Fuzzy linear programming for bulb production

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Abstract. The research was conducted at a bulb company. This company has a high market demand. The increasing of the market demand has caused the company’s production could not fulfill the demand due to production planning is not optimal. Bulb production planning is researched with the aim to enable the company to fulfill the market demand in accordance with the limited resources available. From the data, it is known that the company cannot reach the market demand in the production of the Type A and Type B bulb. In other hands, the Type C bulb is produced exceeds market demand. By using fuzzy linear programming, then obtained the optimal production plans and to reach market demand. Completion of the simple method is done by using software LINGO 13. Application of fuzzy linear programming is being able to increase profits amounted to 7.39% of the ordinary concept of linear programming.

1. Introduction

In a production planning, there are several constraints that limit the production of a company. These constraints can be the engine capacity, the availability of working time, and the availability of raw materials. One of the factors that influence the success of a company is a good production planning. A production planning is said to be good if those planning could reach the market demand by using the minimum cost to get optimal results.

In the previous research results, Linear Programming Method was used to minimize the cost [1]. In addition, linear programming can also be used in telecommunication products [2]. The use of linear programming method is used on land planning [3]. In the previous research, linear programming methods are closely related to mathematics and computer [4]. Meanwhile, for the methods used in this research, the Fuzzy method also applied in previous studies discusses the integration with Fuzzy TOPSIS method [5]. In addition, fuzzy method is used in the information transmission as well [6]. In industrial engineering, Fuzzy methods used in determining the criteria for suppliers that therefore selected by suppliers which are the worthiest to be chosen [7]. Fuzzy methods are similarly used in determining the design of an alga based eco-industrial park that influenced by the variability of the price of the product [8].
Results of previous studies can be seen that there are no studies that discuss the formulation of product demand, especially bulb products by using Fuzzy method. Thus through this research, the optimal value of the company can be calculated and observed.

To fulfill the market demands by using fuzzy logic approach to optimal the resource allocation and determine the value of production interval constraints. From the interval value is then searched the most optimal value. By using Fuzzy Linear Programming, researchers can look for the optimum amount of light bulbs manufactured products to meet market demand and in accordance with the limited production resources.

2. Methods
The data collection was conducted in one of the companies that producing light bulbs in North Sumatra. This research is a quantitative research; the quantitative research is the systematic and empirical studies of quantitative attributes and relationships. As the object of study is the light bulb brand Dai-Ichi G40 and Type A and Type B. The research was carried out by conducting a preliminary study to determine the condition of the company, production processes, and data collection. Data taken in this study is a form of production capacity data, the timing of engine damage, the availability of working time, usage and inventory of raw materials, product selling prices, cost of production, and the cycle time of each work station. Cycle time data is taken by using a stopwatch.

Production planning method that used in this research is Fuzzy Linear Programming (FLP). FLP methods used to maximize the value of Z obtained from Linear Programming by using fuzzy numbers.

2.1 Determining the objective function and constraint
In this study, the decision variable are symbolized by $X_i$. The decision variables are:

- $X_1$ = Dai-Ichi Type G40 Bulb
- $X_2$ = Stanless Star Type A Bulb
- $X_3$ = Stanless Star Type B Bulb

The objective function of the model is to maximize the marginal returns ($Z$) of each bulb produced. The calculation of the marginal benefit of the product by using the formula:

$$\text{Marginal Benefit} = \text{Selling Price/unit} - \text{Production Cost/unit}$$  \hspace{1cm} (1)

The mathematical formulation for the objective function can be written as follows:

$$\text{MAX } Z = \sum_{i=1}^{m} HX_i$$  \hspace{1cm} (2)

In this study, which became the first constraint of the function is an installed production capacity of each machine. The mathematically formulations of the first constraint functions to the installed production capacity are:

$$\sum_{i=1}^{m} X_i \leq \sum_{j=1}^{n} \sum_{k=1}^{p} Y_{jk}$$  \hspace{1cm} (3)

The second constraint function is a function of working hours availability constraints. It is used to look at the relationship between the productions times with the amount of product produced. The formulations used to formulate the second constraint functions are:

$$\sum_{i=1}^{m} a_i X_i \leq \sum_{j=1}^{n} R_j$$  \hspace{1cm} (4)

The third constraint function is a function of raw material usage constraints. It is used to look at the relationship between the use and availability of raw materials to the amount of product produced. The formulations used to formulate the third constraint functions are:

$$\sum_{i=1}^{p} \sum_{i=1}^{m} c_i X_i \leq \sum_{l=1}^{p} T_l$$  \hspace{1cm} (5)
2.2 Establishment of fuzzy linear programming model
Before the formulation of the fuzzy linear programming models, the \( p_0 \) value must be determined. Mathematically the \( p_0 \) value is calculated by:

\[
p_0 = Z_j(t=1) - Z_j(t=0)
\]  

(6)

Fuzzy value is symbolized by \( \lambda \). General formulation of fuzzy linear programming models, namely:

Max : \( \lambda \)

With constraint : \( \lambda p_0 + B_0 X_i \leq d_0 + p_0 \).

3. Research Result

3.1 Fuzzy concept linear programming model

The concept of fuzzy logic provides the interval linear programming models. The concept of fuzzy logic \( t = 0 \) means that all the functions of the constraints that have been established are not using the limit values of tolerance interval. The concept of fuzzy logic \( t = 1 \) means that all the functions of the constraints that have been formed by using the limit values of tolerance interval. Objective function and constraints function are expressed in linear programming models can be seen as follows:

\[
\text{MAX } Z = 90X_1 + 110X_2 + 140X_3
\]

\[
X_1 + X_2 + X_3 \leq 5280000 - 167904 t
\]

\[
X_1 + X_2 + X_3 \leq 4400000 - 191840 t
\]

\[
X_1 + X_2 + X_3 \leq 7920000 - 303336 t
\]

\[
X_1 + X_2 + X_3 \leq 5280000 - 209792 t
\]

\[
X_1 + X_2 + X_3 \leq 5280000 - 256080 t
\]

\[
X_1 + X_2 + X_3 \leq 5280000 - 110352 t
\]

\[
14,01X_1 + 14,99X_2 + 15,67X_3 \leq 50688000 + 12672000 t
\]

\[
7,20X_1 + 8,30X_2 + 10,80X_3 \leq 25000000 + 1000000 t
\]

\[
0,67X_1 + 0,77X_2 + X_3 \leq 2000000 + 500000 t
\]

\[
X_1 + X_2 + X_3 \leq 2000000 + 100000 t
\]

\[
X_1 + X_2 + X_3 \leq 2000000 + 100000 t
\]

\[
X_1 + X_2 + X_3 \leq 2000000 + 100000 t
\]

\[
0,07X_1 + 0,08X_2 + 0,10X_3 \leq 250000 + 20000 t
\]

\[
0,84X_2 + 1,09X_3 \leq 1750000 + 250000 t
\]

\[
0,04X_1 + 0,04X_2 + 0,05X_3 \leq 150000 + 10000 t
\]

\[
X_1 \geq 316817
\]

\[
X_2 \geq 1669172
\]

\[
X_3 \geq 400173
\]

\[
X_1, X_2, X_3 \geq 0
\]

From the calculation by using the software LINGO 13 obtained the calculation results in Table 1 and Table 2.
Table 1. Linear programming result t=0

| Month   | Type C          | Type A          | Type B          | Profit (Rupiah) |
|---------|-----------------|-----------------|-----------------|-----------------|
| August  | 316.817 unit    | 1.669.172 unit  | 400.173 unit    | 258.067.240     |
| September | 315.339 unit | 1.698.055 unit  | 443.051 unit    | 274.081.080     |
| October | 313.205 unit    | 1.725.947 unit  | 489.697 unit    | 274.042.480     |

Table 2. Linear programming result t=1

| Month   | Type C          | Type A          | Type B          | Profit (Rupiah) |
|---------|-----------------|-----------------|-----------------|-----------------|
| August  | 367.857 unit    | 1.732.143 unit  | 500.000 unit    | 293.642.860     |
| September | 315.339 unit | 1.698.055 unit  | 620.818 unit    | 302.081.080     |
| October | 313.205 unit    | 1.725.947 unit  | 599.999 unit    | 302.042.500     |

3.2. Fuzzy linear programming

The fuzzy linear programming model formulation for company was as follows:

\[
\text{MAX } Z = \lambda \\
-35575620 \lambda + s90 \leq X_1 + 110 X_2 + 140 X_3 \leq 258067240 \\
-167904 \lambda + X_1 + X_2 \leq 5112096 \\
-191840 \lambda + X_1 + X_2 \leq 4208160 \\
-303336 \lambda + X_1 + X_2 \leq 7616664 \\
-256080 \lambda + X_1 + X_2 \leq 5023920 \\
-209792 \lambda + X_1 + X_2 \leq 6830208 \\
-138600 \lambda + X_1 + X_2 \leq 6021400 \\
-229152 \lambda + X_1 + X_2 \leq 5050848 \\
-110352 \lambda + X_1 + X_2 \leq 5169648 \\
12672000 \lambda + 14,01 X_1 + 14,99 X_2 + 15,67 X_3 \leq 63360000 \\
1000000 \lambda + 7,20 X_1 + 8,30 X_2 + 10,80 X_3 \leq 26000000 \\
500000 \lambda + 0,67 X_1 + 0,77 X_2 \leq 2500000 \\
500000 \lambda + X_1 + X_2 \leq 3000000 \\
500000 \lambda + X_1 + X_2 \leq 3000000 \\
100000 \lambda + X_1 + X_2 \leq 2100000 \\
100000 \lambda + X_1 + X_2 \leq 500000 \\
20000 \lambda + 0,07 X_1 + 0,08 X_2 + 0,10 X_3 \leq 2700000 \\
250000 \lambda + 0,84 X_2 + 1,09 X_3 \leq 20000000 \\
10000 \lambda + 0,04 X_1 + 0,04 X_2 + 0,05 X_3 \leq 1600000 \\
X_1 \geq 316817 \\
X_2 \geq 1669172 \\
X_3 \geq 400173 \\
X_1, X_2, X_3 \geq 0
\]
From the calculation using the software LINGO 13 obtained calculation results in Table 3.

| Month   | λ   | Product          | Profit (Rupiah) |
|---------|-----|------------------|-----------------|
|         |     | Type C           | Type A           | Type B |
| August  | 0.536 | 377.219 unit     | 1.669.172 unit   | 425.572 unit |
|         |       | Rp. 277.138.710  |                 |        |
| September | 0.500 | 315.339 unit     | 1.698.055 unit   | 520.818 unit |
|         |       | Rp. 288.081.080  |                 |        |
| October | 0.499 | 313.205 unit     | 1.725.947 unit   | 499.999 unit |
|         |       | Rp. 288.042.480  |                 |        |

By using the concept of fuzzy linear programming, it can be analyzed that the market demand has been reached. The profits generated for the month of August, September, and October respectively is Rp. 277.138.710, Rp.288.081.080 and Rp.288.042.480. Companies can also define necessary intervals additions by using the value $\lambda = 0.536, 0.500, \text{and } 0.499$. In other words, the largest scale value $t = 1$ to $0.536 = 0.464$. Of the value of $t$, the company only needs 327 878 seconds as the overtime or equal to 1 hour.

4. Conclusion

Application of fuzzy linear programming is used to increase profits. The increased profits amounted to 7.39%, 4.67% and 4.65% of the ordinary concept of linear programming. Suryo research results obtained the increase of 10.6% from the usual linear programming. From these two studies, it can be concluded that the FLP can optimize the number of production companies. FLP combines the usual linear programming model and the concept of fuzzy logic as a means of decision-making in determining the optimum number of products taking into resource constraints of production. In a subsequent study can be added more than one objective function so that it can be modeled as Multi-Objective Fuzzy Linear Programming.

Acknowledgment

This research was supported by University of Sumatera Utara. We thank our colleagues from Information System Center who provided insight and expertise that greatly assisted the research. All the faculty, staff members and lab technicians of Industrial Engineering Department, whose services turned my research a success. Dr. Himsar Ambarita, my mentor, whose reminders and constant motivation encouraged me to meet the deadlines.

My Wife, Kartika Widya Astuty and children, Omaar Al Faridzi Siregar and Alisha Rizki Siregar, family members and friends, without whom I was nothing; they not only assisted me financially but also extended their support morally and emotionally.

References

[1] Al-Shihabi S., A hybrid of max–min ant system and linear programming for the k-covering problem, *Computers & Operations Research* 76(2016) pp 1–11
[2] Fortz B, Compact mixed integer linear programming models to the minimum weighted tree reconstruction problem, *European Journal of Operational Research* 256 (2017) pp 242–251
[3] Kumar P, Mixed integer linear programming approaches for land use planning that limit urban sprawl, *Computers & Industrial Engineering* 102 (2016) pp 33–43
[4] Touil I, A feasible primal–dual interior point method for linear semidefinite programming, *Journal of Computational and Applied Mathematics* 312 (2017) pp 216–230.
[5] Chen SM, Multicriteria decision making based on the TOPSIS method and similarity measures between intuitionistic fuzzy values, *Information Sciences* 367–368 (2016) pp 279–295.

[6] Fu L, A fuzzy-theory-based method for studying the effect of information transmission on nonlinear crowd dispersion dynamics, *Commun Nonlinear Sci Numer Simulat* 42 (2017) pp 682–698.

[7] Ghorabaee and Mehdi K, 2016 Multi-criteria evaluation of green suppliers using an extended WASPAS method with interval type-2 fuzzy sets, *Journal of Cleaner Production* vol 137 pp 213-229.

[8] Ubando, Aristotle T, 2016 Fuzzy mixed integer non-linear programming model for the design of an algae-based eco-industrial park with prospective selection of support tenants under product price variability, *Journal of Cleaner Production* vol 136 pp 183-196.