Düzce Üniversitesi Bilim ve Teknoloji Dergisi

Araştırma Makalesi

Determination of The Most Suitable Milking Machine with Macbeth and Gray Relational Analysis Methods

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ABSTRACT

Milking machines are an important element of the livestock sector, which is one of the main activities of the countries. Milking machines have become a part of the life of livestock keepers. Such equipment can be considered as applications of mechanical engineering on the livestock sector. Especially livestock enterprises are going through a difficult process in supplying such machines with optimum features and maximum benefit. In terms of productivity, competitiveness and sustainability of livestock sector enterprises, decision-making processes should be scientific. With this perspective, in this study, the problem of determining the optimum milking machine was evaluated with Multi-Criteria Decision Making (MCDM) methods. In the study, six different milking machines were analyzed with two different MCDM methods according to eight criteria. In this frame, the criterion weights of the related decision problem were calculated by the MACBETH method. Moreover, MACBETH and Gray Relational Analysis (GIA) methods were used separately to determine the most suitable milking machine. Furthermore, rankings obtained+- by different methods were tested with Spearman Rank Correlation Analysis and the result was found to be highly positive. The results of the study were shared with the decision makers. Besides, academic, and sectoral suggestions were made for future studies on similar topics.

Keywords: *Milking Machines, MACBETH Method, Gray Relational Analysis Method*

Macbeth ve Gri İlişkisel Analiz Yöntemleri İle En Uygun Süt Sağım Makinesinin Belirlenmesi

ÖZ

Süt sağım makineleri, ülkelerin temel faaliyetlerinden olan hayvancılık sektörünün önemli bir unsurudur. Sağım makineleri, hayvancılık ile uğraşan bakıcıların hayatının bir parçası haline gelmiştir. Bu tür ekipmanlar makine mühendisliğinin hayvancılık sektörü üzerine uygulamaları olarak düşünülebilir. Özellikle hayvancılık işletmeleri bu tür makinelerin optimum özellikte ve maksimum fayda sağlayacak olanının tedarik edilmesi konusunda zorlu bir süreç geçirmektedirler.

Hayvancılık sektörü İşletmelerinin verimliliği, rekabet edebilirliği ve sürdürülebilirliği açısından karar

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verme süreçlerinin bilimsel olması gerekmektedir. Bu düşünce ile çalışmada, optimum süt sağım makinesinin belirlenmesi problemi Çok Kriterli Karar Verme (ÇKKV) yöntemleri ile değerlendirilmiştir. Çalışmada altı farklı süt sağım makinesi, sekiz kritere göre iki farklı ÇKKV yöntemi ile analiz edilmiştir. İlgili karar probleminin kriter ağırlıkları MACBETH yöntemi ile hesaplanmıştır. En uygun süt sağım makinesinin belirlenmesinde ise MACBETH ve Gri İlişkisel Analiz (GİA) yöntemleri ayrı ayrı kullanılmıştır. Farklı yöntemlerle elde edilen sıralamalar Spearman Sıra Korelasyon Analizi ile test edilmiş ve sonuçların pozitif yönde birbiriyle yüksek düzeyde ilişkili olduğu görülmüştür. Çalışmadan elde edilen sonuçlar karar verici konumundaki yetkililerle paylaşılmıştır. Gelecekte yapılacak benzer konudaki çalışmalar için akademik ve sektörel önerilerde bulunulmuştur.

Anahtar Kelimeler: *Süt Sağım Makineleri, MACBETH Yöntemi, Gri İlişkisel Analiz Yöntemi*

I. INTRODUCTION

There are innumerable kinds of applications carried out in the field of mechanical engineering. When evaluated together with hybrid approaches, mechanical applications can be made in many different sectors. Milking machines, which have an important place in the livestock sector, are also a product of mechanical thinking. Such milking machines provide great convenience to the users.

Because during the supply process, users report the positive or negative aspects of the product to the vendors. Vendors also inform the relevant user opinions to the enterprises where the machines are produced. Thus, engineers again take over the milking machine and realize the new design in line with the received opinions. When evaluated from this aspect, the supply problem of milking machines can be considered as an engineering design process.

When statistics were examined, it is clear that more than half of livestock enterprises are small-scale, and the most important source of income of these enterprises was milk followed by meat [1]. Milking dairy cows by hand is cumbersome. However, milking machines provide a lot of convenience in this work. In addition, these machines can increase the efficiency as they complete the milking work under optimum benefit conditions for both the animal and the keeper. The general opinion for milking machines in the livestock sector is that "What the tractor is in farming, the milking machine is in the dairy industry". The need for such machines in Turkey has been identified through extensive field research [2]. More specifically, in the last ten years, the number of sheep and goats has increased by 78%, while the number of cattle has increased by 45% in Turkey [3]. In parallel with this, while the number of milking equipment has increased by 65%, the number of milking facilities has increased by 15% [4]. When looked more closely, the number of small cattle in the sample of Duzce, where the research was conducted, increased by 129% in the last ten years, while the number of cattle increased by 20% [5]. These data reveal the increase in the number of cattle and sheep in Turkey in the last ten years, but also reflect the increase in the number of machinery and facilities in dairy production. It is predicted that the number of milking facilities will increase by 38% [6]. This supports how important milking machines are. Furthermore, one of the most important supply problems faced by livestock sector enterprises is how to obtain a milking machine that will provide optimum benefit [7].

When it pertains to environmental and natural compatibility, milking machines offer a significant benefit to their customers. One of the main reasons for this is because, according to their functioning principles, they do not produce any hazardous waste for the environment or nature. Further, they perpetually contribute to the relevant businesses in terms of their sustainability.

However, it has been discovered that traditional ways of supplying such machinery are used by the relevant small and medium-sized dairy farms. More specifically, these farms used a limited number of criteria when choosing the machinery. Since this approach does not offer a multi-faceted evaluation opportunity, it may cause harm rather than benefit to the relevant business as of the results. Scientific decision-making procedures, on the other hand, can be utilized to overcome such supply issues [8]. MCDM methods are among the scientific decision-making methods. There was no study discovered in the literature that employed MCDM, MACBETH, and Gray Relational Analysis methodologies in a hybrid way to solve a supply problem in the livestock industry.

In this study, criteria and alternatives were determined for the problem of determining the most suitable milking machine by using the data obtained from the enterprises selling all livestock equipment in Düzce province, Turkey. The main reason why Düzce was chosen as a sample is that small and medium-sized enterprises milking in the livestock sector are often located in this province. In the study, officials of the relevant enterprises were selected as decision makers. The criteria and alternatives for the problem were determined by scanning the decision makers and the relevant. In the analysis part, the weights of the criteria were analyzed and determined by the MACBETH method. Then, the priority order of the relevant alternatives was determined separately by MACBETH and Gray Relational Analysis method. In addition, the consistency of the analysis results performed with these two different methods was tested with Spearman Rank Correlation Analysis.

The current study is expected to fill the gaps in the literature with several ways; 1- It is the first study to determine the most suitable milking machine with MCDM methods, 2- It is the first study to determine the most suitable milking machine among the applications of MACBETH and Gray Relational Analysis methods, 3- It is the first study to redesign milking machines in line with user opinions in terms of mechanical engineering.

From a sectoral standpoint, this research is expected to improve awareness that MCDM methodologies may be used to a variety of supply difficulties faced by relevant businesses. In the next parts of the study, literature review, methodology, application of the research and the results in the last part are given respectively.

II. LITERATURE REVIEW

A. DEBUT OF MILKING MACHINES

In 1860, American Lee Colvin started to work on a new system to both eliminate the problems in milking and increase the workforce. In Colvin's mechanism, hoses with rubber caps were attached to the cow's udder and then attached to a bucket and bellows. As a result of belching, milk could be milked from the cow. Most of the milking machines work with the same logic. Today, depending on the developing technology, the majority of milking machines are controlled via computers [9].

Machine milking is a method applied in large enterprises to save time and labor by ensuring that all milk is milked in a short time. More and healthier milk can be obtained in machine milking [10]. In machine milking, success in milking can be achieved by using the machine with the appropriate technical features correctly, without harming the health of the animal, without leaving any leftover milk and by milking in an appropriate time. For efficient milking, it is crucial to have a milking machine with suitable technical features and to use this machine correctly. Milking machines are in direct contact with living organisms during operation and are used every day, at least twice a day. For this reason, these machines should be checked and maintained at certain time intervals. Machines should be cleaned after each milking and attention should be paid to their technical performance [11].

B. MECHANICAL STRUCTURE OF MILKING MACHINES

The milking machine consists of five parts, namely vacuum pump and motor, vacuum hoses, pulsator, milking heads and vats where milk is collected. While the vacuum pump has a similar effect to the sucking movement of the calf, the pulsator part provides the massage effect of the calf with its tongue, and thus the milk is taken out. Figure 1 shows the working principle of the milking machine. Although the working principles are the same, there are different types and capacities of milking machines [12].

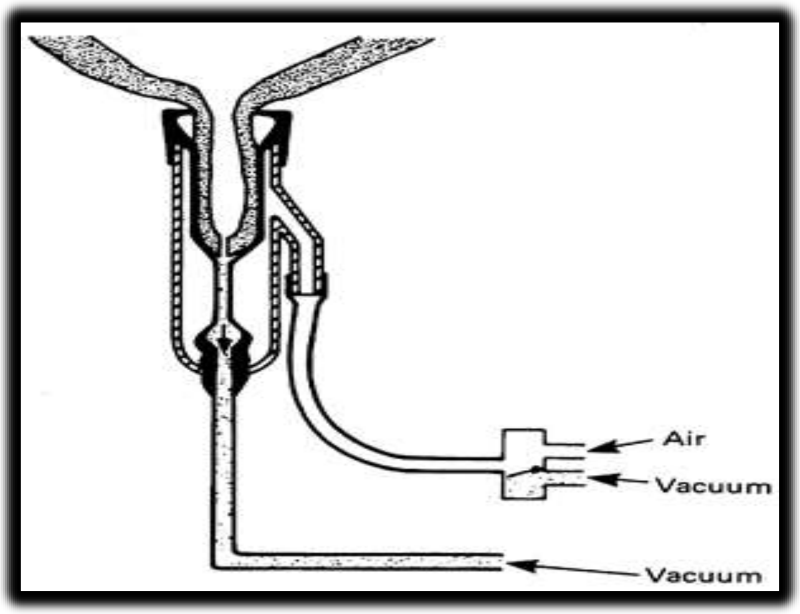

Figure 1. *Working Principle of Milking Machine*

C. MCDM METHODS IN THE SELECTION OF MILKING MACHINES IN THE LIVESTOCK SECTOR

Today, the rapid increase in technological developments shows itself in the livestock sector as well as in every sector. Reaching these developments with the right tools at the right time provides great convenience in reducing costs and increasing production. Technological and technological equipment that develops as innovations are preferred in related businesses because they reduce costs and have positive reflections on customer satisfaction.

When milking enterprises are considered, there are tools and equipment that must be provided during the establishment of these enterprises. Milking machines or fixed milking units are also vital parts for these operations, considering the establishment projects of dairy farms and the quantity of animals that may be milked according to these projects.

One of the most important aspects of creating a strong supply chain management system is selecting suppliers and allocating orders [13]. This is due to the fact that, in order to acquire a cost-effective product quality, firms rely increasingly on suppliers. Furthermore, because purchasing expenditures account for more than half of all internal costs, it is one of the most important jobs for firms [14] [15]. It is considered a multidimensional, multi-criteria decision-making process since many and often contradictory factors must be reviewed and analyzed in order to designate consistent providers. As a result of the literature review, since there was no study on the determination of MCDM methods and milking machines, the study was continued with the other parts.

D. STUDIES WITH GRA AND MACBETH

In a study [16] presented a new framework for the comparative assessment of the effectiveness of integrated municipal solid waste management. The fuzzy MACBETH multi-criteria decision-making model, which was used to look into the ambiguities and inefficiencies connected to solid waste management systems, was incorporated in the framework. The model's applicability was evaluated in the South European region, and the weights of the most important criteria were established. In another study[17] aimed to show the usability of MCDM methods in the decision problems faced by the administrators of educational institutions and to raise awareness among researchers working on this subject. In the study, students who would receive an award in a secondary education institution operating in a province were evaluated with the MACBETH method. One of the related studies [18] aimed to merge the MACBETH and MULTI-MOORA methods-based MCDM methodology. In this mixed method, the weights of the criteria were established using the MACBETH technique, and the final ranking of the alternatives was then calculated using the MULTI-MOORA method. As a consequence of the study, an application of the car selection of a marble firm was also supplied to demonstrate the applicability of the suggested technique.

One of another related studies [19] used GRA to rate the product end-of-life choices in the face of uncertainty in relation to a number of material-level parameters. The threshold technique and GRA were combined [20] for the purpose of choosing green suppliers. In a similar study, a researcher [21] aimed to describe and assess a country's well-being more precisely. Using Gray Relational Analysis, Better Life Index (BLI) 2017 data from 35 OECD member nations and 3 non-member states were examined for this purpose (GRA). She reached the conclusion that the nations with the greatest scores were Norway, Australia, United States, Canada, Iceland, Switzerland, Denmark, and Sweden, while the nations with the lowest ratings were South Africa, Turkey, Mexico, and Greece. In order to compare the financial performance outcomes with the corporate governance rankings and brand values determined by Brand Finance, some researchers [22] measured the financial performance of six banks that were traded on the Borsa Istanbul Corporate Governance Index (XKURY) using MCDM methods. They used the GRA, TOPSIS, ARAS, and MOORA techniques to examine the financial performance of the relevant banks. They concluded that there were contradictions and inconsistencies in the financial performance rankings created within the context of the relevant integrated MCDM ranking findings.

III. METHODOLOGY

A. THE MAIN PROBLEM OF THE STUDY

The main problem is that the user of milking machines needs more scientific and optimum criteria for selection of milking machine. The currently used methods does not provide a comprehensive and optimum evaluation opportunity since such machines were supplied by small and medium-sized dairy farms and individual farmers in traditional methods or utilizing a limited number of criteria. As a result, it could be destructive to the firm rather than beneficial. Thus, using MCDM methods for selection of milking machine would provide a higher and optimum benefit for milking machine users. After choosing Turkey as the universe and Düzce province as a sample in the research, first of all, the milking machine brands in the firms selling milking machine in the province were examined. Among these, the six most commonly used milking machines in the sector were determined as alternatives. As a consequence of the discussions with the necessary authorities, it was determined that using the names exactly would be unethical. In addition, criteria were established based on the decision makers' judgments as well as the relevant research. More specifically, opinions of the decision makers were determined by making a survey to narrow down criteria and ask them to add any relevant criteria that is beneficial in relation in the sector. Lastly, the data of the survey were examined by the authors and then it was finalized by comparing it with the literature. Thus, the six criteria were determined. The hierarchical model expressing the purpose, alternatives and criteria of the study is shown in Figure 2.

The following are the study's criteria in the model:

Criteria: K1, K2, K3, K4, K5, K6, K7, K8

In the criteria: K1=Price, K2=Support Services Fee, K3=Vacuum Power, K4=Vacuum Tank Volume, K5=Claw Capacity, K6=Size, K7=Weight and K8=Customer Advice.

It is useful to explain some of the criteria given below, apart from the obvious ones. Accordingly, after the milking machines have been milked for a certain period of time, especially the filters connected to the vacuum tank and the equipment that makes the milking and claw movement break down. The support services see criterion (K2) in the basic data matrix of the study was calculated as the average of the replacement and repair costs of the above-mentioned filter and claw equipment for each alternative from the technical service businesses in the sample. Moreover, while determining the data for the customer advise (K8) criterion in the basic data matrix, the businesses in the sample were asked to score the customer satisfaction out of 100 about each alternative. The geometric mean of the scores obtained for each alternative was taken and placed in the data matrix.

Alternatives are shown as A1, A2, A3, A4, A5, A6.

In the alternatives: A1=Brand A, A2=Brand B, A3=Brand C, A4=Brand D, A5=Brand E and A6=Brand F

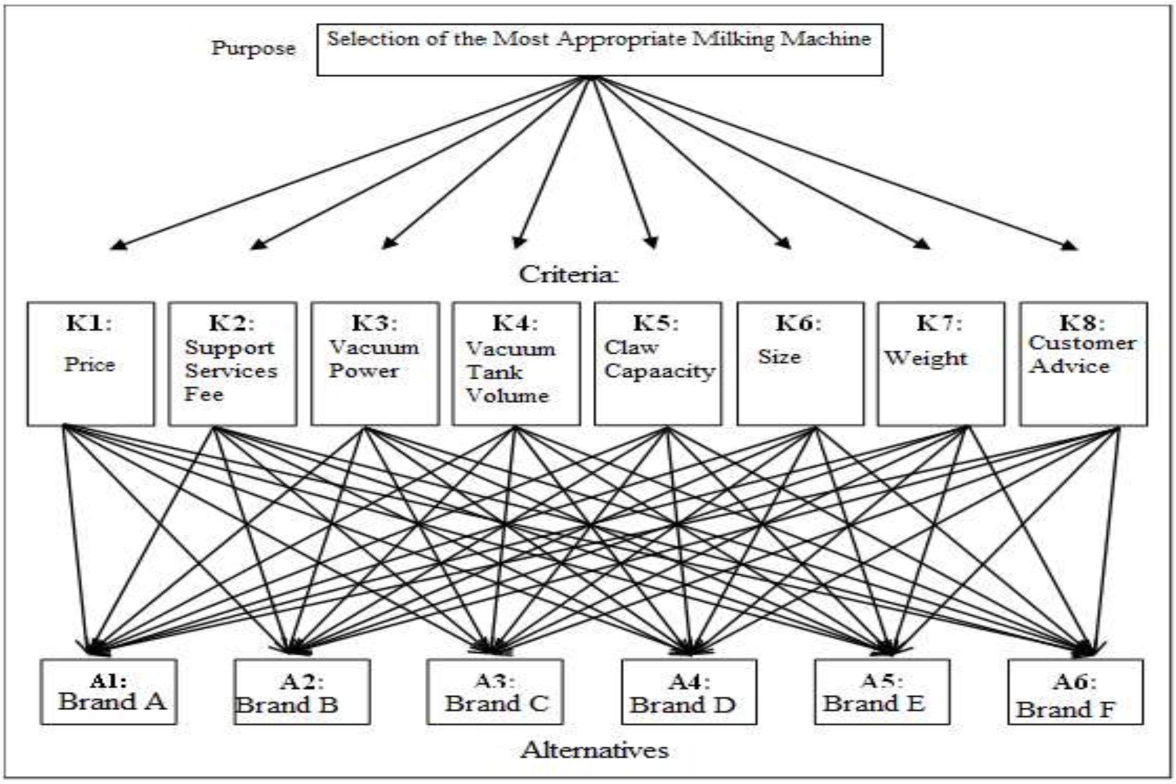

Figure 2. *The Most Appropriate Dairy Milking Machine Selection Model*

B. SAMPLE OF THE STUDY AND DATA COLLECTION METHOD

The theoretical background of this study includes MCDM methods with MACBETH and Gray Relational Analysis methods, and supplier selection problems. While the universe of the research is Turkey, the sample is enterprises selling livestock equipment in Düzce. Data were obtained based on the2027pinionns of the expert personnel of Düzce Province Agriculture and Livestock Directorate and 13 company officials who were decision makers. The created model was applied to all enterprises selling livestock sector equipment in Düzce. Thus, a full count was made for the sample.

C. ANALYSIS METHOD OF THE STUDY

In this study, MACBETH and GRA methods were used among the MCDM methods for the supplier selection problem suitable for the research purpose. MACBETH and GRA method have been used in the research as it has several advantages. First, MACBETH technique, in contrast to other traditional decision-making methods [16] [23] does not call for the use of extra tools to analyze the characteristics, making it appropriate for dealing with complicated issues. Second, in GRA, simple mathematical relations are utilized in gray relational analysis to deal with ambiguous, poor, and incomplete data. By integrating all of the performance attribute values being taken into account for each alternative into one, single value, it resolves multi-attribute decision-making difficulties [24]. In addition, Spearman Rank Correlation Analysis was applied for the consistency of the obtained rankings.

While analyzing the data, the M-MACBETH decision support program adapted according to the solution stages of the MACBETH method was used. In addition, Microsoft EXCEL program was used for the analysis of the GRA method and Spearman Rank Correlation Analysis.

C. 1. Macbeth Method

The MACBETH method was developed in the 1990s to create a range scale and to calculate the relative preference levels among alternatives. [25]. In this method, decision makers are asked to make judgments about the difference in attractiveness between two alternatives at the same time from a set of semantic scale sets with seven categories, namely extreme, very strong, strong, moderate, weak, very weak, and none. This method calculates relative attractiveness using verbal judgments. In this way, decision makers do not need to make numerical interpretations when comparing alternatives.

The steps of the MACBETH method can be expressed as follows [18];

Step 1. First, the decision criteria are defined, and the value tree is created.

Step 2. After creating the value tree, alternatives are determined. Then the performance levels of the alternatives are defined. At least two levels are determined as the upper reference (good) and the lower reference (neutral) level. In this method, 100 points are defined as the upper reference and zero points as the lower reference [26]

Step 3. A matrix is created to compare the alternatives among themselves. The matrix is sorted with the most important alternative to the left and the least important alternative to the right. The procedure is done for the alternatives is repeated for the criteria.

Step 4. Pairwise comparisons are created for both alternatives and criteria. The following semantic judgments are used in the MACBETH method [26] [27].

Table 1. *Semantic Judgements*

Semantic Categories	**Quantitative Scale**	**Descriptions**
No	0	No differences between alternatives
Very Weak	1	One alternative is very weakly important over the other
Weak	2	One alternative is very weakly important over the other
Moderate	3	One alternative is reasonable important over the other
Strong	4	One alternative is strongly important over the other
Very Strong	5	One alternative is very strongly important over the other
Extreme	6	One alternative is extremely important over the other

Step 5. The consistency of the created judgments is checked. If there is any inconsistency, the M-MACBETH program detects where the inconsistency is [28].

Step 6. After checking that the generated judgments are consistent, these judgments are displayed as a numerical scale using linear programming models. With the help of this scale, the scores of the alternatives are determined.

Step 7. By multiplying the criterion weights and alternative scores as a matrix, the total scores of all alternatives are determined and the alternative with the highest score is selected. Using the following formulas [I] and [II], the final overall score is obtained [29] [25].

$$V(A_j)=\sum_{j=1}^{n} wj(vj(Aj)) \qquad [I]$$

$$\sum_{j=1}^{n} wj = 1, wj > 0 \text{ and} \begin{cases} vj\left(A_j^{good}\right) = 100 \\ vj\left(A_j^{neutral}\right) = 0 \end{cases} \qquad [II]$$

W_j: the weight of the jth criteria.

$V(A_j)$: Point value of element A_j

C. 2. Gray Relational Analysis Method

Gray Relational Analysis method is a decision-making method based on Gray System Theory, developed by Deng in 1982 [30]. In Gray System Theory, the expression 'Grey' refers to understanding the system. If there is a situation in a system where the information is not known at all, the system is expressed as 'Black'. If there is sufficient information, the system is expressed as 'White' [31]. Gray Relational Analysis uses this situation to determine the correlation of similarities and differences between the reference series in a system and the factor series to be compared [32].

Gray Relational Analysis is an effective method that can be used in discrete data, incomplete and uncertain information. Therefore, the GRA (Gray Relational Analysis) method emerges as a methodology that can be used in solving weak, incomplete, and uncertain systematic problems. The main purpose of Gray Relational Analysis is to make the decision-making process easier in cases where there is insufficient or no information by establishing a relationship between natural sciences and social sciences [30].

The application steps of the gray relational analysis method are given below [33] [24].

Step 1: Creating the Decision Matrix: In the first step of the method, as in other MCDM methods, the data set for the decision problem is created. The initial matrix (X) consisting of x_i alternative values and $x_i(j)$ values for each criterion value corresponding to alternative values is expressed in equation [III].

$$X = \begin{bmatrix} x_1(1) & x_1(2) & I & x_1(n) \\ x_2(1) & x_2(2) & I & x_2(n) \\ \vdots & \vdots & \ddots & \vdots \\ x_m(1) & x_m(2) & I & x_m(n) \end{bmatrix} \qquad [III]$$

$i = 1,2, \dots, m, \qquad j = 1,2, \dots, n$ such that,

Step 2: Creating the Reference Series: In this step, reference values are determined to make comparisons between attributes. In the decision matrix, the reference series is formed by choosing the highest value if the j_{th} attribute is beneficial, and the smallest value if it is cost oriented. The comparison matrix is obtained by adding the reference values determined with the help of Equation [IV] to the decision matrix.

$$X_0 = (x_0(j)) \qquad j = 1,2,\dots,n \qquad [IV]$$

Step 3: Creating the Normalization Matrix: In the data set created for the decision problem, there are values in different dimensions and units obtained from different sources. For this reason, the normalization process is applied to reduce the data set with different values in a wide range to smaller intervals. The normalization process enables the data set to be drawn to comparable values and facilitates the analysis. This process is called ‘gray relational generation’ in gray theory.

The normalization process is performed in three different ways: benefit, cost, and optimal situation, according to the preference indexes of the attributes.

If the criterion is utility-oriented, normalization is performed with the equation [V].

- If the criterion is utility-oriented, normalization is performed with the equation [V].

$$x_{ij}^* = \frac{x_I(j) - \min x_I(j)}{\max x_I(j) - \min x_I(j)} \qquad [V]$$

- If the cost-oriented criterion contributes positively to the purpose, normalization is made according to the equation [VI].

$$X_{ij}^* = \frac{\max x_I(j) - x_I(j)}{\max x_I(j) - \min x_I(j)} \qquad [VI]$$

- If the criterion is optimal, normalization is performed according to a determined optimal value (x_0b (j)), such as equality [VII].

$$X_{ij}^* = \frac{|x_I(j) - x_{0b}(j)\,|}{\max x_I(j) - x_{0b}(j)} \quad , \qquad min\ x_i(j) \le x_{0b}(j) \le max\ x_i \qquad [VII]$$

The normalized decision matrix created as a result of the normalization process is shown in equation [VIII].

$$X^* = \begin{bmatrix} x^*{}_1(1) & x_1{}^*(2) & I & x_1{}^*(n) \\ x_2{}^*(1) & x^*{}_2(2) & I & x^*{}_2(n) \\ \vdots & \vdots & \ddots & \vdots \\ x_m{}^*(1) & x^*{}_m(2) & I & x^*{}_m(n) \end{bmatrix} \qquad [VIII]$$

Step 4: Creating the Absolute Value Table: The differences between the normalized reference series and the normalized criterion values are calculated with the equation [IX], and the absolute value table is created.

$$\Delta_{0i} = |x_0^*(j) - x_I^*(j)| \qquad I = 1,2,\dots,m \quad j = 1,2,\dots,n \qquad [IX]$$

Step 5: Creating the Gray Relational Coefficient Matrix: The gray relational coefficient represents the distance of the value of each alternative from the reference series. The distances of the absolute value elements created in the previous step to the reference series are determined using the equation [X].

$$\gamma_{0i}(j) = \frac{\Delta_{min} + \delta\Delta_{max}}{\Delta_{0i}(j) + \delta\Delta_{max}} \qquad [X]$$

Δ_{max} and Δ_{min} values in the equation [X] are calculated using equation [XI].

$$\Delta_{max} = \max_I \max_j \Delta_{0i}(j)$$

$$\Delta_{min} = \min_I \min_j \Delta_{0i}(j) \qquad [XI]$$

The parameter δ expressed in Equation [X] is defined as the 'discriminant factor' or 'contrast control factor'. The discriminant coefficient is used to set the difference between Δ_0i and Δ_max. That is, gray relational degrees expand or narrow the range of gray relational coefficients. Although it is frequently used as δ=0.5 in the literature, the δ parameter can take different values between 0-1. A value of δ=0 indicates no contrast, and a value of δ=1 indicates a high level of discrimination. The discrimination coefficient can be adjusted by the decision maker. Different discriminant coefficient values do not change the overall ranking but produce different GRA results. In cases where the differences in the data set are large, values close to zero can be chosen for the discriminating coefficient to reduce the contrast.

Step 6: Calculation of Gray Relational Degrees and Ranking of Alternatives: The relationship between the reference series (x_0^*) and the comparable series (x_i^*) in a system is measured by gray relational degrees. If the gray relational degree is large, it can be deduced that the relationship between (x_0^*) and (x_i^*) is strong.

If it is assumed that all attributes are of equal importance, gray relational degrees are calculated as in equation [XII].

$$\Gamma_{0i} = \frac{1}{n}\sum_{j=1}^{n} \gamma_{0i}(j) \qquad j = 1,2,3,\dots,m \qquad [XII]$$

If the criteria have different degrees of importance, the gray relational degrees are calculated using equation [XIII].

$$\Gamma_{0i} = \sum_{j=1}^{n} [w_I(j).\gamma_{0i}(j)] \qquad I = 1,2,3,\dots,m \qquad [XIII]$$

The gray relational degrees calculated as a result of the method are ordered in descending order and the most suitable option for the decision problem is determined [34].

C. 3. Spearman Rank Correlation Analysis

Spearman rank correlation analysis was used to measure and analyze the linear relationship between two different ordinal variables that are not normally distributed. The coefficient value set of Spearman rank correlation analysis is [-1,1]. As the coefficient gets closer to 1 in absolute value, the strength of the relationship increases, and as it gets closer to 0, the strength of the relationship decreases. In addition, the Spearman rank correlation analysis coefficient is symmetrical, the correlation coefficient does not change when the X and Y ordinal variables are swapped [35].

Spearman rank correlation analysis can be defined as: Let the values of the X and Y variables be determined from randomly selected samples with n diameters. The values of the sample units in terms of the variable X are given their order of magnitude and these orders of magnitude are represented by R(xi). Likewise, the values of the sample units in terms of the Y variable are given the order of magnitude and these orders of magnitude are represented by R(yi). Thus, the ρ statistic, which is the rank correlation coefficient depending on the values of R(xi) and R(yi), is as follows.

$$P = 1 - \frac{6 \cdot \sum d_i^2}{n \cdot (n^2-1)},$$

$$\sum d_i^2 = \sum d_i^2 (R_{(xi)} - R_{(yi)})^2 \qquad [XIV]$$

At a significance level defined using the statistical test in formula [XIV], the H0 hypothesis, which claims that there is no relationship between the X and Y variables, is tested against the H1 hypothesis, which claims that there is a relationship (same or opposite) between the X and Y variables [36].

IV 4. FINDINGS AND COMMENTS

A. DETERMINING THE CRITERION WEIGHTS IN THE MOST APPROPRIATE MILKING MACHINE MODEL

Eight criteria were determined after reviewing the relevant literature and consulting the decision makers. These criteria were recorded in the M-MACBETH 2.5.0 program, which is an application of the MACBETH method. In the program, the criteria are defined as “K1, K2, K3, K4, K5, K6, K7, K8” respectively. In addition, 6 alternatives identified are defined as “A1, A2, A3, A4, A5, A6” to the relevant interface in the program, respectively. Originally, the alternatives are “Brand A, Brand B, Brand C, Brand D, Brand E and Brand F” respectively.

The geometric mean of the opinions of 13 decision makers about the criteria was calculated. Then, these average values were processed into the relevant interfaces in the M-MACBETH program and the final weight values of the criteria were calculated as expressed in Table 2.

Table 2. *Evaluations of the Decision Makers’ Criteria and Final Weight Values*

	K1	**K2**	**K3**	**K4**	**K5**	**K6**	**K7**	**K8**	**Final Weights**
K1	no	v.weak	v.weak-weak	strong-v.strong	strong-v.strong	v.strong-extreme	extreme	extreme	**31,340**
K2	v.weak	no	v.weak	v.weak-weak	strong-v.strong	strong-v.strong	strong	strong-v.strong	**25,370**
K3	v.weak-weak	v.weak	no	v.weak-strong	v.weak	weak	weak	weak	**16,410**
K4	strong-v.strong	v.weak-weak	v.weak-strong	no	v.weak	weak	v.weak-weak	weak	**13,430**
K5	strong-v.strong	strong-v.strong	v.weak	v.weak	no	v.weak-weak	v.weak	v.weak	**7,460**
K6	v.strong-extreme	strong-v.strong	weak	weak	v.weak-weak	no	v.weak	v.weak	**2,990**
K7	extreme	strong	weak	v.weak-weak	v.weak	v.weak	no	no	**1,500**
K8	extreme	strong-v.strong	weak	weak	v.weak	v.weak	no	no	**1,500**

Many visual analyzes can be made using the outputs of the M-MACBETH program. The histogram view of the criteria weights from these analyzes is shown in Figure 3.

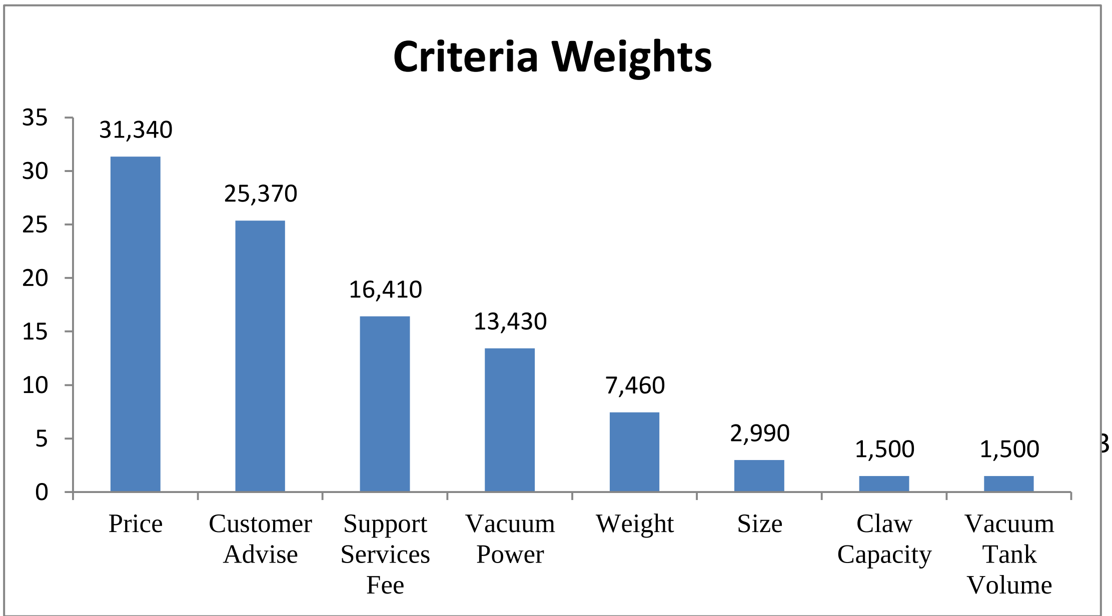

Figure 3. *Histogram View of Criterion Weights*

B. DETERMINATION OF THE MOST APPROPRIATE MILKING MACHINE WITH MACBETH METHOD

After determining the weights of the criteria by using the M-MACBETH program, priority ranking was made among the alternatives with the same method and program. The final ranking that emerges when the relevant processes of the program were carried out were as seen in Table 3. When the results in Table 3 were evaluated, it was discovered that the "Brand E" option had the highest score of 78.040.

Table 3. *Final Ranking of Alternatives by MACBETH Method*

	K1	K2	K3	K4	K5	K6	K7	K8	Final Ranking
Brand A	62,500	100,000	100,000	42,860	66,670	33,330	83,330	0,000	**58,280**
Brand B	50,000	54,550	0,000	14,290	0,000	100,000	66,670	50,000	**45,480**
Brand C	0,000	0,000	42,860	85,710	33,33	88,890	0,000	100,000	**35,570**
Brand D	75,000	90,910	14,290	100,000	100,000	0,000	33,330	50,000	**58,510**
Brand E	87,500	68,180	42,860	0,000	66,670	77,780	66,670	100,000	**78,040**
Brand F	100,000	81,820	28,570	28,570	50,000	44,440	100,000	16,670	**62,800**
Criteria Weights:	***0,313***	***0,164***	***0,134***	***0,015***	***0,015***	***0,030***	***0,075***	***0,254***	

C. DETERMINATION OF THE MOST APPROPRIATE MILKING MACHINE WITH THE GRA METHOD

In order to apply the solution steps of the GRA method using 8 criteria and 6 alternatives in the study, it should be expressed together with the performance values in the basic data set. In this direction, the data set showing the performance values of each alternative within the framework of the criteria is expressed in Table 4.

Table 4. *Basic Data Set for the Problem of Determining the Most Appropriate Milking Machine*

	(Min.) **K1**	*(Min.)* **K2**	*(Max.)* **K3**	*(Max.)* **K4**	*(Max.)* **K5**	*(Min.)* **K6**	*(Min.)* **K7**	*(Max.)* **K8**
A1	2360	68,3	230	22	240	0,751	52,5	0
A2	2450	72,8	180	18	110	0,545	55,0	5
A3	2950	79,3	200	28	180	0,584	62,0	9
A4	2315	69,0	185	30	300	0,839	58,0	5
A5	2150	70,6	200	17	240	0,585	55,0	9
A6	2110	69,1	190	20	200	0,702	50,0	1

C.1. Generating the Gray Relational Coefficient Matrix

After the absolute value table was created, Δ_{max} and Δ_{min} values were determined by using the values in this table, and ζ=0.5, which was suggested in the literature, was used as the discriminating coefficient. The data matrix of the gray relational coefficients created using the calculated parameters was given in Table 5.

Table 5. *Gray Relational Coefficients Data Table*

	(Min.) K1	(Min.) K2	(Max.) K3	(Max.) K4	(Max.) K5	(Min.) K6	(Min.) K7	(Max.) K8
A1	0,627	1,000	1,000	0,448	0,613	0,416	0,706	0,333
A2	0,553	0,550	0,333	0,351	0,333	1,000	0,545	0,529
A3	0,333	0,333	0,455	0,765	0,442	0,790	0,333	1,000
A4	0,672	0,887	0,357	1,000	1,000	0,333	0,429	0,529
A5	0,913	0,705	0,455	0,333	0,613	0,786	0,545	1,000
A6	1,000	0,873	0,385	0,394	0,487	0,484	1,000	0,360
Δ_{max}	***1***							
Δ_{min}	***0***							
ζ	***0,5***							

C.2. Calculating Gray Relational Degrees

There are two different ways to calculate gray relational degrees. In the first way, the criterion weights are used. In the second way, the weight of each criterion is considered equal and the calculation is made under this condition. In this study, the first way was followed. Accordingly, the criteria weights were obtained in the application of the MACBETH method and were used exactly at this stage of the analysis. In this case, the gray relational degrees of the alternatives were expressed in Table 6

Table 6. *Gray Relational Grades of Alternatives and Final Ranking of Alternatives*

w_i	***0,313***	***0,164***	***0,134***	***0,015***	***0,015***	***0,030***	***0,075***	***0,254***	**Final Ranking**
	(Min.) **K1**	(Min.) **K2**	(Max.) **K3**	(Mxs.) **K4**	(Max.) **K5**	(Min.) **K6**	(Min.) **K7**	(Max.) **K8**	
A1	0,627	1,000	1,000	0,448	0,613	0,416	0,706	0,333	**0,660**
A2	0,553	0,550	0,333	0,351	0,333	1,000	0,545	0,529	**0,523**
A3	0,333	0,333	0,455	0,765	0,442	0,790	0,333	1,000	**0,541**
A4	0,672	0,887	0,357	1,000	1,000	0,333	0,429	0,529	**0,610**
A5	0,913	0,705	0,455	0,333	0,613	0,786	0,545	1,000	**0,795**
A6	1,000	0,873	0,385	0,394	0,487	0,484	1,000	0,360	**0,702**

D. INTERPRETATION OF FINDINGS

As stated in Table 6, the most suitable milking machine for the final ranking formed by calculating the Gray Relational Degrees was again A5. Also, according to the result of this method, alternative A2 was evaluated as the worst choice. If the results obtained with two different methods were compared, the findings would be interpreted more accurately. In this frame, the ranking results derived by two separate MCDM algorithms were subjected to Spearman Ranking Correlation Analysis. The results of the associated analysis were shown in Table 7.

Table 7. *Spearman Rank Correlation Analysis Results*

	Y: (Values of MACBETH)	**X: (Values of GRA)**	**y: (MACBETH Ranking)**	**x: (GRA Ranking)**	**d: (Ranking Differences)**	**d^2: (Square of Differences)**
Brand A	58.280	**0,660**	4	3	1	1
Brand B	45.480	**0,523**	5	6	-1	1

Brand C	35.570	**0,541**	6	5	1	1
Brand D	58.510	**0,610**	3	4	-1	1
Brand E	78.040	**0,795**	1	1	0	0
Brand F	62.800	**0,702**	2	2	0	0
Sum of Squares of Differences ($\sum d_i^2$):						**4**

$\rho = 1 - \frac{6 \cdot \sum d_i^2}{n \cdot (n^2-1)}$ (Spearman rank correlation analysis coefficient)

$\sum d_i^2 = 4$ (The sum of the squares of the differences)

n = 6 (Total number of alternatives)

$\rho = 1 - \frac{6 \cdot 4}{6 \cdot (6^2-1)}$

$= 1 - \frac{24}{210}$

$\approx 1 - 0.114$

≈ 0.886

The Spearman Rank Correlation Analysis showed that the association (correlation) between the ranks generated by two separate MCDM approaches was near to 1 and strong. Thus, the study was consistent in terms of reliability.

V. CONCLUSION AND EVALUATION

The main aim of the study was to employ scientific techniques to supply dairy farms with milking equipment. The associated data was evaluated independently using the MACBETH and GRA methodologies, both of which are MCDM approaches. Six options and eight criteria for the most suitable milking machine selection problem were determined as a consequence of the relevant literature and the opinions of the decision makers. The MACBETH technique was used to establish the weights of the criterion. As a result, "Price" received the greatest weight (K1), followed by "Customer recommendation" (K8). These findings corroborate the decision-makers' initial assessments.

When the findings of both the MACBETH and GRA techniques were compared, it was discovered that the best milking machine (A5) in the alternative rankings was "Brand E". As a result, the most suitable mobile milking machine (A5) was “Brand E”. In addition, Spearman rank correlation analysis, which is a statistical test, was performed to determine the consistency of the results obtained with these two methods. The result of the analysis was positive, and the relations of the results were high. That is, the findings of these two techniques were obviously consistent, with the first two rankings remaining the same and the third and fourth places being swapped. As a result, it was demonstrated that MCDM approaches might be utilized to solve supplier selection challenges in milking operations. These results were similar to the results of the Spearman correlation analysis used by [37] to determine the relationships between financial performance rankings using MCDM methods ARAS and WASPAS. In other words, similar to this study, in the authors' study, it was determined that there was a strong positive relationship between the ranking results of the companies involved in the two methods. Similarly, in the study of [22], the ranking results of the GIA, TOPSIS, ARAS, MOORA and Copeland methods were determined by Spearman rho analysis for the relationships between corporate governance and brand values. They determined that there were differences and contradictions between the financial performance rankings made within the framework of the related integrated MCDM ranking results.

It is quite expected that the study's findings will close a significant gap in the literature. The following are suggestions for further research. Especially in livestock sector decision problems, the model of the study can be revised and used. Firstly, the criteria and alternatives of the study can be expanded and applied to more different problems in this sector. Secondly, the created model can be analyzed with different and up to date MCDM methods like CRITIC and MABAC [38] Thirdly, different analysis programs can be used by writing code with programs such as MATLAB. Fourthly, methods such as Entropy or AHP, which are frequently used in the literature, can be preferred in order to determine the weights of the criteria, Last but not least, different MCDM methods can be applied in hybrid form and the results obtained can be compared with previous similar studies.

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