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EVALUATION of MACHINE SELECTION CRITERIA with MACBETH METHOD in A GINNERY FACTORY

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ABSTRACT

Selecting proper machine is very crucial and challenging decision making process for managers due to the effects on both quality and lead time of production. Cotton have been used in wide variety of industries as raw or semi-processed materials through centuries. Like the other machine selection problems, selecting accurate gin machine is crucial when to consider the effects of the gin machine on quality of cotton and fiber value. This paper proposes a multi-criteria decision analysis (MCDA) to evaluate criteria to selecting gin machine. This study was conducted at a ginnery factory within Aydın region. MACBETH (Measuring Attractiveness by a Categorical Based Evaluation Technique) which is a multi-criteria evaluation approach was used to evaluate four criteria based on non-numerically value judgements of managers. This study aims to analyze the importance levels of criteria with MACBETH method.

Keywords: *Production Management, MACBETH Method, Machine Selection.*

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BİR ÇIRÇIR FABRİKASINDA MAKİNE SEÇİM KRİTERLERİNİN MACBETH YÖNTEMİ ile DEĞERLENDİRİLMESİ

ÖZET

Uygun makine seçimi, hem kaliteyi hem de üretim süresini etkilediği için yöneticiler için çok önemli ve zorlu bir karar verme sürecidir. Pamuk, yüzyıllardır ham veya yarı işlenmiş malzeme olarak çok çeşitli endüstrilerde kullanılmaktadır. Diğer makine seçim problemlerinde olduğu gibi, doğru makine seçimi, çırçır makinesinin pamuğun kalitesi ve yapısı üzerindeki etkilerinden dolayı çok önemlidir. Bu makalede, çırçır makinesinin seçim kriterlerini değerlendirmek için çok kriterli karar analizi önermektedir. Bu çalışma Aydın bölgesindeki bir çırçır fabrikasında gerçekleştirilmiştir. Çok ölçütlü bir değerlendirme yaklaşımı olan MACBETH (Kategorik Bazlı Değerlendirme Tekniği ile Çekiciliği Ölçme), yöneticilerin sayısal olmayan değer yargılarına dayanarak dört kriteri değerlendirmek için kullanılmıştır. Bu çalışmanın amacı MACBETH yöntemiyle kriterlerin önem düzeylerini analiz etmektir.

Anahtar Kelimeler: *Üretim Yönetimi, MACBETH Yöntemi, Makine Seçimi.*

1. INTRODUCTION

Buying new machine and selecting proper one is very effortful decision process for managers because decision makers should both deal with financial issues related to initial investment of machine buying such as return on investment, net present value and internal rate of return (Abdel-Kader, 1997; Kim, Park and Yoon, 1997) and selecting to proper one with caring of different evaluation criteria. Moreover, selecting proper machine which affect to quality, flexibility and delivery time of product (Abdel-Kader, 1997; Chen and Small, 1996; Kaplan, 1986) and properly evaluating different criteria increases to chance to make more accurate decision-making (Thokala et al., 2016). So that, machine selection is a multicriteria decision problem for managers and many reseachers have used some multicriteria decision analysis (MCDA) methods to help managers in decision making stage. In this study, we use MACBETH method, which is one of the multiple-criteria decision analysis method to analyze the importance level of cotton gin machine selection criteria.

The paper is organized as follows; In Section 2 presents the literature review that related to MACBETH applications. Section 3

introduces MACBETH technique to evaluate criteria of cotton gin machine selection. Application of model and general information of firm have been introduced in the Section 4. The concluding remarks that have been acquired are in the Section 5.

2. LITERATURE REVIEW

Multiple-criteria decision analysis is a tool to aid decision makers to order alternatives and choose the best one based on two or more criteria (Roy, 1996). When to evaluate multiple criteria in decision making process give change to users making more accurate decision-making (Thokala et al., 2016).

MCDA uses four basic steps, which starts with identifying objectives. Later criteria is defined and objectives are classified into criteria and all possible alternatives are collected from decision makers, after preferences of decision makers are collected and performance of the alternatives are analyzed based on the defined criteria. Lastly, results are discussed and giving advices to decision makers about best alternative (Roy, 1996).

Most of researchers follow these basic steps except assessment methods (Lauras, Marques, and Gourc, 2010). Researchers can use different assessment methods such as analytical hierarchy process (AHP) (Saaty, 1990; Saman, Murat and Rifat, 2013), multi-objective optimization on the basis of ratio analysis (MOORA) (Brauers and Zavadskas, 2009; Stanujkic, 2016). MACBETH (measuring attractiveness by a categorical based evaluation technique) is a multi-criteria evaluation method was developed by Bana e Costa and Vansnick (1994). MACBETH compares alternatives based on their differences of attractiveness with using semantic decisions of decision makers. When the literature is examined, it is seen that the manufacturing enterprises use the MACBETH method to select and evaluate among various alternatives. In this section, some applications used in the MACBETH method will be mentioned.

MACBETH method is broadly used on very different fields to make assessments. For example, Bana e Costa and Oliveira (2012) evaluate faculty members' performance based on teaching, research, university management and knowledge transfer criteria. Moreover, performance of predictive maintenance programs (Bana e Costa, Carnero and Oliveira, 2012), attractiveness of governments to parties based on utilities (Roubens, Rusinowska and De Swart, 2006), technical performance of three hydrogen storage technologies (Montignac, Noirot and Chaudourne, 2009), measuring the weak and the strong

environmental responsibility degree of mutual funds in U.S. (Cabello, Ruiz, Pérez-Gladish and Méndez-Rodríguez, 2014), calculating and evaluating performance and efficiency of same airport along several years based on some constraints (Baltazar, Jardim, Alves and Silva, 2014), analyzing maintenance strategies in electric power distribution systems in health care organization (Carnero and Gomez, 2017), measuring airport performance and efficiency (Baltazar, Rosa and Silva, 2018) can be evaluated through MACBETH approach.

Some of the researchers combine two or more models to evaluate alternatives. Study of Gürbüz, S. E. Alptekin and G. I. Alptekin (2012) is a good example about hybrid method. Analytic Network Process (ANP), Choquet integral (CI) and MACBETH are used respectively to evaluate four ERP projects. MACBETH is used to find CI parameters. A.G.M. Junior, M. M. C. Junior, Belderrain, Correia and Schwanz (2012) use factor analysis and MACBETH method to evaluate ports performance of Brazilian. Moreover, Faria, Ferreira, Jalali, Bento and António (2018) combine MACBETH and cognitive mapping tecniques to evaluate quality life in urban areas.

3. MACBETH METHOD

Measuring Attractiveness by a Categorical Based Evaluation Technique (MACBETH) method is one of the multi criteria decision making methods. Method depends upon the qualitative judgements between alternatives and criteria. MACBETH look like Analytic Hierarchy Process (AHP). Because both of them have used pairwise comparison matrices. The main difference between these two methods is that AHP uses ratio scale but MACBETH uses interval scale (Burgazoğlu, 2015). Semantic categories which are used for pairwise comparisons can be seen in Table 1.

Table 1. Semantic Categories for MACBETH

Semantic Categories	Scale
no	0
very weak	1
weak	2
moderate	3
strong	4
very strong	5
extreme	6

Reference: Burgazoğlu, 2015: 262

MACBETH method uses linear programming model for finding the importance levels of the alternatives or criteria. This linear programming model has been constructed as follows (Burgazoğlu, 2015).

$$i, j, k, l: total\ number\ of\ alternatives\ or\ criteria; i, j = 1,2,3, \dots, n$$

$$o_i: the\ value\ of\ alternative\ i\ or\ criterion\ i$$

$$o_1: the\ value\ of\ the\ most\ important\ criterion\ or\ alternative$$

The objective function of this linear programming model can be seen in Equation1.

$$z_{min} = \Phi(o_1) \quad (1)$$

The next step of this linear programming model is to write constraints. The first contraint group is ordinal constraint.

$$\delta(i, j): preference\ level\ difference\ between\ o_i\ and\ o_j$$

Ordinal constraints can be written as in Equation 2.

$$\forall o_i, o_j, i, j \in \{1,2,3, \dots, n\}: o_i > o_j \Longrightarrow \Phi(o_i) \geq \Phi(o_j) + \delta(i, j) \quad (2)$$

Next constraint group is semantic constraints. Semantic constraints can be written as in Equation 3.

$$\forall o_i, o_j, i, j, k, l \in \{1,2,3, \dots, n\}: \Phi(o_i) - \Phi(o_j) \geq \Phi(o_k) - \Phi(o_l) + \delta(i, j, k, l) \quad (3)$$

The last constaint of this linear programming model is reset constraint. Reset constraint can be seen in Equaiton 4.

$$o_n: the\ value\ of\ the\ least\ important\ criterion\ or\ alternative$$

$$\Phi(o_n) = 1 \quad (4)$$

After solving this linear programming model, the values of the alternatives or criteria have been found. The next step is to normalize these values. Normalization process can be made as in Equation 5.

$$norm_i: normalized\ importance\ value\ of\ alternative\ i\ or\ criterion\ i$$

$$norm_i = \frac{\Phi(o_i)}{\sum_{i=1}^{n} \Phi(o_i)}$$

4. APPLICATION

Textile industry has used cotton as a part of production from several centuries (Lewis and Richmond, 1968). Moreover, seeds of cotton are used as raw materials in animal feed and oil industries. So that, every part of the cotton has been used efficiently by people. History of cotton gin machine has began in 1794 with the invention of Eli Whitney. Later, some other innovaters like Hengry Ogden Holmes and Charles Bennett had improved to features and specifications of gin machine, eventually it took final shape (Anthony and Mayfield, 1994). Cotton gin is used to remove cotton fiber from its seed automatically. Moreover, a study shows that gin machine affects quality and fiber value of cotton (Anthony, 1996). In this study, MACBETH method is used to help the decision makers in the stages of evaluating the cotton gin machine selection criteria.

Türkiye İstatistik Kurumu (TÜİK, 2019) statistics is a good indicator, which expain reason of selection a ginnery factory in Aydın. Data fall in years between 2013 and 2017, total amount of cotton production for Turkey and Aydın region can be seen in Table 2. According to TÜİK information, average of last five years amount of cotton production is 2.450.000 tonnes in Turkey and 331.161 tonnes in Aydın region. 13,52% of average amount of cotton had been produced in Aydın region, which is shown to importance of Aydın region as a cotton producer.

Table 2: Amount of Cotton Production

	Turkey (Tonnes)	**Aydın (Tonnes)**	**Cotton Production Percentage of Aydın Region (%)**
2013	2.250.000	287.031	12,76%
2014	2.350.000	316.856	13,48%
2015	2.050.000	287.473	14,02%
2016	2.100.000	326.475	15,55%
2017	2.450.000	331.161	13,52%
Average Amount of Cotton Production	2.240.000	309.799,2	13,83%

Reference: TÜİK, 2019

In this study, data gathered from one of the ginnery facility located in Aydın. The facility has been operating as a small-medium

enterprise. This factory has purchased cotton from the farmers in every year through the cotton harvest seasons. Later, these cotton have been processed in cotton gin machine in order to separate cotton fiber and seed. Finally, cotton has been bundled and selled.

Based on the interview conducted with the three owners of the factory, four crucial evaluation criteria were found, which are minimum risk of injury, minimum machine failure, quality and speed of machine. Minimum risk of injury from machinery criterion meaning is to prevent or minimize the employees' injury from machine and maximize workers' safety through production. The second criteria has been used to decision process of purchasing machine is facing minimum machine failure during production. Cotton should be properly processed in machine and machine should remove cotton from its seed accurately and best quality, that is third criteria and process as much as possible cotton in least time, that is speed is last criteria.

In the first step of factory application criteria have been discussed with the decision makers in the factory. Then, a form has been constructed the data. This form has been filled by three decision makers in the company. Group decision can be seen in Table 3.

Table 3. Pairwise Comparison Matrix of Decision Makers

	The second most important criterion	**The third most important criterion**	**The least important criterion**
The most important criterion	strong	strong	strong
The second most important criterion		strong	strong
The third most important criterion			weak

According to the decision makers' evaluations, the linear programming model can be constructed as follows. The objective function of this linear programming model can be seen as follows.

$$z_{min} = \Phi(o_1)$$

The next step of this linear programming model is to write constraints. The ordinal constraint group can be constructed as follows.

$$\Phi(o_1) \geq \Phi(o_2) + \delta(1,2)$$

$$\Phi(o_1) \geq \Phi(o_3) + \delta(1,3)$$

$$\Phi(o_1) \geq \Phi(o_4) + \delta(1,4)$$

$$\Phi(o_2) \geq \Phi(o_3) + \delta(2,3)$$

$$\Phi(o_2) \geq \Phi(o_4) + \delta(2,4)$$

$$\Phi(o_3) \geq \Phi(o_4) + \delta(3,4)$$

Next constraint group is semantic constraints. Semantic constraints can be written as follows.

$$\Phi(o_1) - \Phi(o_2) \geq \Phi(o_3) - \Phi(o_4) + \delta(1,2,3,4)$$

$$\Phi(o_1) - \Phi(o_3) \geq \Phi(o_3) - \Phi(o_4) + \delta(1,3,3,4)$$

$$\Phi(o_1) - \Phi(o_4) \geq \Phi(o_3) - \Phi(o_4) + \delta(1,4,3,4)$$

$$\Phi(o_2) - \Phi(o_3) \geq \Phi(o_3) - \Phi(o_4) + \delta(2,3,3,4)$$

$$\Phi(o_2) - \Phi(o_4) \geq \Phi(o_3) - \Phi(o_4) + \delta(2,4,3,4)$$

The last constraint of this linear programming model is reset constraint. Reset constraint can be written as follows.

$$\Phi(o_n) = 1$$

After solving this linear programming model, the values of the criteria have been found. The next step is to normalize these values. The results of the linear programming model and the normalized importance levels can be seen in Table 4.

Table 4. The Results of The Model and Normalized Values of The Criteria

	Criterion name	**Result of The Model**	**Normalized Importance Levels (%)**
The most important criterion	Minimum risk of injury	11	50,000000
The second most important criterion	Minimum machine failure	7	31,818182
The third most important criterion	Speed	3	13,636364
The least important criterion	Quality	1	4,545455

5. CONCLUSION

Decision making process of selecting proper machine challenging process due to the effects of financial situation of company and quality and flexibility of production. Moreover, managers have to deal with different

criteria when selecting machine. Multiple-criteria decision analysis methods are beneficial approaches and they can be used by managers when evaluating different machine and criteria. In this paper, data gathered from small-medium enterprise of the ginnery factory located in Aydın region. Four different criteria which are minimum risk of injury, minimum machine failure, quality and speed were analysed with MACBETH method based on qualitative judgements of three owners of the factory. Minimum risk of injury, that is to minimize the occurrence of work accidents caused by machine used, it has been determined the most important evaluation criteria by decision makers when purchasing gin machine. Managers mostly care of the feature of the machine which caused least injury in factory. Minimum machine failure is second criteria is considered by managers when selecting gin machine. According to the information obtained, machine failures are caused some serious financial damage and time loss for the producers and sometimes cause production stop or slow down. Respectively, quality and speed of machine are the third and fourth machine selection criteria.

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