Zeki Sistemler Teori ve Uygulamaları Dergisi 1(1) 2018, 26-30

Determining Amounts of Energy Saver Devices in an Electronic Industry Using Fuzzy Linear Programming

Çağatay Teke[1,*] and Alper Kiraz[2]

[1] Industrial Engineering Department, Bayburt University Bayburt, Turkey, cagatayteke@bayburt.edu.tr
[2] Industrial Engineering Department, Sakarya University Esentepe Campus Serdivan/Sakarya, Turkey, kiraz@sakarya.edu.tr

Abstract
Rapid and accurate decision making is not only important for people but also for organizations. However, uncertainty makes decision making difficult. Fuzzy logic approach is deal with uncertainty situations. Namely, fuzzy logic is a precise logic of uncertainty and approximate reasoning. Besides, Fuzzy Linear Programming (FLP) is also known as a strategy that can take into consideration to fuzziness. Determining amounts of production is one of the most important factors effecting the profitability level of enterprises. The aim of this study which is prepared since classical mathematical programming models are inadequate to examine situations that consist of uncertainty; is to bring up how FLP model for providing the best decision making under fuzzy environments can be used at determining amounts of energy saver devices. Required data is obtained and the problem is figured out via Zimmerman approach which is one of the approaches for FLP. In this way, problems that may occur such as cost, waste of time, overstock and customer loss will be prevented. As a result, the solution gives the amount of production for each energy saver device in order to get optimal solution for profit maximizing. This study makes a contribution to practicality of FLP, by supplying a wider moving area than classical set theory to decision makers.

Keywords: Fuzzy linear programming, production planning, electronic industry

Bulanık Doğrusal Programlama ile Elektronik Endüstrisindeki Enerji Tasarrufu Cihazlarının Miktarlarının Belirlenmesi

Özet
Hızlı ve doğru karar verme, sadece insanlar için değil, aynı zamanda organizasyonlar için de önemlidir. Ancak belirsizlik karar vermeyi zorlaştırmaktadır. Bulanık mantık yaklaşımı belirsizlik durumları ile ilgilidir. Yani, bulanık mantık kesin bir belirsizlik ve yaklaşık anlam çıkarma mantığıdır. Ayrıca, Bulanık Doğrusal Programlama (BDP), aynı zamanda, bulanıklığı dikkate alabilecek bir strateji olarak da bilinir. Üretim miktarlarının belirlenmesi, işletmelerin karlılık düzeyini etkileyen en önemli faktörlerden biridir. Klasik matematiksel programlama modellerinin, belirsizlikten kaynaklanan durumları incelemek için yetersiz olması nedeniyle hazırlanan bu çalışmanın amacı; bulanık ortamlarda en iyi karar vermeyi sağlayan BDP modelinin, enerji tasarrufu cihazlarının miktarlarını belirlemede nasıl kullanılabileceğini ortaya koymaktır. Gerekli veriler elde edildikten sonra problem, bulanık doğrusal programlama yaklaşımlarından biri olan Zimmerman yaklaşımıyla çözülmüştür. Bu sayede maliyet, zaman kaybı, stok fazlası ve müşteri kaybı gibi problemler önlenecektir. Sonuç olarak, çözüm, kar maksimizasyonu için en uygun çözümü elde etmek amacıyla her bir enerji tasarrufu cihazı için üretim miktarını vermektedir. Bu çalışma, karar vericilere klasik küme teorisinden daha geniş bir hareket alanı sağlayarak, BDP'nın pratikliğine katkı sağlamaktadır.

Anahtar kelimeler: Bulanık doğrusal programlama, üretim planlama, elektronik endüstrisi.

1. Introduction

Decision making generally depends on decision support system tools. Selecting and applying of decision making method which is the most appropriate with structure of the problem provide a useful insight to executives for giving rational decision. Structure of the problem must be understood in order to select the appropriate decision support method. If there is any imprecision, uncertainty or incompleteness situation in the problem, decision support tools integrated fuzzy logic should be used for getting better solution. In this study, fuzzy linear programming (FLP) method is preferred because expected profit and the demand of the energy saver devices are uncertain.

Zadeh and Bellman propounded the notion of maximizing the decision for decision making problems. A fuzzy approach concerning multi-objective Linear Programming (LP) problems was introduced by Zimmermann. Studies in recent years suggest new

[*] Corresponding Author

Recieved : 3 Aug. 2018
Accepted : 28 Sep. 2018

techniques with the purpose of ranking fuzzy numbers and coming to an optimal solution (Gani et al., 2009).

Many authors proposed several approaches and solved their own problems with FLP model. For example; Abdullah and Abidin are used FLP with single objective function for getting optimal solutions and profits of red meat production problem. They successfully obtained to the profit of red meat production with the variability of fuzzy memberships in FLP (Abdullah et al., 2014). Kalaf et al. have developed a fuzzy multi-objective model for solving aggregate production planning problems that contain multiple both periods and products in fuzzy environments. They adopted a new method that utilizes a Zimmermans approach. This proposed model attempts to minimize total production costs and labor costs synchronically (Kalaf et al., 2015). Elamvazuthi et al. were solved a FLP problem in which the parameters involved are fuzzy quantities with logistic membership functions. They determined monthly profit and production planning quotas via numerical example of home-textile group to explore the applicability of the method (Elamvazuthi et al., 2009). Demiral used FLP model for production planning problem of a dairy industry because of the uncertain supply of milk and demand of dairy products. Results of his study was shown that FLP is more realistic than LP (Demiral, 2013). Herath and Samarathunga are presented a fuzzy multi-criteria mathematical programming model. This study was undertaken to find out the optimal allocation for profit maximizing and cost minimizing subjected to the utilizing of 'water and demand' constraint. They achieved to get optimal production plan with this model (Herath and Samarathunga, 2015).

In this study, FLP method is used for determining amounts of 6 different energy saver devices under uncertainty environment. The objective of this paper is to determine amounts of these devices for obtaining maximum profit and minimum deviation of demand by taking capacities of labour and production into consideration.

This paper is organized as follows. Section 2 and 3 respectively describes FLP and types of FLP. Zimmerman Method is described in Section 4. A case study and its results presented in Section 5. Finally, conclusions are given in Section 6.

2. Fuzzy Linear Programming

2.1. Linear programming

Programming problem. From an analytical perspective, a mathematical program attempts to identify a minimum or maximum point of a function, which furthermore satisfies a set of constraints. Objective function and problem constraints are linear in LP (Dervişoğlu, 2005).

A classical model of LP, also called a crisp LP model, may have the following formulation:

$$\begin{aligned} &Max \quad Cx \\ &s.t. \\ &A_i x \le b_i \qquad i=1, \dots , m \end{aligned} \tag{1}$$

in which x is an n × 1 alternative set, C is a 1 × n coefficients of an objective function, Ai is an m × n matrix of coefficients of constraints and bi is an m × 1 right-hand sides.

The traditional problems of LP are solved with LINDO optimization software and obtain the optimal solution in a precise way. If coefficients of constraints, objective function or the right-hand sides are imprecise, in other words, being fuzzy numbers, traditional algorithms of LP are unsuitable to solve the fuzzy problem and to obtain the optimization.

In the real world, the coefficients are typically imprecise numbers because of insufficient information, for instance, technological coefficients. Many researchers formed FLP of various types, invented approaches to convert them into crisp LP, and finally solved the problems with available software (Lee and Wen, 1996).

2.2. Fuzzy linear programming

FLP follows from the fact that classical LP is often insufficient in practical situations. In reality, certain coefficients that appear in classical LP problems may not be well-defined, either because their values depend on other parameters or because they cannot be precisely assessed and only qualitative estimates of these coefficients are available. FLP is an extension of classical LP and deals with imprecise coefficients by using fuzzy variables (Ren and Sheridan, 1994).

We consider the FLP Problem

$$\begin{aligned} &Max\, \tilde{Z} = \tilde{C}^T x \\ &s.t. \\ &\tilde{A} x \le \tilde{b} \\ &x \ge 0 \end{aligned} \tag{2}$$

The solution of this problem is to find the possibility distribution of the optional objective function Z. Many researchers had handled this problem by converting the fuzzy objective function and the fuzzy constraints into crisp ones (Gasimov and Yenilmez, 2002).

3. Types of Fuzzy Linear Programming

FLP model divides into parts in terms of fuzzy coefficients. For instance, while objective function is fuzzy, constraints cannot be fuzzy. Combinations of possible situations are briefly introduced as below:

- Objective Function is Fuzzy

In a real life, there are many situations that parameters of objective function (profit and cost) are imprecise. FLP model of this was propounded by Verdegay.

- Right-Hand Sides are Fuzzy

There are two approach for this type of problem. While first approach concerning asymmetric models belongs to Verdegay, second approach concerning symmetric model belongs to Werners.

- Right-Hand Sides and Coefficients of Constrains are Fuzzy

Negoita and Sularia developed an approach for this type of FLP model.

- Objective Function and Constrains are Fuzzy

As it is understood the title, in this model, both objective function and constrains involve fuzziness. Zimmermann and Chanas have different approaches about it.

- All Coefficients are Fuzzy

Sometimes, all coefficients can be fuzzy in the problem. Carlsson and Korhonen developed the approach for this.

4. Zimmermann Method

LP with a fuzzy objective function and fuzzy inequalities shown by Zimmermann is indicated as follows (Lee and Wen, 1996):

$$C^T x \tilde{\geq} b_0$$
$$(Ax)_i \tilde{\leq} b_i \quad (3)$$
$$x \geq 0 \quad i = 1,\ 2,\ \dots,\ m$$

Inequality is a symmetrical model of which the objective function becomes one constraint. To write a general formulation, inequality is converted to a matrix form as (Lee and Wen, 1996):

$$-C^T x \tilde{\leq} -b_0 \quad (4)$$

In which

$$B = \begin{bmatrix} -C \\ A_i \end{bmatrix} \quad b = \begin{bmatrix} -b_0 \\ b_i \end{bmatrix} \quad (5)$$

The inequalities of constraint signify "be as small as possible or equal" that can be allowed to violate the right-hand side b by extending some value. The degree of violation is represented by membership function as (Lee and Wen, 1996):

$$\mu_0(x) = \begin{Bmatrix} 0 & ,if\ Cx \leq b_0 - d_0 \\ 1 - \dfrac{b_0 - Cx}{d_0} & ,if\ b_0 - d_0 \leq Cx \leq b_0 \\ 1 & ,if\ Cx \leq b_0 \end{Bmatrix} \quad (6)$$

$$\mu_i(x) = \begin{Bmatrix} 0 & ,if\ (Ax_i) \geq b_i + d_i \\ 1 - \dfrac{(Ax)_i - b_i}{d_i} & ,if\ b_i \leq (Ax)_i \leq b_i + d_i \\ 1 & ,if\ (Ax)_i \leq b_i \end{Bmatrix} \quad (7)$$

In which d is a matrix of admissible violation.

This problem can be transformed by introducing the auxiliary variable λ as follows:

$$\mu_0(x) \geq \lambda$$
$$\mu_i(x) \geq \lambda \quad (8)$$
$$\lambda \in [0,1]$$

This problem can be stated as LP as follows:

$$Max\ \lambda$$
$$s.t.$$
$$\mu_0(x) \geq \lambda \quad (9)$$
$$\mu_i(x) \geq \lambda$$
$$\lambda \in [0,1]$$

This problem was shown with membership functions of fuzzy objective function and fuzzy constrains as follows:

$$Max\ \lambda$$
$$s.t.$$
$$1 - \frac{b_0 - Cx}{d_0} \geq \lambda$$
$$1 - \frac{(Ax)_i - b_i}{d_i} \geq \lambda,\ \forall i \quad (10)$$
$$\lambda \in [0,1]$$
$$x \geq 0$$

After some simplification, FLP model obtains as follows:

$$Max\ \lambda$$
$$s.t.$$
$$C^T x - \lambda d_0 \geq b_0 - d_0$$
$$(Ax)_i + \lambda d_i \leq b_i + d_i,\ \forall i \quad (11)$$
$$\lambda \in [0,1]$$
$$x \geq 0$$

Table 1. Data for FLP model

	Variables					
Variable name	X_1	X_2	X_3	X_4	X_5	X_6
Unit profits (TRY per item)	0.55	0.41	0.32	0.38	0.1	2.51
Expected demands (item per month)	16204	16220	17110	5935	7021	3436
Tolerances for demands (item per month)	242	208	167	150	140	138
Labour usage (minute per item)	0.427	0.468	0.315	0.63	0.35	0.99
Expected profit (TRY)	35000					
Tolerance for profit (TRY)	3000					
Monthly production capacity (item)	70,000					
Monthly labour capacity (minute)	208,000					

5. Application

5.1. Problem definition

Data used for the application was obtained a factory in an electronic industry. It produces 6 different energy saver devices. Since the expected profit and the demand of the product types are uncertain the problem is built as

FLP model in order to determine production amounts per month for each product type for maximizing the profit. Data about the production and its constraints are given in Table 1.

5.2. FLP model

Problem was modelled as monthly basis. The FLP model of the problem is given below:

$$
\begin{aligned}
& C^T x = 0.55x_1 + 0.41x_2 + 0.32x_3 + 0.38x_4 + \\
& 0.1x_5 + 2.51x_6 \\
& b_0 = 35{,}000 \qquad d_0 = 3000 \\
& b_1 = 16204 \qquad d_1 = 242 \\
& b_2 = 16220 \qquad d_2 = 208 \\
& b_3 = 17110 \qquad d_3 = 167 \\
& b_4 = 5935 \qquad d_4 = 150 \\
& b_5 = 7021 \qquad d_5 = 140 \\
& b_6 = 3436 \qquad d_6 = 138
\end{aligned}
\tag{12}
$$

$$
\begin{aligned}
& Max\ \lambda \\
& s.t. \\
& 0.55x_1 + 0.41x_2 + 0.32x_3 + 0.38x_4 + \\
& 0.1x_5 + 2.51x_6 - 3000\lambda \geq 32{,}000 \\
& x_1 + 242\lambda \leq 16446 \\
& x_2 + 208\lambda \leq 16428 \\
& x_3 + 167\lambda \leq 17277 \\
& x_4 + 150\lambda \leq 6085 \\
& x_5 + 140\lambda \leq 7161 \\
& x_6 + 138\lambda \leq 3574 \\
& x_1 + x_2 + x_3 + x_4 + x_5 + x_6 \leq 70{,}000 \\
& 0.427x_1 + 0.468x_2 + 0.315x_3 + 0.63x_4 + \\
& 0.35x_5 + 0.99x_6 \leq 208{,}000 \\
& \lambda \in [0,1] \\
& x_i \geq 0 \\
& i = 1,2,\ldots,6 \\
& \forall x_i \in Z^+
\end{aligned}
\tag{13}
$$

5.3. Problem solution

FLP model of the problem has been solved using Lindo optimization software. Results of the solution are given in Table 2 and Table 3.

As can be seen from the solution, the factory should produce 16360 x1, 16354 x2, 17217 x3, 6031 x4, 7111 x5, 3525 x6.

Table 2. Results of the solution

Variable	Value	Reduced Cost
λ	0.354	0
X_1	16360	-0.000183
X_2	16354	-0.000137
X_3	17217	-0.000107
X_4	6031	-0.000127
X_5	7111	-0.000033
X_6	3525	-0.000837

Table 3. Results of the solution

Row	Slack or Surplus	Dual Price
2	0.000000	-0.000333
3	0.234396	0.000000
4	0.284109	0.000000
5	0.814645	0.000000
6	0.839502	0.000000
7	0.383535	0.000000
8	0.092342	0.000000
9	3402	0.000000
10	178159.125	0.000000

Total profit of the factory can be calculated as follows:

$$
\begin{aligned}
& (0.55\times16360)+(0.41\times16354)+(0.32\times17217)+(0.38\times6031)+ \\
& (0.1\times7111)+(2.51\times3525)=3306321\ TRY
\end{aligned}
\tag{14}
$$

6. Conclusion

This paper has discussed the use of FLP for solving a production planning problem in an electronic industry. It can be concluded that this method introduced is a promising method for solving such problems. This problem was solved by using Zimmerman approach which is one of the approaches for FLP, because the model has fuzziness in both objective function and constraints. Amounts of 6 different energy saver devices are determined for obtaining maximum profit and minimum deviation of demand by taking capacities of labour and production into consideration. The example illustrates how particular problems of real production systems can be treated by the theory on fuzzy sets.

References

Abdullah L., Abidin N. H., 2014. A Fuzzy Linear Programming in Optimizing Meat Production. International Journal of Engineering and Technology, 6(1):436-444, 2014.

Demiral M. F., 2013. A Case Study at Dairy Industry with Fuzzy Linear Programming. The Journal of Faculty of Economics and Administrative Sciences, Suleyman Demirel University, 18(2):373-397.

Dervişoğlu E., 2005, Fuzzy Linear Programming: Review and Implementation, Sabanci University, İstanbul.

Elamvazuthi I., Ganesan T., Vasant P., Webb J. F., 2009. Application of a Fuzzy Programming Technique to Production Planning in the Textile Industry, International Journal of Computer Science and Information Security. 6(3): 238-243.

Gani A. N., Duraisamy C., Veeramani C., 2009. A note on fuzzy linear programming problem using L-R fuzzy number. International Journal of Algorithms, Computing and Mathematics, 3:93-106.

Gasimov R. N., Yenilmez K., 2002. Solving Fuzzy Linear Programming Problems with Linear Membership Functions. Turk J Math, 26:375-396.

Herath H.M.I.U., Samarathunga D.M., 2015. Multi-Objective Fuzzy Linear Programming In Agricultural Production Planning. International Journal of Scientific and Technology Research, 4(10):242-250.

Kalaf B. A., Bakar R. A., Soon L. L., Monsi M. B., Bakheet A. J. K., Abbas I. T., 2015. A Modified Fuzzy Multi-Objective Linear Programming to Solve Aggregate Production Planning. International Journal of Pure and Applied Mathematics, 104(3):339-352.

Lee C. S., Wen C. G., 1996. River assimilative capacity analysis via fuzzy linear programming. Fuzzy Sets and Systems, 79:191-201.

Ren J., Sheridan T. B., 1994. Optimization with fuzzy linear programming and fuzzy knowledge base, IEEE, 0-7803-1896-X/94.