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Çok Ürünlü Üretim Planlama Problemlerini Çözmek İçin MINMAX Yaklaşımına Dayanan Bir Bulanık Hedef Programlama Modeli: Mobilya İmalat Fabrikasında Örnek Bir Çalışma

A Fuzzy Goal Programming Model Based on MINIMAX Approach for Solving Multi Product Production-Planning Problems

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ÖZ

Bu çalışmada, bulanık hedef programlama (BHP) kullanarak mobilya üreten bir firma için bir üretim planı önerisi getirilmekte ve karar vericinin miktar ve kar amacına ulaşılması hedeflenmektedir. Bu hedefler kesin olarak belirlenemediği için bulanık sayılarla ifade edilmiştir. Önerilen modelde, her bölümdeki işçi sayısı yeniden düzenlenmiştir. Önerilen modelin kullanılması durumunda, şirketin önceki dönemde olduğundan%8 daha az işçi kullanarak faaliyetlerine devam edebileceği ve üretim bölümlerinin daha verimli çalışacağı öne sürülmüştür.

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ABSTRACT

In this study, a production plan proposal is made for a company that produces furniture using fuzzy goal programming (FGP) and aim to reach Produce amount and profit goal of the decision maker. These goals were determined to be fuzzy because they cannot be determined precisely. In the proposed model, the number of workers in each section has been rearranged. In the case of using the proposed model, it was suggested that the company could continue its activities by using 8% less workers than in the previous period and the production departments would work more efficiently.

1. Introduction

In order to minimize the loss of material, machine time and workforce, production planning is required in modern enterprises in order to ensure that the enterprises operate economically. The purpose of production planning is to ensure that the resources allocated for the respective production and minimize the total production costs (Kogan and Khmelnitsky, 1995; Jain and Palekar, 2005). But some strategic issues may be more important than cost minimization. One of the main objectives of decision makers is to meet the demand for products. Production planning is one of the basic principles of planning for every industrial unit. It seems necessary to use a sophisticated programming system in order to meet product's demands in an efficient way at different planning periods (Mosadegh et al.,2017).

Multi-period and multiproduct production planning is a planning activity between 3 and 18 months (Zhu et al.,2018; Gansterer 2015). A medium-term plan is being prepared for a

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period of three months to one year (Sipper and Bulfin, 1998). In the medium-term production planning model, it is decided to determine the level of production and the number of labor force should be considered each month in order to minimize the total cost by considering demand forecasts.

In order to start the production planning, the processing times for the machine and the employees time must be measured. Production planning steps should be simplified. In addition, all parameters and limitations should be taken into consideration when planning decisions are taken and the alternatives should be evaluated (Stevenson, 1996).

As mentioned by Wang and Liang (2004), production planning problems with multiple conflicting targets coincide with real-world problems. GP models aim to minimize deviations of the parameters in the objective function. The parameters used as deterministic the first studies on Goal programming. However, decision-makers cannot determine the target functions, constraints and resource values to be used in production planning problems as flawlessly. In fact, real-world problems often occur in an uncertain environment (Yaghoobi and Tamiz, 2007; Zhu et al., 2018). The production planning takes place in an uncertain framework that the decision-maker must determine. The boundaries is due to the inaccuracy of the size of available resources (Jamalnia and Soukhakian, 2009).

Zadeh (1968) define fuzzy sets that do not have a crisply defined membership, but rather allow objects to have grades of membership from 0 to 1. Mamdani (1974) applied fuzzy sets first time in order to control of dynamic plant. Zimmermann (1975) first used fuzzy set theory in traditional Linear Programming (LP) problems. In this study, fuzzy purposes and fuzzy constraints are used. Bellman and Zadeh (1970) suggested that LP programming problems could be solved by using linear membership functions in the proposed approach. Fuzzy linear programming solution for fuzzy optimization methods has been developed. Finally, Hintz and Zimmermann (1989) developed fuzzy linear programming solutions using fuzzy optimization methods. Narasimhan 1980 first used Fuzzy set theory in GP problems. Goals and constraints are considered as fuzzy unlike conventional GP.

The furniture production was carried out by independent and small-scale enterprises and labor-intensive production since the beginning of the 1990s, furniture production has started to change and production has begun to industrialize. In the last twenty-five years, significant developments have been achieved in the field of production in the sector (Yücesan, 2016).In this respect, production planning in furniture sector is very important. In this study, it is aimed to achieve the produce amount and profit goal of the decision maker by using FGP. These goals were determined to be fuzzy because they cannot be determined precisely. Also, it is aimed to reveal the necessity of using scientific methods in these activities. FGP applications for the furniture industry are very limited. In this respect, this study is thought to contribute to the literature.

2. Literature review

While the use of FGP is common in many areas, studies for the furniture industry are quite limited. In this section, some studies with FGP are presented. Especially in recent years, there are a lot of studies done with multi-disciplinary areas FGP.

Kağnıcıoğlu et. al. (2006) uses 0-1 integer FGP in order to solve exam assignment problem. Fuzzy model with real data has been solved by using Max-Min approach of Bellman and Zadeh. research assistants have been used as input for proposed approach. They claimed that the proposed model is effective for various data sets. Sharma et al. (2007) used FGP to optimally allocate agricultural land. Goals such as production, profit, water, labor requirements and machine time are modeled as fuzzy. The aim of the proposed model is to reach the highest membership level by taking into account the determined tolerance values of the variables. Madadi and Wong (2014), aim to reach the targeted quality level with a multi-criteria FGP model in automotive parts manufacturing company. In the proposed model, goals, resources, service level are considered fuzzy by considering the performance and availability of the model production lines. Khalili-Damghani and Shahrokh (2014) proposed integrated production planning using fuzzy mixed integer goal programming method. The production plan is for three purposes. These objectives are total cost minimization, service level and quality maximization. The proposed model is compared with the previous production plan. It is claimed that the 17% delivery time will decrease by 37.5% if the proposed model is used. Silva and Marins (2014) presented a production plan proposal using a FGP model in a company producing sugar and ethanol. Uncertainties in sugar and ethanol production are considered fuzzy. Bhargava et al. (2015) used FGP to maximize production capacity, maximize profit, minimize labor and furnace use. The main purpose of the study is to meet the desire of the decision makers. Ertuğrul and Öztaş (2016) aim to generate optimal course programming, fuzzy parameters are determined as goals. Then the fuzzy model defuzzificated with Max-Min method developed by Bellman and Zadeh. Chen et al. (2017) considers each customer's needs as a response variable and design requirements as the input variable. The aim of this study is to optimize the maximum customer satisfaction, minimum cost and minimum technical difficulty of DRs parameters using FGP. Mosadegh et. al.(2017) present a FGP model with considering shortage and inventory, overtime, idle time and manpower constraints. Gupta et. al. (2018) presented an efficient FGP proposal to solve the multi-product production and distribution problem. In order to compose the efficient FGP model, fuzzy programming is presented together with goal programming and interactive programming. The aim of this method is to minimize transportation costs and transportation times at the same time. While aiming to achieve this goal, they have also taken into consideration the parameters of budget, inventory levels, stock, market demand and available warehouse space. Umarusman (2018) proposed a model in order to determine optimal system by FGP. Budget parameter is identified as a goal. Finally, MA and Min-max approach are compared with respect to results. Kaçmaz et. al. (2018) proposed menu planning for special patients in hospitals with using FGP. The amount of nutrients that special patients should take cannot be determined precisely. Therefore, the FGP approach has been proposed as a suitable method for this problem.

Our study will contribute to the literature in some ways. Fuzzy goal programming applications in the furniture industry are quite rare. Moreover, in the literature search, FGP was not used for use in furniture seating groups.

3. Fuzzy Goal Programming

GP method is one of the main methods used in production planning problems. Charnes and Cooper (1961), the first implementers of the of this method, have created the goal programming model for linear problems. The traditional GP problem must precisely determine the target level to be reached by the decision-makers. This is often difficult and costly for decision-makers. Fuzzy set theory allows decision makers to overcome this challenge.

Goals which are not determine precisely can be considered fuzzy (Yaghoobi and Tamiz, 2007). There are three types of fuzzy goals. The following FGP model contains these three kinds of fuzzy goals.

$$\text{OPT} \quad \begin{aligned} &(AX)_i \lesssim b_i \quad i = 1,\cdots,i_0 && (1)\\ &(AX)_i \gtrsim b_i \quad i = i_0+1,\cdots,j_0 && (2)\\ &(AX)_i \cong b_i \quad i = j_0+1,\cdots,K && (3)\end{aligned}$$

where OPT means finding an P optimal decision X such that all fuzzy goals are satisfied. $(AX)_i = \sum_{j=1}^{n} a_{ij}x_j$, $i = 1,\cdots K, b_i$ is the aspiration level for the *i*th goal, C_i is an optional set of hard constraints as found in linear programming (LP) and the symbol '~' a fuzzifier representing the imprecise fashion in which the goals are stated.

$$\mu_i(AX) = \begin{cases} 1 & (AX)_i \le b_i \\ 1 - \dfrac{(AX)_i - b_i}{\Delta_{iR}} & b_i \le (AX)_i \le b_i + \Delta_{iR} \quad i=1,...,i_0 \\ 0 & (AX)_i \ge b_i + \Delta_{iR} \end{cases} \quad (4)$$

$$\mu_i(AX) = \begin{cases} 1 & (AX)_i \ge b_i \\ 1 - \dfrac{b_i - (AX)_i}{\Delta_{iL}} & b_i - \Delta_{iL} \le (AX)_i \le b_i \quad i=i_0+1,...,j_0 \\ 0 & (AX)_i \le b_i - \Delta_{iL} \end{cases} \quad (5)$$

$$\mu_i(AX) = \begin{cases} 0 & (AX)_i \ge b_i \\ 1 - \dfrac{b_i - (AX)_i}{\Delta_{iL}} & b_i - \Delta_{iL} \le (AX)_i \le b_i \quad i=j_0+1,...,K \\ 1 - \dfrac{b_i - (AX)_i}{\Delta_{iL}} & b_i \le (AX)_i \le b_i + \Delta_{iR} \\ 0 & (AX)_i \ge b_i + \Delta_{iR} \end{cases} \quad (6)$$

where Δ_{iL} and Δ_{iR} are chosen constants of the maximum admissible violations from the aspiration level b_i. Values are determined by decision-makers in subjective judgments. Fuzzy goals can be considered as a fuzzy set. Also fuzzy sets can be expressed by triangular linear membership functions as in Figure 1.

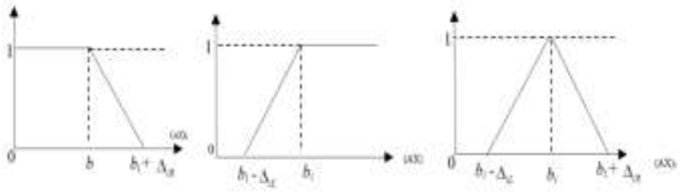

Figure 1. Linear membership functions

Fuzzy goal in Fig. 1 is an example triangular linear membership functions (TLMF) all of the above membership functions belong to the class of problems with piecewise linear concave membership functions (Yang et al. 1991). Yang et al. have proposed a model to solve an FGP problem with TLMFs. they have extended the well-known Zimmerman (1975) to transform the problem into a conventional single objective LP model aiming maximize λ. λ is a degree achievement fuzzy function with $0 \le \lambda \le 1$ as follows model ;

$$\begin{aligned} &\max\ \lambda \\ &s.t\ \ \lambda \le 1 - \frac{(AX)_i - b_i}{\Delta_{iR}} \quad i=1,...,K \qquad (7)\\ &\quad\ \ \lambda \le 1 - \frac{b_i - (AX)_i}{\Delta_{iL}} \quad i=1,...,K \\ &\quad\ \ \lambda \ge 0,\ X \in C_s. \end{aligned}$$

λ is a degree achievement fuzzy function with $0 \le \lambda \le 1$

3.1 MINMAX Approach to FGP Problems

MINMAX (GP) was first introduced by Flavell (1976). This proposed approach aims to minimize the deviation from the target. It aims to achieve optimally conflicting goals. General MINMAX goal programming (MMGP) is stated as follows (8) :

$$\begin{aligned} &min\ \ D \\ &s.t.\ \ \alpha_i + \beta_i p_i \le D \qquad i=1,...,K \\ &\quad (AX)_i + n_i - p_i = b_i \quad i=1,...,K \qquad (8)\\ &\quad D, n_i, p_i \ \ge 0 \qquad i=1,...,K \\ &\quad X \in C_s. \end{aligned}$$

where bi is the precise aspiration level for the *i*th goal (i = 1, . . . ,K), n_i, p_i are negative and positive deviations from aspiration value of the *i*th goal, $\alpha_i(\beta_i) = w_i / k_i\, n_i(p_i)$ is unwanted, otherwise $\alpha_i(\beta_i) = 0$ The parameters w_i and k_i are the weights reflecting preferential and normalizing purposes attached to the achievement of the *i*th goal (Yaghoobi and Tamiz, 2007).

Yaghoobi and Tamiz (2007) extend to model (8) to solve the FGP models and showed the proposed solution stages model (9).

$$
\begin{aligned}
& \max \lambda \\
& s.t. \quad (AX)_i - p_i \le b_i \qquad i=1,\dots,i_0 \\
& \quad (AX)_i + n_i \ge b_i \qquad i=i_0+1,\dots j_0 \\
& \quad (AX)_i + n_i - p_i = b_i \qquad i=j_0+1,\dots K \\
& \quad \lambda + \frac{1}{\Delta_{iR}} p_i \le 1 \qquad i=1,\dots,i_0 \qquad (9) \\
& \quad \lambda + \frac{1}{\Delta_{iL}} n_i \le 1 \qquad i=i_0+1,\dots j_0 \\
& \quad \lambda + \frac{1}{\Delta_{iL}} n_i + \frac{1}{\Delta_{iR}} p_i \le 1 \qquad i=j_0+1,\dots K \\
& \quad \lambda, n_i, p_i \ge 0 \qquad i=1,\dots,K \\
& \quad X \in C_s
\end{aligned}
$$

4. Research method

4.1 Problem Description and Its Modeling

The Production Process consists of a total of 5 sections. These sections are metal section, dyeing section, furnishings section, textile processing section, sponge sizing section, and wood processing section. There are total of 154 sub-processes. In the metal section: 3, 13 in the dyeing section, 62 in the textile processing section, 36 in the sponge section, 40 in the wood section and 4 in the textile processing section. The workflows of the 11 sitting groups are different (Yücesan, 2016). Production flow chart of sitting groups is given Figure 2.

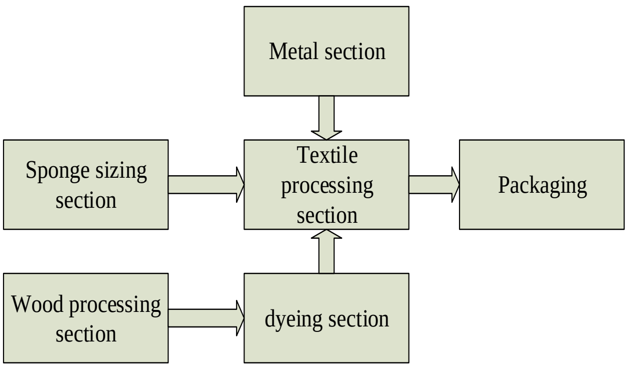

Figure 2. Production flow chart of sitting groups

Production planning can be an effective tool in determining manpower, production and, idle time and planning period. On the other hand, a planning which aims to determine company's yearly production policy should take all aspects of problem into consideration and fulfill managers' defined goals.

Policies considered in this paper are as follow:

- *First goal*: Since the loss caused by delay is high, management never accepts shortage. Managers do not want their production to fall below a certain value in order not to lose their existing market shares. Therefore, managers have set a production target for the enterprise.
- *Second goal*: Especially in the furniture industry where the competition is intense, the enterprise must provide a certain amount of profit in order to carry out its activities in a healthy manner. Therefore, another objective of the enterprise is profit.
- *Third goal*: Managers always want workstations to work balanced. Thus, it is possible to pass the bottlenecks that will limit the production. It will also guide new products to be designed in the future.

The operational conditions together with the assumptions of the model are as follows.

(i) It is assumed that production planning inputs do not change for a year.

(ii) It is assumed that the inventory level stock is not zero.

(iii) It is assumed that the labor force working on the machines in the furniture production line did not change during the period of the planning.

(iv) The initial product quantity for all products is zero.

(v) Maintenance and failure of the machines aren't considered

(vi) No further operation can be started on that workstation unless an operation is completed.

(vii) A process initiated on a workstation is continued continuously until it finishes.

(viii) Between workstations, the transport times of the products are considered within the processing times and these periods are independent of the way they are transported.

(iix) Production route of each product is determined. It will not change during the periods.

(ix) There is no overtime in the enterprise.

(x) The tempo is assumed to be 100% when calculating time studies.

(xi) In production planning, working time is assumed to be 7 hours in one day. 1 hour reserved for maintenance and unexpected errors. Also, the proposed production plan is considered as 3 months.

(x) Some parameters that cannot be determined precisely considered to fuzzy.

(xi) The tolerance values used in the model are determined by the decision-makers using their information and interpretations.

4.2. Problem Modeling

The following notations are used for the fuzzy target programming model. The proposed model is solved in LINGO 18.0. LINGO is designed to solve mathematical optimization problems. It is very common to use this program since its user friendly and compact.

y_i: product quantity of *i*

c_i: living room cost of *i*

μ_{ij}: usage coefficient of component y_i sub-processes *j*.

δ_n : maximum work time of the workstation

b1: the aspiration level for the profit goal

b2: the aspiration level for the production goal

Δ_{iR}, Δ_{iL} :chosen constants of the maximum admissible violations from the aspiration level bi

$w_{15}, w_{16}, w_{17}, w_{18}, w_{19}, w_{20}$: number of workers in work stations.

tm15, tm16, tm17, tm18, tm19, tm20: percent use of workstations

$$max\ \lambda \quad (10)$$

$$\sum_{i=1}^{11} y_i + n_1 - p_1 = 3470 \quad (11)$$

$$\sum_{i=1}^{11} ((pr_i y_i) - (co_i y_i)) + n_2 \geq 3650000 \quad (12)$$

$$tm15 - tm17 + n_3 - p_3 = 0 \quad (13)$$

$$tm17 - tm19 + n_4 - p_4 = 0 \quad (14)$$

$$tm19 - tm20 + n_5 - p_5 = 0 \quad (15)$$

$$\lambda + (1/200)n_1 + (1/200)p_1 \leq 1 \quad (16)$$

$$\lambda + (1/15000)n_2 \leq 1 \quad (17)$$

$$\lambda + (1/18000)n_3 + (1/18000)p_3 \leq 1 \quad (18)$$

$$\lambda + (1/18000)n_4 + (1/18000)p_4 \leq 1 \quad (19)$$

$$\lambda + (1/18000)n_5 + (1/18000)p_5 \leq 1 \quad (20)$$

$$\sum_{i=1}^{11} \sum_{j=1}^{3} (\mu_{20,j} y_i) \leq (\delta_{20} / w_{20}) \quad (21)$$

$$\sum_{i=1}^{11} \sum_{j=1}^{13} (\mu_{15,j} y_i) \leq (\delta_{15} / w_{15}) \quad (22)$$

$$\sum_{i=1}^{11} \sum_{j=1}^{62} (\mu_{17,j} y_{ij}) \leq \delta_{17} / w_{17}) \quad (23)$$

$$\sum_{i=1}^{11} \sum_{j=1}^{36} (\mu_{18,j} y_{ij}) \leq \delta_{18} / w_{18}) \quad (24)$$

$$\sum_{i=1}^{11} \sum_{j=1}^{40} (\mu_{19,j} y_{ij}) \leq \delta_{19} / w_{19}) \quad (25)$$

$$\sum_{i=1}^{11} \sum_{j=1}^{4} (\mu_{19,j} y_{ij}) \leq \delta_{16} / w_{16}) \quad (26)$$

$$p_1, p_2, p_3, p_4, p_5, n_1, n_2, n_3, n_4, n_5 \geq 0$$

$$y_i \geq 0, \ \text{i=1,...,11}$$

The following fuzzy goal programming model is given. In this model, it is aimed to reach the targets of production, profit and balance the work stations working times. For this purpose, it is aimed to minimize deviation variables which are indicative of the difference in working time of workstations. It is not possible for all workstations to work together in equal time. m15, m17, m19, m20 workstations are intended to work in equal time.

Eq.(10) is the objective and λ is a degree achievement fuzzy goals with $0 \leq \lambda \leq 1$Eq (11) and Eq. (12) refers to production and profit goal respectively. Eq.(13-15) is set for the goal of balance to work staions working time. n_i and p_i are the negative and positive deviation variables for the *i*th goal. Eq.(16-20) refer designate both left and right admissible violations for the fuzzy goals. Eq. (21-26) constraints of workstations. Eq.(21) represent maximum working level of metal section. j refers the subprocess quantity, 3 sub-processes of 11 products are performed in metal section. (δ_{20} / w_{20}) refers maximum working time of this sections. this value is determined by the decision maker at 2073600 second. tm15-20 variables indicate the usage capacity of workstations. They calculate with workstation active time which is find from the GP model.

5. Results of the FGP model application

The profit of the proposed production plan is 3650759 and the associated λ value is 0.86. The results show that the degree of satisfaction of the decision maker is appropriate. The profit that can be obtained according to the proposed plan is 3650759 TL and the amount of the product is estimated 3498 living groups. Other outputs of the proposed model are shown in Table 1.

Table 1. Outputs of the proposed model

λ	0.873
n_1	0
n_2	313.7785
n_3	0
n_4	0
n_5	0
p_1	25
p_3	20118.67
p_4	2274.233
p_5	2272.933
Profit	3783563
Production	3495
tm20 (%)	98.80993
tm15 (%)	99.99945
tm17 (%)	99.02922
tm18 (%)	100
tm16 (%)	86.91737
tm19 (%)	98.91954

Labor costs have an important place in the production of the sitting groups. In order to reorganize the number of workers, the current period was analyzed and the number of workers was rearranged. At the beginning of the study group, a total of 164 people were employed at the previous production plan, including seven at tm15, forty-eight at tm16, five at tm17, thirty at tm18, ten at tm19, and four at tm20. According to the proposed model, it will be able to continue its operations if four at tm15, forty-five at tm16, sixty at tm17, thirty-one at tm18, five at tm19, three at tm20. If the proposed model is used, the company's activities can be sustained by using approximately 8% less workers. In addition, workstations will be used more efficiently in the proposed model. The comparison of the proposed model with the previous period is shown in Figure 3.

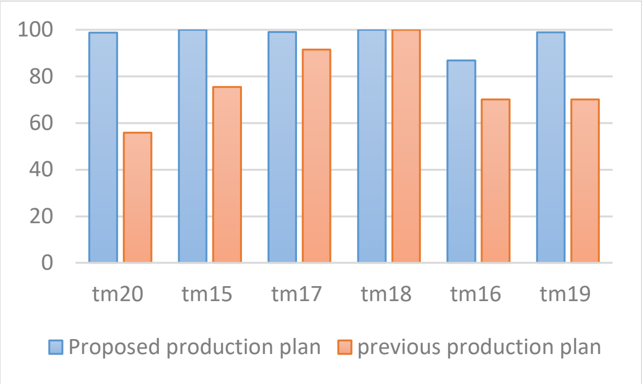

Figure 3. Comparison of proposed plans with previous

6. Conclusions and Future Research Directions

In the past years, furniture production was realized in small workshops and low production volumes. Due to today's competitive conditions, furniture production has started to move from labor-intensive production to technology-supported series production. Production volumes increased, prices decreased and competition increased. In today's competitive conditions, the continuity of the enterprises is possible with the most effective use of the production facilities available.

The fact that production planning problems depend on many parameters and the objectives contradict each other make the decision-makers work very hard. The complex and difficult-to-solve decision problems have to be simplified by various assumptions. In order to solve the production planning problem, some assumptions have been made and production planning problem has been made suitable for solution by goal programming.

Businesses should either improve their production opportunities or use existing opportunities effectively to increase profits. Due to the structure of the furniture companies, it is a difficult and costly process to increase the production opportunities in the short term. In this study, it is assumed that the production facilities are fixed and it is aimed to reach the goals determined by the existing opportunities. This study presents an FGP model that can be used in decision making processes for an enterprise that produces production under uncertainty in the furniture industry. FGP provides many advantages to decision makers. The most important of these advantages is that working time which is not determined precisely and targets can be expressed as fuzzy.

Based on the proposed production plan model, new results can be obtained for different purposes by changing the number of different product numbers, types and working periods in the future periods. Thus, the usage rates and profitability of workstations can be determined. After the production plan has been created, a production schedule can be created using this plan. In addition to the objectives in the proposed model, new goals can be considered in new models to be developed in order to increase product quality based on raw materials suppliers and prices.

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