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Research Article

Machine Selection for a Textile Company with CRITIC and MAUT Methods

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Abstract

The main purpose of the companies is to make a profit and to ensure that this profitability is continuous. In this context, the selection of the machines used by the companies in production is an important issue. Businesses have to choose the most suitable machine to reduce their costs and produce efficiently. For this reason, the decision of machine selection is also very important for textile enterprises. Machine selection in textile enterprises is a Multi-Criteria Decision problem in which a large number and contradictory criteria are taken into account. In this study, machine selection will be made with CRITIC and MAUT methods for a textile company. In the study, the weights of the decision criteria that are effective in the decision-making were determined by the CRITIC method. Then, the machine selection was made by evaluating the alternatives with the MAUT method. According to the results of the study, CRITIC and MAUT methods were evaluated as integrally applicable to machine selection.

Keywords: Multi-Criteria Decision Making, CRITIC, MAUT, Flat Knitting Machine Selection.

CRITIC ve MAUT Yöntemleri ile Bir Tekstil İşletmesi İçin Makine Seçimi

Öz

İşletmelerin temel amacı kâr etmek ve bu kârlılığın sürekli olmasını sağlamaktır. Bu bağlamda işletmelerin üretimde kullandığı makinelerin seçimi stratejik bir karardır. İşletmeler maliyetlerini düşürmek ve verimli üretim yapabilmek için en uygun makineyi seçmek zorundadırlar. Bu nedenle makine seçim kararı tekstil işletmeleri için de çok önemlidir. Tekstil işletmelerinde makine seçimi, çok sayıda ve birbiriyle çelişen kriterin dikkate alındığı çok kriterli bir karar problemidir. Bu çalışmada bir tekstil işletmesi için CRITIC ve MAUT yöntemleri ile makine seçimi yapılmıştır. Çalışmada öncelikle makine seçimi kararı vermede etkili olan karar kriterlerinin ağırlıkları CRITIC yöntemi ile belirlenmiştir. Daha sonra MAUT yöntemi ile alternatifler değerlendirilerek makine seçimi yapılmıştır. Çalışma sonuçlarına göre CRITIC ve MAUT yöntemlerinin makine seçiminde bütünleşik olarak uygulanabilir olduğu değerlendirilmiştir.

Anahtar Kelimeler: Çok Kriterli Karar Verme, CRITIC, MAUT, Düz Örgü Makinesi Seçimi.

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1. Introduction

Businesses can ensure their continuity by constantly making profits and growing. Otherwise, they will have difficulty maintaining their presence in increasing global competition. A significant amount of capital is allocated for machinery and equipment, especially in production enterprises, and these fixed capital investments significantly affect operating profitability. For this reason, businesses make production plans, including planning machinery and equipment, to achieve low-cost and efficient production. Choosing a machine that will reduce costs and increase productivity when planning production is essential for ensuring operating profitability. In this context, the selection of machinery and equipment, transport vehicles, and other construction machinery used in production are extremely important and strategic decisions for enterprises.

The machine selection problem is one of the important decision-making problems for production companies. Incorrect machine selection can negatively affect the performance of the production system. The speed, quality, and cost of production depend significantly on the machines used. The machine selection decision is a difficult and long process, as well as requires advanced knowledge and expertise (Ertuğrul, 2007:171).

The choice of machines used in production is a situation that requires the consideration of numerous and contradictory criteria. Multi-Criteria Decision Making(MCDM) methods have been developed to solve decision problems where there are many and conflicting criteria. MCDM methods offer scientific and effective solutions to decision problems where there are many contradictory criteria. MCDM methods achieve the decision-maker to choose the best alternative by optimizing multiple criteria(Zeydan etc, 2020:418-429).

In this study, the choice of a flat knitting machine for a textile enterprise was realized by CRITIC(CRiteria Importance Through Intercriteria Correlation) and Maut(Multi-Attribute Utility Theory) methods which are one of the MCDM methods.

In the study, the weights of the criteria were determined by the CRITIC method, alternatives were evaluated by the MAUT method and ranking and selection were made with the help of hand results. There are not many studies in the Turkish literature in which CRITIC and MAUT methods are used together. In addition, there are no studies using CRITIC and MAUT methods on textile machine selection in the literature. This study will contribute to the Turkish literature in this aspect.

This article is divided into five sections. After the introduction section containing information about the decision problem in the study, the second section contains a literature review. In the third section, the method of work and data are given and in the fourth section, the application of flat knitting machine selection is given. The results obtained in the last part of the study were examined and discussed.

2. Literature review

There are many studies in the literature on the selection of machines used in the production systems of companies. It is seen that CRITIC and MAUT methods are used in solving many decision problems, especially in the fields of engineering and social science. In the literature review section, firstly, studies in which CRITIC and MAUT methods are used together and together with different methods are included. These studies are shown in Table 1.

Table 1. Literature review on CRITIC, MAUT methods, and other MCDM methods.

Researcher	Year	Methods	Decision Problem
Boscovıc et al.	2021	CRITIC and ARAS	Mobile network provider operator selection
Li et al.	2020	Fuzzy DEMATEL, Entropy, and VIKOR	Machine tool selection
Yürük and Orhan	2020	CRITIC, ENTROPİ and MAUT	Financial performance analysis of manufacturing industry sub-sectors
Vargün, Doğan and Bal	2020	MAUT	Personnel selection for the accounting unit
Orhan and Aytekin	2020	CRITIC, MAUT, and SAW	Comparison of the R&D performances of Turkey and the countries that recently joined the EU
Eş and Kocadağ	2020	ENTROPİ, MAUT and VIKOR	Supplier selection
Stirbanovic et al.	2019	VIKOR and TOPSIS	Evaluation of flotation machines
Yalçın and Karakaş	2019	CRITIC and EDAS	Corporate sustainability performance analysis for an energy company
Özdağoğlu and Çirkin	2019	OCRA, MAUT	Electronic device selection
Akın	2019	Entropy-ROV and CRITIC-ROV	Bed edge border sewing machine selection
Bulgurcu	2019	MAUT and CRITIC	Smartwatch selection
Ulutaş and Cengiz	2018	CRITIC and EVAMIX	Choosing a laptop for a business
Gunawan and Ramadhan	2018	MAUT	Performance evaluation of employees
Ulutaş	2017	EDAS	Choosing a sewing machine for a textile workshop

Adalı and Işık	2017	CRITIC and MAUT	Contract manufacturer selection
Chan, Suen, and Chan	2006	AHP and MAUT	Selection of resolution model in disputes
Özceylan, Kabak and Dağdeviren	2016	Fuzzy AAS and PROMETHEE	CNC machine selection
Wu, Ahmad, and Xu	2016	Fuzzy VIKOR	CNC machine tool selection
Ertuğrul and Öztaş	2015	MOORA and TOPSIS	Selection of Sewing machine
Diakoulaki, Mavrotas and Papayannakis	1995	CRITIC	Performance analysis of companies
Ertuğrul	2007	Fuzzy AHP	Machine selection in the textile business

3. Material and Method

This study aims to select a flat knitting machine for a textile company. The steps of the decision model applied in the study are shown in Figure 1.

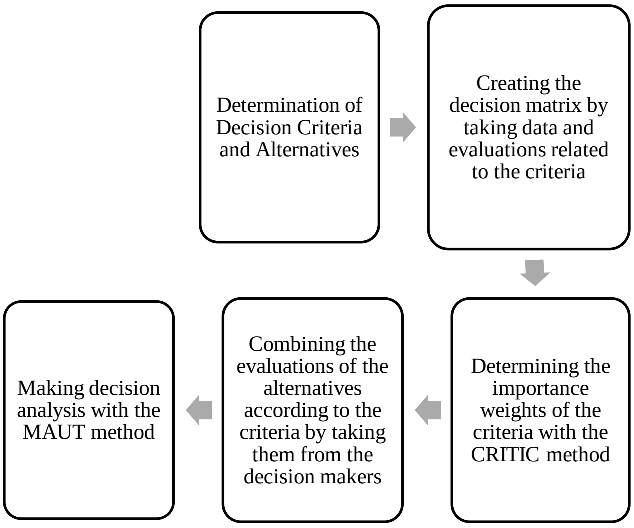

Figure 1. Steps of the decision-making process.

The criteria used in the study and effective in machine selection were determined as a result of literature review and expert opinions. The criteria that are effective in choosing a flat knitting machine are determined as price, the number of Saddle knitting, accessibility to the pattern programmer, accessibility to qualified employees who can use the machine, availability to spare parts, service speed, and facilities, energy consumption. Decision criteria consist of quantitative and qualitative criteria. The values obtained by alternatives according to quantitative criteria were obtained from the product promotion catalogs of the companies. The values related to the qualitative criteria were obtained by using the 1-7 Likert scale with the engineers and technical staff in the manager position of the manufacturing enterprises. It is important to demonstrate the advantages and disadvantages of flat knitting machines in practice that the values related to qualitative criteria are taken from expert technical personnel. The decision criteria used in choosing a flat knitting machine are encoded and given in Table 2.

Table 2. Criteria and weights of criteria in the flat knitting machine selection.

Code	Criteria	Nature of Criteria
K1	Price	Cost
K2	Number of saddle weaves	Benefit
K3	Access to pattern programmer	Benefit
K4	Access qualified personel to use the machine	Benefit
K5	Availability of spare parts	Benefit
K6	Service oppotunities	Benefit
K7	Energy Consumption	Cost

3.1. CRITIC Method

The CRiteria Importance Through Intercriteria Correlation (CRITIC) method is a multi-criteria decision-making method developed by Diakoulaki et al. (1995). The CRITIC method is a recommended method for weighting criteria. The method is one of the objective weighting methods. In the CRITIC method, criteria are weighted according to the data in the decision matrix, without relying on expert opinions and decision-maker preferences. In this method, it uses the standard deviation values and correlation coefficients of the criteria to determine the relationships between the criteria. In the decision matrix, the values of the alternatives according to the quantitative criteria were obtained by measurement. The values that the alternatives will receive according to the qualitative criteria are obtained by the decision makers' evaluation of the alternatives according to the criteria. Evaluations obtained from matrix values according to qualitative criteria are obtained by transforming them into quantitative values. The steps of the CRITIC method can be shown as follows (Alinezhad and Khalili, 2019:199-201, Hassan, Kamal, Moniruzzaman, Zulkifli, and Yusop, 2015).

The first step in the CRITIC method is the generate of the decision matrix. The decision matrix in size of mxn, which contains alternatives and criteria created by decision-makers, is also shown in Equation (1):

$$M = \begin{bmatrix} x_{11} & \dots & x_{1j} & \dots & x_{1n} \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ x_{i1} & \cdots & x_{ij} & \cdots & x_{in} \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ x_{m1} & \dots & x_{mj} & \cdots & x_{mn} \end{bmatrix}; \quad i = 1,2,...m, \quad j = 1,2,...n \qquad (1)$$

The x_{ij} value in the decision matrix shows the value taken by the alternative i. according to criterion j. After the decision matrix is created, The Matrix is normalized. The benefit qualified and cost qualified criteria in the decision matrix is normalized by the formula (2) and (3), respectively.

$$r_{ij} = \frac{x_{ij} - x_j^{\min}}{x_j^{\max} - x_j^{\min}} \quad (2)$$

$$r_{ij} = \frac{x_j^{\max} - x_{ij}}{x_j^{\max} - x_j^{\min}} \quad (3)$$

As a result of the calculation, r_{ij} values are normalized values of x_{ij} values. After the normalized decision matrix is created, the standard deviation is calculated with correlation coefficients between criteria so that the importance weights of the criteria can be calculated. The weights of the criteria are calculated by the formula (4).

$$w_j = \frac{C_j}{\sum_{i=1}^{n} C_j} \quad ; \quad i = 1,2,.....n \quad (4)$$

In the formula, w_j indicates the importance weight of criterion j, in other words, the degree of importance and priority. Cj indicates the index value of criterion j.

$$C_j = \sigma_j \sum_{k=1}^{n} (1 - p_{jk}) \qquad j = 1.2,......n \quad (5)$$

In the formula (5), shows the standard deviation of criterion j and the correlation coefficient between the criteria. The standard deviation of each criterion is calculated by equation (6).

$$\sigma_j = \sqrt{\frac{1}{n-1} \sum_{j=1}^{n} (x_{ij} - \overline{x})^2} \quad ; \quad i = 1,2,....m \quad (6)$$

$$p_{jk} = \frac{\sum_{i=1}^{m} (x_{ij} - \overline{x}_j)(x_{ik} - \overline{x}_k)}{\sqrt{\sum_{i=1}^{m} (x_{ij} - x_j)^2 \sum_{i=1}^{m} (x_{ik} - \overline{x}_k)^2}} \quad (7)$$

In Equation (7) and indicates the average of the criteria.

3.2. MAUT Method

The MAUT method was developed by Keeney and Raiffa (1976). The method can be used to solve decision problems that have both quantitative and qualitative criteria. The Maut method is a method that analyzes alternatives based on benefit values derived from criteria. In the method, a utility value is calculated for each alternative according to the determined criteria. In the MAUT method, it is aimed that the alternatives obtain the highest total utility value and ranking is made according to these utility values. The application steps of the method can be summarized as follows. (Ishizaka and Nemery 2013; Alinezhad and Khalili, 2019; Tzeng and Huang, 2011).

First, the decision matrix is created.

$$X = \begin{bmatrix} x_{11} & \dots & x_{1j} & \dots & x_{1n} \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ x_{i1} & \cdots & x_{ij} & \cdots & x_{in} \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ x_{m1} & \dots & x_{mj} & \cdots & x_{mn} \end{bmatrix}_{mxn} ; 1 = 1,2....m, \quad j = 1,2....n \quad (8)$$

In the decision matrix, x_ij indicates the value of the alternative i according to criteria j. After the decision matrix is created, the values of the alternatives for the utility criterion in the decision matrix are normalized with formula (9). The values of the alternatives for the cost-qualified criteria are normalized using the formula (10) shows the normalized values of the decision matrix.

$$r_{ij} = \frac{x_{ij} - x_{ij}^{\min}}{x_{ij}^{\max} - x_{ij}^{\min}} \quad (9)$$

$$r_{ij} = 1 + \frac{x_{ij}^{\min} - x_{ij}}{x_{ij}^{\max} - x_{ij}^{\min}} \quad (10)$$

After the decision matrix is normalized, the utility values of the alternatives are calculated. The utility values are calculated by equation (11).

$$U_i = \sum_{j=1}^{n} u_{ij}.w_j \quad ; \qquad i = 1,2,.....m \quad (11)$$

The indicates the utility values and indicates the importance weight of the criterion j. The sum of the importance weights of the criteria is $\sum W_j = 1$. The utility values of the alternatives are sorted in descending order for the final ranking. The alternative with the highest total utility value is the best.

4. Application

In the application section, the CRITIC method was used in determining the weights of decision criteria for determining the most suitable machine, and the MAUT method was used in sorting and selecting alternatives. With the proposed CRITIC and MAUT integrated decision model, a survey was conducted with the engineers and technical staff of the companies operating in the textile sector to choose a flat knitting machine. A survey was conducted by interviewing a total of 40 experts in the positions of managers and technical personnel. With the literature review and interviews, 4 flat knitting machine brands were determined as an alternative. Electronic machines selected in the study were coded as M1, M2, M3, M4. Experts were asked to evaluate alternatives according to qualitative criteria. These criteria are “access to the pattern programmer”, “finding qualified personnel to use the machine”, “accessibility to spare parts and service possibilities”. In the survey, experts were asked to evaluate the alternatives for these criteria on a 1-7 Likert scale. The decision matrix was formed by taking the arithmetic average of the expert evaluations. The values obtained by the alternatives according to the quantitative criteria of "price", "number of saddle weaves" and "electricity consumption" were obtained from the manufacturing companies. The decision matrix created is given in Table 3. Since the "price" (K1) and "electricity consumption" (K7) criteria in the decision matrix are cost criteria, the values of these criteria are desired to be the smallest, while the benefit criteria are requested to have the highest value.

The correlation coefficients between the criteria are calculated by the formula (7).

Tablo 3. The Decision Matrix

	K1($)	K2	K3	K4	K5	K6	K7 (Kw)
M1	38,000	3	4,900	4,660	5,540	5,250	2,3
M2	32,500	2	6,030	5,950	6,300	6,270	1,2
M3	32,000	2	2,090	2,090	1,900	2,040	1,5
M4	16,500	3	2,090	1,750	1,610	1,800	0,6

After the decision matrix was created, the weights of the criteria were calculated with the CRITIC method. Equation (6) was used to calculate the standard deviation values. The normalized decision matrix is calculated with equality (2) and equality (3) and shown in Table 4.

Table 4. Standard deviation values of criteria and Normalized decision matrix

	K1	K2	K3	K4	K5	K6	K7
M1	0	1	0.713	0.692	0.837	0.771	0
M2	0.255	0	1	1	1	1	0.647
M3	0.279	0	0	0.080	0.061	0.053	0.470
M4	1	1	0	0	0	0	1
Std. Dev.	0.429	0.577	0.508	0.483	0.517	0.505	0.415

After calculating the normalized decision matrix and standard deviation values, the correlation matrix between the criteria was calculated and given in Table 5.

Table 5. The Correlation coefficients between criteria.

	K1	K2	K3	K4	K5	K6	K7
K1	1	0.312	-0.612	-0.645	-0.683	-0.659	0.902
K2	0.312	1	-0.162	-0.231	-0.124	-0.161	-0.081
K3	-0.612	-0.162	1	0.997	0.993	0.997	-0.409
K4	-0.645	-0.231	0.997	1	0.990	0.996	-0.421
K5	-0.683	-0.124	0.993	0.990	1	0.998	-0.510
K6	-0.659	-0.161	0.997	0.996	0.998	1	-0.466
K7	0.902	-0.081	-0.409	-0.421	-0.510	-0.466	1

After calculating the correlation coefficients between the criteria, the importance weights of the criteria were calculated by using the equation (3.4) and given in Table 6.

Table 6. Criteria and weights of criteria in the flat knitting machine selection.

Code	Criteria	Weight of Criteria
K1	Price	0,172
K2	Number of saddle weaves	0,202
K3	Access to pattern programmer	0,115
K4	Access qualified personel to use the machine	0,113
K5	Availability of spare parts	0,121
K6	Service oppotunities	0,117
K7	Energy Consumption	0,157

When the criteria weights are examined, it is seen that the importance weights of the criteria are close to each other and there is no big weighting difference between them. However, it is seen that the most important and priority criterion is the number of saddle knitting in flat knitting machines. In addition, it is seen that the criteria of accessibility to the pattern programmer, finding qualified personnel who can use the machine, and access to spare parts are very close to each other and less important in order of importance compared to other criteria. Price, the number of saddle weaves, and electricity consumption was the standout criteria.

After determining the criterion weights by the CRITIC method, the decision matrix was created for choosing a flat knitting machine among 4 brands by the MAUT method. The evaluation of alternatives by engineers, managers, and other technical personnel according to the criteria was combined by taking the arithmetic mean. The decision matrix created is shown in Table 7.

Table 7. The Decision Matrix

	K1($)	K2	K3	K4	K5	K6	K7(Kw)
M1	38,000	3	4,900	4,660	5,540	5,250	2,3
M2	32,500	2	6,030	5,950	6,300	6,270	1,2
M3	32,000	2	2,090	2,090	1,900	2,040	1,5
M4	16,500	3	2,090	1,750	1,610	1,800	0,6
Min	**16,500**	**2**	**2,090**	**1,750**	**1,610**	**1,800**	**0,6**
Max	**38,000**	**3**	**6,030**	**5,950**	**6,300**	**6,270**	**2,3**

After determining the objective weights of the criteria, the MAUT method was used for the selection of a flat knitting machine. The decision matrix is normalized using equations (9) and (10). The normalized decision matrix is given in Table 8.

Table 8. Normalized decision matrix according to the MAUT method.

	K1	K2	K3	K4	K5	K6	K7
M1	0	1	0.713	0.692	0.837	0.771	0
M2	0.255	0	1	1	1	1	0.647
M3	0.279	0	0	0.080	0.061	0.053	0.470
M4	1	1	0	0	0	0	1

After obtaining the normalized matrix, the total utility values for each alternative were calculated with the equation (11). The utility values of the alternatives are shown in Table 9.

Table 9. Benefit Matrix weighted by CRITIC method.

	K1	K2	K3	K4	K5	K6	K7
M1	0	0.202	0.082	0.078	0.101	0.090	0
M2	0.044	0	0.115	0.113	0.121	0.117	0.101
M3	0.048	0	0	0.009	0.007	0.006	0.074
M4	0.172	0.202	0	0	0	0	0.157

The total utility values for the alternatives are obtained by summing the utility values calculated according to each criterion. The calculated total utility values and ranking of the alternatives according to their total utility values are shown in

Table 10. M2 machine was determined as the best alternative in the ranking made according to the MAUT method. The machines are listed as M2, M1, M4, M3, starting from the best.

Table 10. Ranking of flat knitting machines according to the CRITIC-weighted MAUT method.

Machines	Total utility values	Ranking
M1	0.555	2
M2	0.614	1
M3	0.145	4
M4	0.531	3

5. Results and Discussion

Decision-making is the process of choosing the most suitable one from among the alternatives. The first step in making the right decision is to define the decision problem and design the process. Decisions can be classified from a variety of care. It is possible to classify decisions as long-term decisions and short-term decisions in terms of the duration of the decision's impact, in other words, its maturity. From this point of view, constant capital investment decisions in companies are expressed as long-term decisions. Decisions to purchase constant assets, such as machinery and equipment, which are expressed as constant capital investments in companies, are decisions of a strategic nature for companies. The main reason that fixed capital investment decisions are characterized as strategic is that they are the basic requirement of low-cost and efficient production. Second, constant capital investment decisions are rarely decisions made, unlike working capital decisions, and are not open to changes and corrections. For this reason, machine purchase decisions involving long-term investments should be analyzed using scientific and appropriate methods and should be true. In this context, it is seen that decisions to purchase flat knitting machines for textile enterprises are strategic and long-term decisions.

Decision problems that require the consideration of a large number of contradictory criteria are solved by multi-criteria decision-making methods. The profitability and continuity of the business need to decide to purchase flat knitting machines with the problem of MCDM using scientific methods. In this study, the most suitable flat knitting machine was selected with CRITIC and MAUT methods, which are among the multi-criteria decision-making methods for a textile company. The selection of a flat knitting machine is a decision problem in which many conflicting criteria are effective. In this study, the importance weights of the criteria were determined by the CRITIC method, and the machine selection and evaluation were made with the MAUT method. In the study, the best of 4 falt knitting machines were determined according to 7 criteria evaluation criteria, 4 of which were qualitative and 3 of which were quantitative. According to the ranking made by the MAUT method, the M’ machine was determined as the best alternative. The machines are listed as M2, M1, M4, M3, starting from the best.

6. Conclusions and Recommendations

CRITIC method is characterized as objective weighting method. The method uses values in the decision matrix without the need for expert or decision-maker opinions when determining the importance weights of criteria. As with the criteria affecting the decision of choosing a flat knitting machine, the situation may arise when the decision criteria in decision problems cannot be determined in terms of their superiority over each other in terms of their weight of importance. In such cases, the CRITIC method seems to provide a solution by overcoming the uncertainty experienced in weighting. In this sense, according to the results of the study, it was concluded that the CRITIC method is a method that provides an objective solution, taking into account the uncertainty experienced in setting the priorities of two or more criteria. The Maut method used in sorting alternatives in the study evaluates alternatives based on the total benefit function. In the method, the total benefit value is reached by collecting the calculated benefit values for alternatives according to each criterion. According to the results of the study, it was concluded that the Maut method is an easy-to-understand and viable method. It was concluded that CRITIC and MAUT methods used in the study are integrated methods that can be used to solve machine selection problems. As with the machine purchase problem, making comparisons using different MCDM methods in solving decision problems that involve uncertainty in determining criterion weights will enrich the literature and contribute.

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