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OPTIMIZATION OF SIPIROK WOVEN FABRIC PRODUCTION USING *FUZZY-MULTI OBJECTIVE* LINEAR PROGRAM

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ABSTRACT

The Sipirok woven fabric industry is one of the industrial characteristics of South Tapanuli Regency in North Sumatra. In general, the challenges encountered in the industry are related to production optimization. There have been numerous research on production optimization that use mathematical methods such as the simplex method. However, the simplex technique has limits, as it only has one objective function. As a result, the *Fuzzy Multi-Objective* Linear Program method is employed in this study. Because *Fuzzy Multi-Objective* linear program includes two objective functions, maximizing profits and reducing/minimizing processing time, it can be used to tackle optimization issues in the Sipirok woven fabric company. This sort of research employs primary data, specifically interviews and direct observation at the research site, the Sipirok Woven Fabric Industry. This study's calculations were supplemented by the simplex method, which was then followed by the two-phase simplex method to generate the ultimate outcome of woven fabric manufacture. The woven fabric industry now produces 472 units of Samuel's woven fabric, with a maximum profit of Rp. 37,920,000 and a minimum processing time of 7,110 hours, where the variable value λ is 0.10 to represent the maximum degree of each objective function.

Keywords: Optimization, Woven Fabric Production, Simplex Methods, Linear Program, *Fuzzy-Multi Objective*

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PRELIMINARY

The Indonesian economy is currently playing a critical role, and as a result, the corporate sector is advancing at a quick pace. Every company must always outperform the competitors in order to gain market share. Companies must provide additional incentive guidelines to maintain the status of the firm, paying close attention to obtaining quality in the product. As is the case with Sipirok Woven Fabric, which, among other things, is a mainstay of South Tapanuli. There are several small-scale woven textile factories in the Sipirok sub-district; this industry converts raw resources in the form of yarn into woven fabric. The fabric can be used as a base material for apparel, shawls, skirts, pillowcases, and curtains, however it was solely studied for clothing items in this study.

Proper planning is required in the production business world in order to resolve demand difficulties that may result in a drop or increase in sales in the future (Industri et al., 2019). Production planning is an action or activity that determines what goods must be manufactured, how much must be manufactured, when must be manufactured, and how many personnel are required throughout the manufacturing cycle (Purwanti & Pramestari, 2022) .

In this situation, developing production plans and estimating sales, as well as arranging the acquisition of essential raw materials, are all dependent on the proper allocation and use of available production time, materials, and human resources. Production planning is an internal company attempt to meet market demand (Rachma, 2020). Currently, most businesses, particularly those in the industrial sector, will encounter a challenge, namely increased competition (Nuryana, 2019). A company's strategic aspect is essential to compete in the business world by planning and producing products or services that fulfill market demands. When faced with competition, companies must optimize in order to survive (Alfian, 2019).

Optimization is a discipline of mathematics that explores the smallest and greatest values of an probability function as well as the discovery of other values (Ujianto & Maringka, 2018). The direct program is a numerical model that determines the best option while taking into account the particular needs as a straight imbalance (Purwanti & Pramestari, 2022). They expect the best results with the few resources they have (Akbar & Tinggi Ilmu Ekonomi Persada Bunda Email, 2022) Strategies for achieving optimal results, such as graphical strategies and procedures for solving linear programming problems with two factors of choice (Hidayah & Juniati, 2019). There are limitations to this strategy, particularly the usage of only two factors (Asmara et al., 2018).

Further research use the simplex method to determine the optimal value of a direct program with numerous restrictions and factors (Hani & Harahap, 2021). The simplex method is a method for solving linear programming problems with a single objective function (Sugianto, 2020). The advantage of this method is that it can calculate four variables with the objective function of maximizing profits in production (Aini et al., 2021) The researcher did not stop there, and in subsequent research, researcher used a new method, namely, *Fuzzy-Multi Objective* Linear Program.

Multi-objective Fuzzy Linear Program is a more efficient way than Linear Program. This method has the advantage of being able to obtain two objective functions, namely maximizing profits and minimizing processing time. The *Fuzzy Multi-Objective* Linear

Program was also employed in this work to promote the optimization of sipirok weaving production.

METHODS

This type of research uses primary data in the form of interviews and direct observations at the research site of the Sipirok Woven Fabric Industry ((Izzatunnisaa & Endang Prasetyaningsih, 2022) This study was conducted from March to July. In this study, the technique used is a Fuzzy Multi Objective Linear Program that can be used to deal with a variety of issues. The material of the study is obtained through concentrated writing by searching for information and data on materials related to the study whose sources are derived from several articles. In addition to writing studies, the study also uses contextual analysis by utilizing information on the texture of the Sipirok woven texture industry.

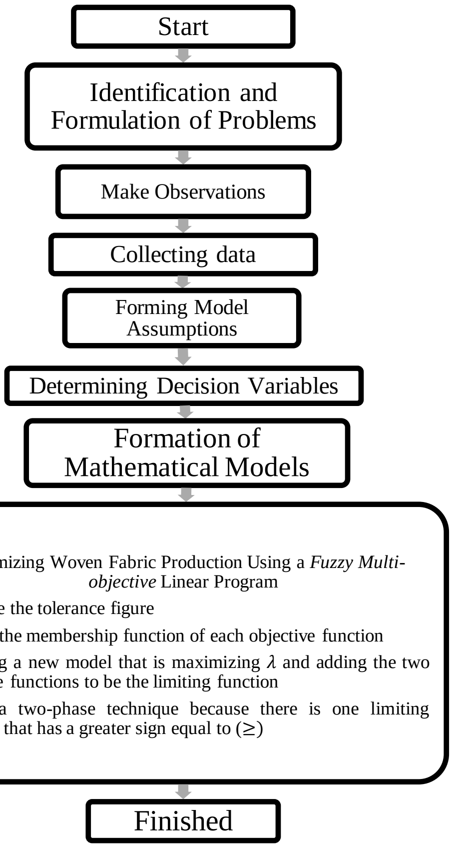

Figure 1. Research Flow

The data used in this study is primary data, obtained by performing a survey in the woven fabric industry's region and conducting interviews with firm owners. To achieve the objective of optimizing sipirok woven fabric production utilizing the *fuzzy multi-objective* linear programming method. The membership function and objective function are then determined by raising the tolerance number and building a new model that is maximized to acquire the limiting function, then utilizing the two-phase procedure because the limiting function has a greater sign equal to (≥).

Linear Programs

Linear programming is a technique for solving a linear problem by first determining the function and purpose (increasing or limiting) the problems and issues that exist in the mathematical model of a linear equation. (Rahmawati & Harahap, 2021). The formulation of the linear program model is the most important step in a linear program which includes identification of topics relating to the goals and issues of the problem. The linear program has three important parts, namely: the decision variable , the objective function , and the constraint function (Aksan et al., 2020). Based on the challenges discussed above, an effective solution to the problem of determining how much to produce to meet client wants is required, and this problem can be solved without additional facilities, specifically by using the *Fuzzy multi-objective* (Nasution & Prakarsa, 2020).

***Fuzzy Multi-Objective* Linear Program**

Multiple linear programming objectives are enhancement techniques to acquire some objective ability at some limit . In solving complex and *multi-objective linear programming problems* , it is not as simple as finishing optimization with only one objective capability, but rather by taking into account the capability of two objectives. (Erfianti & Muhaijir, 2019). *Fuzzy* has degrees allowed in the range 0 to *1* (Devani, 2020). In addressing the *multi-objective fuzzy* linear program in this article, there are several stages, namely:

First of all, the information obtained is converted into the general type of the linear program , after that it is converted into the standard type of the simplex technique. The basic calculation is done twice, not using the resistance value ($t = 0$) and using the resistance value ($t = 1$). Then the equation is obtained with function objective maximize/minimize (Nasr et al., 2021)

$$\begin{aligned} z_1(x) &= c_{11}x_1 + c_{12}x_2 + \cdots + c_{1n}x_n = c_1x \\ z_2(x) &= c_{21}x_1 + c_{22}x_2 + \cdots + c_{2n}x_n = c_2x \\ &\vdots \\ z_k(x) &= c_{k1}x_1 + c_{k2}x_2 + \cdots + c_{kn}x_n = c_kx \end{aligned} \tag{1}$$

There are constraints

$$Ax \leq b$$

$$x \geq 0$$

$c_i = (c_{i1}, \ldots, c_{in})$

$i = 1, 2, \ldots, k$

$x = (x_1, \ldots, x_n)^T$ and

$A = [a_{ij}]$, the matrix size is $m \times n$.

Second, the objective function is maximization/minimization of the fundal model mental is added to the stock tolerance values (t) shown in sales.

$$\begin{aligned} z_1(x) &= c_{11}x_1 + c_{12}x_2 + \cdots + c_{1n}x_n = c_1 x \\ z_2(x) &= c_{21}x_1 + c_{22}x_2 + \cdots + c_{2n}x_n = c_2 x \\ &\vdots \\ z_k(x) &= c_{k1}x_1 + c_{k2}x_2 + \cdots + c_{kn}x_n = c_k x \end{aligned} \quad (2)$$

There are constraints $Ax \leq b + t$

$$x \geq 0 \ .$$

Third, continuing the second model, a third model is created by replacing the first objective function in the equation below with the minimizing objective function:

$$\begin{aligned} -z_1(x) &= -c_{11}x_1 - c_{12}x_2 - \cdots - c_{1n}x_n = -c_1 x \\ z_2(x) &= c_{21}x_1 + c_{22}x_2 + \cdots + c_{2n}x_n = c_2 x \\ &\vdots \\ (x) &= c_{k1}x_1 + c_{k2}x_2 + \cdots + c_{kn}x_n = c_k x. \end{aligned} \quad (3)$$

There are constraints

$$Ax \leq b + t$$

$$x \geq 0 \ .$$

The calculation of Equation (3) produces *fuzzy constraints* for the two objective functions, with i [Bix] serves as a membership function in the i-th set. The membership function of the fuzzy set choice model will take the form of the following equation:

$$\mu_D[x]=\min_i\{\mu_i[B_i x]\} \quad (4)$$

The best solution will be found in the membership function, which means the largest membership value (Hutauruk et al., 2023)

$$\max_{x\geq 0}\mu_D[B_i x]=\max_{x\geq 0}\min_i\{\mu_i[B_i x]\} \quad (5)$$

If the i-th constraint in equation (5) is violated, μi[Bix] = 0, and if followed, μi[Bix] = 1. According to equation (6), the value of μi[Bix] will decrease monotonically in the range [0, 1], as seen in the model in Figure 2.

1

$[B_i x]=\{[0,1]$ (6)

0

if $B_i x \leq d_i$

if $_i < B_i \leq d_i + p$

if $B_i x > d_i + p_i$

with $i=0,1,2,...,m$.

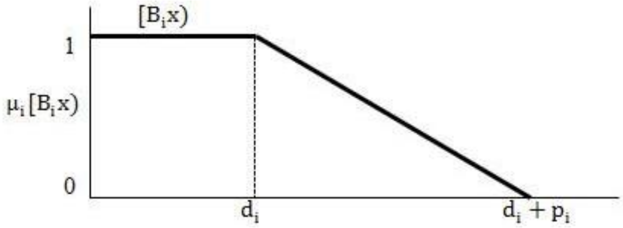

Figure 2. Membership Function

Figure 2 displays the tolerance intervals for the objective function and constraint violations, which decrease monotonically with pi. Equation (6) is substituted into Equation (5) to produce:

$$max_{x\geq 0} = max_{x\geq 0} min_i \left\{1 - \frac{B_i x - di}{p_i}\right\} \quad (7)$$

When λ = min{μi[Bix]}, there are constraints λ ≤ μi[Bix] and x ≥ 0, with i = 0, 1, 2,..., a new linear program is created with the objective function that maximizes (Sitanggang & Mustika, 2021).

RESULT AND DISCUSSION

In this study, two types of production are used: instant woven fabric motifs and samuel woven fabric motifs . Threads for the base cloth and threads for the motifs are used to create this woven fabric. Table 1 shows demand, supply, tolerances, profitability, and order times.

Table 1 . Production Data for the Sipirok Woven Fabric Industry for 2022

Material	Woven fabric motifs (instant)	Woven cloth motifs (samuel)	Supply	Tolerance Supply
Basic fabric thread (various colors)	286m _	2 86 m	171,600 m	80,800 m
Thread (Colorful)	48m _	143m _	57,300m _	29,000m _
Profit	40,000/unit	80,000/unit	-	-
Working Time	10 hours / unit	15 hours / unit		

Instant woven fabrics motifs is x_1, and Samuel wofen fabrics motifs is x_2. Equation (1) and data from Table 1 are considered, and the initial model does not use stock tolerance values.

Maximize: $z_1 = 40{,}000x_1 + 80{,}000x_2$ (profit)

Minimize: $z_2 = 10x_1 + 15x_2$ (work time)

With constraints

$$\begin{aligned} 286x_1 + 286x_2 &\leq 171{,}600 \\ 48x_1 + 143x_2 &\leq 57{,}300 \\ x_1, x_2 &\geq 0 \end{aligned} \quad (8)$$

Then it can be obtained for $x_1 = 300$, $x_2 = 300$, $z_1 = 36{,}000{,}000$ and $z_2 = 7{,}500$. The original model above then use the stock tolerance values for the value (t = 1) to produce the following model.:

Maximize: $z_1 = 40{,}000x_1 + 80{,}000x_2$ (profit)

Minimize: $z_2 = 10x_1 + 15x_2$ (work time)

With restrictions

$$\begin{aligned} 286x_1 + 286x_2 &\leq 171{,}600 + 80{,}000t \\ 48x_1 + 143x_2 &\leq 57{,}300 + 29{,}000t \\ x_1, x_2 &\geq 0 \end{aligned} \quad (9)$$

Calculations for model two produce $x_1 = 415.7$, $x_2 = 464$, $z_1 = 53{,}746{,}000$ and $z_2 = 11{,}116.8$. As expenses, The first objective function is obtained by using equation (3), which is as follows:

Minimize: $z_1 = -40{,}000x_1 - 80{,}000x_2$ (profit)

Minimize: $z_2 = 10x_1 + 15x_2$ (work time)

According to the previous model formulation constraint connected to equation (6), the membership functions for each objective function are generated, leading to the results shown below:

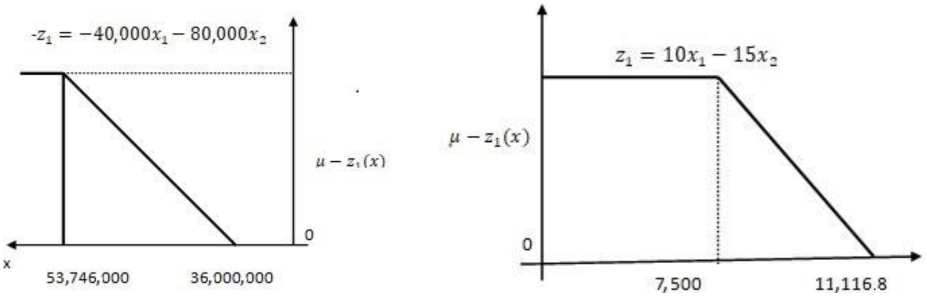

Figure 3. The Membership Function of Each Objectives

With a view to maximizing value and including both objectives in the constraint function, a new model of the membership function of each objective is developed, resulting in four new constraint functions and a new model, which are as follows:

Maximize λ

With constraints

$$
\begin{aligned}
-17{,}801{,}400\,\lambda + 40{,}000 + 80{,}000 &\geq 36{,}000{,}000 \\
3{,}637.76\lambda + 10\,x_1 + 15\,x_2 &\leq 7{,}500 \qquad (10) \\
80{,}800\,\lambda + 286\,x_1 + 286\,x_2 &\leq 252{,}400 \\
55{,}000\,\lambda + 48\,x_1 + 143\,x_2 &\leq 86{,}300 \\
x_{1.2} &\geq 0
\end{aligned}
$$

A two-phase strategy is used to solve the final solution because there is only one constraint function with a sign greater than or equal to (≥). The results of optimizing the production of woven fabrics are shown in Table 2.

Table 2. ***Fuzzy Multi-Objective*** **Linear Programming Model Result**

BV	Optimal Value
λ	0.10 _
x_1	0
x_2	474
z_1	37,920,000
z_2	7,110

Table 2 shows the final results with the optimal solution obtained $x_2 = 474$, $z_1 = 37{,}920{,}000$ and $z_2 = 7{,}110$. By producing 472 units of Samuel woven fabrics and a maximum profit of IDR 37,920,000 with a minimum processing time of 7,110 hours and a variable value of 0.10 which indicates the degree of membership for each objective function.

CONCLUSION

Based on the results of research conducted in obtaining 2 objectives functions of maximizing profits and minimizing processing time in the production of Sipirok woven fabrics using a *fuzzy multi-objective* linear program . By producing 472 units of Samuel woven fabrics, a maximum profit of IDR 37,920,000 is obtained and the minimum processing time is 7,110 hours.

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