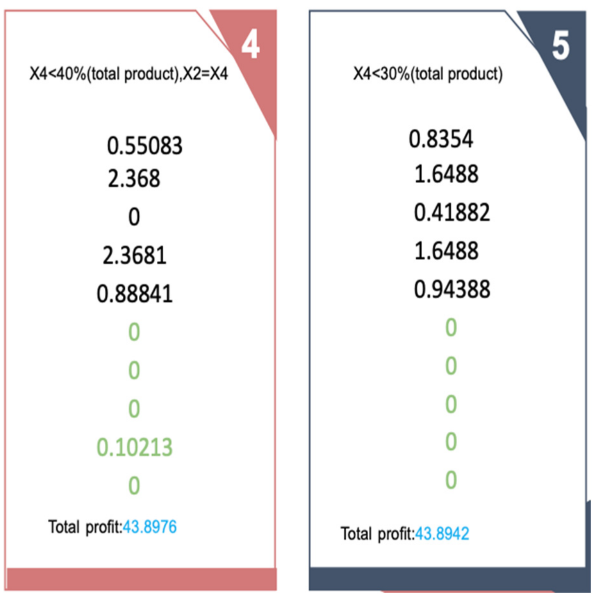

Figure 3 Model 4 is the circumstance where X2 equals X4. Besides, in Model 5, constrained by X4 less than 30% of the total, X3 is beyond zero.

4. Result and discussion

With the result from the first model, their maximum profit can be 43.8994 million by producing 2.51 M units of fabric, 4.58 M units of knit garments, and 0.78 M units of woven garments. After the adjustment, the profit of the factory has improved significantly compared to before, but at the same time, two products (yarn and CM) on the previous production line were therefore abandoned. Such profit maximization is achieved by sacrificing product diversity, so it is hard to say that this is the best model.

We then decided to introduce constraints into the later model. By restricting the production of products with higher output, we can free up a certain amount of productivity to other products with 0 output. In model 5, we limited knit garments to at most 30% of the total production, and the maximum profit became 43.8942 million. With this model, all five products can be produced, but the profit of model 5 is only 5200 less than model 1.

Although the profit of model 1 is the highest, it is a totally theoretical model that is only considered for the aspect of the manufacturer, which has several serious flaws:

- A single source of profit is easily affected by the market prices of raw material and the product itself.
- The market demand for such a product may be much less than the amount that a company can provide

Therefore, in reality, it is impossible for model 1 to reach its theoretical maximum profit. Considering the comprehensiveness and the situation of the real market, model 5 will be a more suitable solution. It still focuses on the most profitable products but also restricts their highest proportion of production to maintain the production of other less profitable products. Here, the possibility that the production volume exceeds the market capacity is greatly reduced, and the factory can also meet the market's demand for other products.

5. Conclusion

The research above shows that under the current situation, this textile manufacturer can improve the profit by managing the production line. The textile factories want to consider the product diversity and maximize the profit at the same time. The expectation was not able to be reached because they did not have an accurately calculated production plan.

With our model, their production plan can be optimized and achieve the result they want. We do not recommend the company to give up all lower profitable products. On the contrary, keeping a certain amount of production lines for various products can help us to react to the market change at any time. According to model 4, they can have much better profit and maintain the same diversity by producing 2.51M units of fabric, 4.58M units of knit garments, and 0.78M units of woven garments.

This mathematical model mainly calculates the profit maximization in terms of production and takes into account part of the market demand, but we also need to notice that it does not fully consider the impact of the market on profits. For example, the product with the highest production volume derived from the model may not be welcomed by the market. This is the limitation of Linear Programming on production planning. However, after we have done some research on market demand, this mathematical model can help the company to calculate the proportion of production required for various products to help the company get the maximum profit. This model is not limited to the textile industry, it can also help other types of manufacturing to optimize production lines to maximize profits.

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