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Machine Selection in a Dairy Product Company with Entropy and SAW Methods Integration

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Abstract

Machine selection is an important and difficult process for the firms, and its results may generate more problems than anticipated. In order to find the best alternative, managers should define the requirements of the factory and determine the necessary criteria. On the other hand, the decision making criteria for choosing the right equipment may vary according to the type of the manufacturing facility, market requirements, and consumer assigned criteria. This study aims to find the best machine alternative among the three machine offerings according to twelve evaluation criteria by integrating entropy method with SAW method.

Keywords: *Production Management, Entropy Method, SAW Method, Machine Selection..*

JEL Classification Codes: *M10, M11.*

Entropi ve SAW Yöntemlerinin Bütünleştirilmesiyle Bir Süt Ürünleri Fabrikasında Makine Seçimi

Öz

Makine seçimi firmalar için önemli ve zor bir süreç olup, bu süreç sonunda firmalar hiç beklemedikleri problemlerle karşılaşabilirler. Firma yöneticileri, en iyi alternatifi bulmak için, fabrikanın ihtiyaçlarını belirlemeli ve gerekli kriterleri saptamalıdır. Diğer yandan, doğru makine seçimini yapabilmek için gerekli kriterler; üretim tesisine, pazar gereksinimlerine ve müşteriler tarafından belirlenen kriterlere göre değişebilmektedir. Bu çalışmanın amacı, entropi ve basit toplamlı ağırlıklandırma (SAW) yöntemlerinin birlikte kullanılması ile üç farklı tedarikçi firmanın sunduğu üç farklı makine arasında on iki farklı değerlendirme kriterinin bir arada göz önüne alınarak tercih yapılmasıdır.

Anahtar Kelimeler: *Üretim Yönetimi, Entropi Yöntemi, SAW Yöntemi, Makine Seçimi.*

JEL Sınıflandırma Kodları: *M10, M11.*

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1. INTRODUCTION

In manufacturing facilites, choosing the right equipment is one of the key elements of staying competitive in the market (Yurdakul, 2004). On the other hand, increased competition is forcing companies to invest in modern equipment in order to satisfy market requirements (Nguyen et al., 2014). Since the cost of the purchased goods and services account for more than 60% of the cost of goods sold (Gencer & Gurpınar, 2007), machine selection is very critical for many firms. In this study, twelve machine selection criteria are evaluated with the integration of entropy and SAW methods in order to make the best available choice among three alternatives.

Simple Additive Weighting (SAW) is a technique, which helps to evaluate the alternatives, by using the relative importance values given by the decision maker (Afshari et al., 2010). The critical part of this method is deciding which criteria is more important and assigning a score to every criteria. On the other hand, entropy method is also used for assessing the weights during a decision making problem when there are many criteria that need to be considered. In this study, more suitable and reliable decision making process tried to be formed by integrating these two methods.

The rest of the paper is organized as follows: In Section 2, related literature about entropy and SAW methods is presented. Section 3 describes entropy method. In the Section 4, SAW method is presented. The application of integrated Entropy and SAW is explained in Section 5, including information about the facility, selection of criteria, relevance of criteria, application of the data, and evaluation of alternatives. In Section 6, conclusions and final remarks are discussed.

2. LITERATURE REVIEW

Entropy method has been used for determining the weights of the supplier selection criteria (Erol, 2004). Just in Time (JIT) philosophy and Total Quality Management (TQM) based purchasing process has been organized for constructing strategic alliances with the selected suppliers. Ten different ferro molybdenum suppliers have been analyzed according to the five selection criteria. The few supplier strategy has been constructed with this study. The supplier selection criteria have been on-time delivery, quality, lead time, environmental performance and flexibility. The weights of these supplier selection criteria have been found with entropy method (Erol & Ferrell, 2009). Entropy method has been used for determining the entropic weights of the selection criteria of fuel alternatives in the U.S. waste collection industry. The environmental criteria in the study have been life-cycle emissions, tail-pipe emissions, water footprint and power density. The financial criteria in the study for evaluating the fuel alternatives have been vehicle cost, fuel price, fuel price stability, and fueling station availability (Maimoun et al., 2016). The entropy method has been used for finding the criteria weights for each sub-basin in the evaluation of agricultural best management practice scenarios for effective watershed management (Sabbaghian et al., 2016).

Fuzzy multi criteria decision making model has been constructed for determining the nuclear power plant location in Turkey. Alternative nuclear power plant locations have been identified in the first phase of the study. The nuclear power plant alternatives have been examined in Poliçe in the Marmara Region, Çilingoz in the Marmara Region, Kefke in the Marmara Region, and İnceburun in the Blacksea Region of Turkey. The three main criteria have been determined for selecting the appropriate location of the nuclear power plant in Turkey. The three main criteria have been the proximity to appropriate existing electricity infrastructure, the proximity to transport infra-structure to facilitate the movement of nuclear fuel and access to large quantities of water for cooling according to the study. Some of the sub criteria for selecting the best location for the nuclear power plant have been population density, geological and seismological issues, atmospheric conditions, cost factors and risk factors according to the study. The importance values of these criteria have been calculated by using fuzzy entropy method (Erol et al., 2014).

Entropy method and analytic hierarchy process (AHP) have been integrated for evaluating product safety (Chen et al., 2014). Fuzzy AHP has been used with entropy weight for determining the efficient production performance in semiconductor fabrication (Kang & Lee, 2007).

The selection of a loading–hauling system for a hypothetical iron ore open pit mine has been evaluated. There have been three transportation system alternatives in the study. These potential system alternatives are shovel-truck, shovel-truck-in-pit crusher-belt conveyor and loader truck systems. There have been seven main criteria in the study. These criteria are operating cost, capital cost, working condition, haul distance, reliability, productivity and useful life. AHP-entropy method has been used for weighting criteria in the study (Bazzazi et al., 2011).

Five different weighting methods have been compared for optimum weave pattern selection in fiber reinforced polymer composites. These weighting methods are Adjustable Mean Bars weights, Modified Digital Logic weights, Numeric Logic weights, Entropy weights and Criteria

Importance through Inter-criteria Correlation weights (Alemi-Ardakani et al., 2016).

There have been many studies using SAW method in the literature. SAW method has been used for measuring the level of security management of companies utilizing the information communication technology outsourcing (Moon et al., 2016). The SAW, techniques for order preference by similarity to an ideal solution (TOPSIS) and Delphi - AHP methods have been integrated for selecting the cloud computing vendor (Liu et al., 2016).

SAW method has been used for determining the suitability of an area for each protection level according to the eight criteria in Eritrea. The criteria for analyzing the marine protected areas in the study have been coral reef areas, mangrove areas, presence/suitability for marine birds, suitability for swimming, suitability for snorkeling, presence of sandy beaches, presence of archaeological sites and fishing areas (Habtemariam & Fang, 2016). The SAW, ordered weighted averaging (OWA) and induced ordered weighted averaging (IOWA) methods have been used for the evaluation of agricultural best management practice scenarios for effective watershed management (Sabbaghian et al., 2016). SAW, preference ranking organization method for enrichment evaluations (PROMETHEE) and elimination et choice translating reality – III (ELECTRE III) methods have been used together for evaluating the sustainability of European transport noise reducing devices projects (Oltean-Dumbrava et al., 2016).

The simulated annealing and seven dispatching rule based complete rescheduling approaches have been compared by using SAW method under the five different weight sets (Hamzadayi & Yildiz, 2016). TOPSIS and SAW methods have been used for designing and surveying Stirling engine performance (Luo et al., 2016). The fuel alternatives have been compared with SAW and TOPSIS multi criteria decision making methods in the U.S. waste collection industry (Maimoun et al., 2016).

SAW and TOPSIS methods have been explained with numerical example for making the multi criteria decision making methods more transparent (Kaliszewski & Podkopaev, 2016).

3. ENTROPY METHOD

The Entropy method is very useful for determining the weights of the criteria in a multi criteria decision making problem because of the fact that there is no need to assess for the criteria weights. The decision matrix will be enough for calculating the weights of the criteria. The procedure of entropy method can be explained as follows (Erol, 2004: 7-8; Erol & Ferrell, 2009: 1196-1197).

$$a_i: alternative\ i; i = 1,2,3, \dots, m$$

$$c_j: criterion\ j; j = 1,2,3, \dots, n$$

$$x_{ij}: performance\ value\ of\ the\ alternative\ i$$

$$from\ the\ viewpoint\ of\ criterion\ j$$

$$D: the\ decision\ matrix$$

The decision matrix can be constructed as in Equation 1.

$$D = \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1n} \\ x_{21} & x_{22} & \cdots & x_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ x_{m1} & x_{m2} & \cdots & x_{mn} \end{bmatrix} \quad (1)$$

$$p_{ij}: normalized\ performance\ value\ of\ the\ alternative\ i$$

$$from\ the\ viewpoint\ of\ criterion\ j$$

The normalized performance values can be calculated as in Equation 2.

$$p_{ij} = \frac{x_{ij}}{\sum_{i=1}^{m} x_{ij}} \ \forall \ i,j \tag{2}$$

$$ND: the\ normalized\ decision\ matrix$$

The normalized decision matrix can be constructed as in Equation 3.

$$ND = \begin{bmatrix} p_{11} & p_{12} & \cdots & p_{1n} \\ p_{21} & p_{22} & \cdots & p_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ p_{m1} & p_{m2} & \cdots & p_{mn} \end{bmatrix} \tag{3}$$

$$E_j: entropy\ value\ for\ criterion\ j; j = 1,2,3,\dots,n$$

$$k: constant$$

Entropy values can be calculated as in Equation 4.

$$E_j = -k \sum_{i=1}^{m} \left[(p_{ij}) \left(ln(p_{ij}) \right) \right] \ \forall \ j \tag{4}$$

The constant value in the method can be calculated as in Equation 5.

$$k = \frac{1}{ln(m)} \tag{5}$$

$$d_j: the\ degree\ of\ diversification\ for\ criterion\ j;\ j = 1,2,3,\dots,n$$

The degree of diversification can be calculated as in Equation 6.

$$d_j = 1 - E_j \tag{6}$$

$$w_j: the\ weight\ value\ of\ criterion\ j;\ j = 1,2,3,\dots,n$$

The weight values can be calculated as in Equation 7.

$$w_j = \frac{d_j}{\sum_{j=1}^{n} d_j} \tag{7}$$

4. SIMPLE ADDITIVE WEIGHTING (SAW) METHOD

The simple additive weighting (SAW) method is a simple, well-known multi criteria decision making method for selecting the best alternative by taking into consideration many different criteria. The process of the SAW method can be explained as follows (Wang et al., 2016: 29).

$$a_i: alternative\ i; i = 1,2,3, \dots, m$$

$$c_j: criterion\ j; j = 1,2,3, \dots, n$$

$$x_{ij}: performance\ value\ of\ the\ alternative\ i\ from\ the\ viewpoint\ of\ criterion\ j$$

$$D: the\ decision\ matrix$$

The decision matrix can be constructed as in Equation 1 like entropy method. The values in the decision matrix should be normalized for the next step of the SAW method. The normalized values of the decision matrix can be calculated as in Equation 8.

$$p_{ij}: normalized\ decision\ value\ of\ the\ alternative\ i$$

$$from\ the\ viewpoint\ of\ criterion\ j$$

$$\begin{cases} if\ the\ criterion\ is\ the\ benefit\ criterion\ \Rightarrow p_{ij} = \dfrac{x_{ij}}{max_j(x_{ij})} \\ if\ the\ criterion\ is\ the\ cost\ criterion\ \Rightarrow p_{ij} = \dfrac{min_j(x_{ij})}{x_{ij}} \end{cases} \quad (8)$$

$$w_j: the\ weight\ value\ of\ criterion\ j;\ j = 1,2,3, \dots, n$$

$$S_i: the\ ranking\ score\ of\ alternative\ i;\ ; i = 1,2,3, \dots, m$$

The ranking scores can be found as in Equation 9.

$$S_i = \sum_{j=1}^{n} \left[(w_j)(p_{ij}) \right]\ \forall\ i \quad (9)$$

In this study, Entropy and SAW methods are integrated and used in the decision making process of a homogenizer in a dairy factory. The decision making process is based on the data set presented by three suppliers. In the following section, the place of application, information about the application and data set will be explained in detail.

5. APPLICATION

The firm which faced the decision making problem in this study is a dairy factory located in Aegean Region in western Turkey. The firm was founded in 2005 with a milk processing capacity of 2.000 lt/day, and expanded its capacity every year because of the increased demand as a result of high product quality and customer satisfaction. The firm has a milk processing capacity of 30.000 lt/day with 75 workers employed in the production process. The 60% of the processed milk used in yogurt production, 30% percent in yogurt drink (ayran) production and remaining 10% is allocated for cheese production. Even though having a functioning homogenizer in the facility, buying a higher capacity homogenizer will shorten the operating hours and reduce the number of production workers, all of which expected to decrease the operating costs.

Homogenizer is one of the key equipments in a *yogurt-production* oriented dairy facility. The milk used in the dairy factory is harvested in different farms, and every batch of milk used in the production naturally has different milk-fat globules, various solids and water (http://www.raw-milk-facts.com/homogenization_T3.html , 28.10.2016). Since fat globules seperate out and rise to the surface as a layer of cream, the use of milk homogenizer is essential in order to have a homogenized milk which has same level of flavor and fat concentration. By using a homogenizer, every unit of yogurt produced in the facility has a very close fat concentration and flavor which is called homogenized yogurt. Yogurt production flow chart of the company can be seen on Figure 1.

In the decision making process, there are twelve criteria that creates our data set. The first and the most important criterion that needs to be considered is the capacity of the homogenizer. The firm already has a homogenizer but because of the increased demand, expanded its operations and capacity. Buying a new homogenizer with a capacity of 10.000 lt. /hr. will shorten the processing time and decrease the operating hours.

Viscosity is the second criterion which is essential in the yogurt production process. According to Physics Hypertextbook, viscosity is the quantity that describes a fluid's resistance to flow (http://physics.info/viscosity/ , 28.10.2016). In order to produce yogurt with a higher firmness, a homogenizer with a higher viscosity capacity is required.

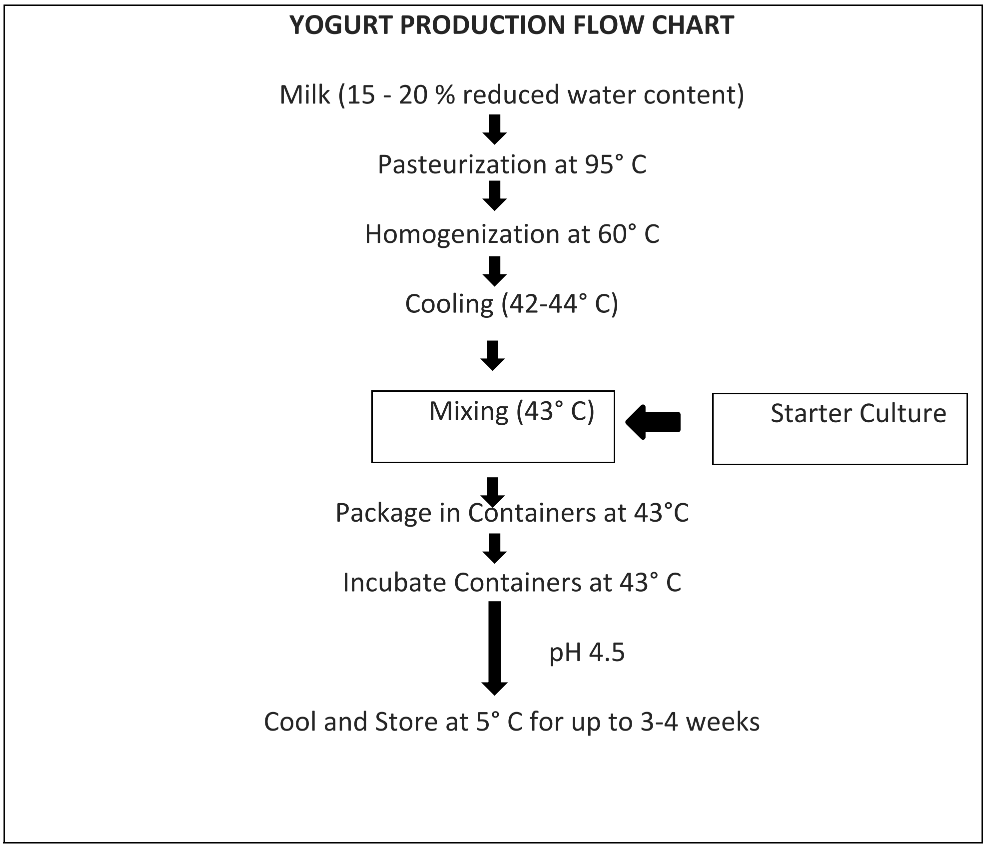

Figure 1. Yogurt Production Flow Chart

Maximum particle size is the determinant of grittiness. Hagura (2011) states that consumers prefer yogurt with a low degree of grittiness. In order to achieve a low degree of grittiness, milk should have a smaller particle size after being processed through a homogenizer, so a smaller particle size is preferred.

Maximum working pressure is the wall strength of the homogenizer during the normal operation. As the maximum working pressure increases, the pressure that the walls may safely hold escalade. In evaluating the decision making criteria, higher maximum working pressure is desired.

As for the maximum inlet and outlet fluid pressure, even though higher pressure values might be preferable, in this yogurt production line, 5 bar input and 2 bar output pumps are sufficient.

In order to keep the processing time shorter, both machine cleansing and machine sterilization times are required to be lower.

For a firm which was established ten years ago, the growth rate is very high. In a short period of time, production line is almost fourteen times bigger than the startup capacity. Even though the product demand is constantly increasing, company wants to keep the investments in a reasonable level and tries to avoid liquidity problems, which makes the cost of investment very critical. Cost of investment consists of equipment price, installation cost, one year free service and part replacements, and service distance. In order to keep the investment cost at the minimum, these four criteria needs to be kept at the minimum.

The data set according to the technical and the non-technical characteristics and the firm alternatives can be seen on Table 1.

Table 1. The Data Set According to The Technical Characteristics and The Firm Alternatives

Criterion No	Criterion Name		Firm 1	Firm 2	Firm 3
1	Capacity	Benefit	10000	10000	10000
2	Viscosity	Benefit	200	200	200
3	Max Particle Size	Cost	800	800	800
4	Max Operating Pressure	Benefit	200	250	200
5	Max Fluid Input Pressure	Benefit	5	5	5
6	Min Fluid Output Pressure	Benefit	2	2	2
7	Cleansing Duration	Cost	30	35	40
8	Sterilization Duration	Cost	30	40	40
9	Price	Cost	89500	97000	95000
10	Other criteria other than technical data (Installation of the Machinery)	Benefit	1	1	1
11	Other criteria other than technical data (One year free service and part replacement) (Estimated cost is 3.500 TL)	Benefit	0	1	1
12	Other criteria other than technical data Service Distance	Cost	170	168	405

The normalized performance values found in accordance with Equation 2 as a step of entropy method can be seen in Table 2.

Table 2. The Normalized Performance Values

	Criterion 1	Criterion 2	Criterion 3	Criterion 4
Alternative 1	0,333333	0,333333	0,333333	0,307692
Alternative 2	0,333333	0,333333	0,333333	0,384615
Alternative 3	0,333333	0,333333	0,333333	0,307692

	Criterion 5	Criterion 6	Criterion 7	Criterion 8
Alternative 1	0,333333	0,333333	0,285714	0,272727
Alternative 2	0,333333	0,333333	0,333333	0,363636
Alternative 3	0,333333	0,333333	0,380952	0,363636
	Criterion 9	**Criterion 10**	**Criterion 11**	**Criterion 12**
Alternative 1	0,317940	0,333333	0,000500	0,228802
Alternative 2	0,344583	0,333333	0,499750	0,226110
Alternative 3	0,337478	0,333333	0,499750	0,545087

The natural logarithm results of the normalized performance values can be seen on Table 3.

Table 3. The Natural Logarithm Results

	Criterion 1	Criterion 2	Criterion 3	Criterion 4
Alternative 1	-1,098612	-1,098612	-1,098612	-1,178655
Alternative 2	-1,098612	-1,098612	-1,098612	-0,955511
Alternative 3	-1,098612	-1,098612	-1,098612	-1,178655
	Criterion 5	**Criterion 6**	**Criterion 7**	**Criterion 8**
Alternative 1	-1,098612	-1,098612	-1,252763	-1,299283
Alternative 2	-1,098612	-1,098612	-1,098612	-1,011601
Alternative 3	-1,098612	-1,098612	-0,965081	-1,011601
	Criterion 9	**Criterion 10**	**Criterion 11**	**Criterion 12**
Alternative 1	-1,145894	-1,098612	-7,601402	-1,474898
Alternative 2	-1,065421	-1,098612	-0,693647	-1,486732
Alternative 3	-1,086256	-1,098612	-0,693647	-0,606809

Entropy, the degree of diversification and the weight values of each criterion can be seen on Table 4.

Table 4. Entropy, Degree of Diversification and Weight Values

	Criterion 1	**Criterion 2**	**Criterion 3**	**Criterion 4**
$\sum_{i=1}^{m}\left[(p_{ij})\left(ln(p_{ij})\right)\right]$	-1,098612	-1,098612	-1,098612	-1,092831
Entropy	1,000000	1,000000	1,000000	0,994737
Degree of diversification	0,000000	0,000000	0,000000	0,005263
Weight	0,000000	0,000000	0,000000	0,011173
	Criterion 5	**Criterion 6**	**Criterion 7**	**Criterion 8**
$\sum_{i=1}^{m}\left[(p_{ij})\left(ln(p_{ij})\right)\right]$	-1,098612	-1,098612	-1,091786	-1,090060
Entropy	1,000000	1,000000	0,993787	0,992215
Degree of diversification	0,000000	0,000000	0,006213	0,007785
Weight	0,000000	0,000000	0,013191	0,016528
	Criterion 9	**Criterion 10**	**Criterion 11**	**Criterion 12**
$\sum_{i=1}^{m}\left[(p_{ij})\left(ln(p_{ij})\right)\right]$	-1,098038	-1,098612	-0,697099	-1,004389
Entropy	0,999477	1,000000	0,634527	0,914234
Degree of diversification	0,000523	0,000000	0,365473	0,085766
Weight	0,001110	0,000000	0,775914	0,182084

After finding weights with entropy method, the normalized decision matrix has been constructed according to SAW method. The normalized values of the decision matrix according to SAW method can be seen on Table 5.

Table 5. The Normalized Values According to SAW Method

	Criterion 1	**Criterion 2**	**Criterion 3**	**Criterion 4**
Alternative 1	1,000000	1,000000	1,000000	0,800000
Alternative 2	1,000000	1,000000	1,000000	1,000000
Alternative 3	1,000000	1,000000	1,000000	0,800000
	Criterion 5	**Criterion 6**	**Criterion 7**	**Criterion 8**

Alternative 1	1,000000	1,000000	1,000000	1,000000
Alternative 2	1,000000	1,000000	0,857143	0,750000
Alternative 3	1,000000	1,000000	0,750000	0,750000
	Criterion 9	**Criterion 10**	**Criterion 11**	**Criterion 12**
Alternative 1	1,000000	1,000000	0,000000	0,988235
Alternative 2	0,922680	1,000000	1,000000	1,000000
Alternative 3	0,942105	1,000000	1,000000	0,414815

With the integration of entropy weights and the normalized decision matrix, the alternatives can be compared according to Table 6 results. The ranking scores of the alternatives can be seen on Table 6.

Table 6. The Ranking Scores of the Alternatives

Alternative Number	The Ranking Score
Alternative 1	0,219709
Alternative 2	0,993898
Alternative 3	0,883719

Alternative 2 is the best option when taking into consideration the twelve different criterion.

6. CONCLUSION

After looking at Table 6, the results suggest that Altenative 2 is offering the best option, Alternative 3 is the second best option with having some better qualities which makes the offer very competitive. On the other hand Alternative 1 has the lowest ranking score and should not be considered by the firm.

The technical attributes of all the alternatives are very close as seen in Table 2. In general, all homogenizer manufacturers have product specifications which are very close to each other, and they manufacture their products according to demand of the market and make small changes if consumers require.

Because of the similiar techniqual attributes of the alternatives, the price of the machine, service and part replacement and service distance criteria become more important. Even though alternative 1 has the most competitive pricing, it lacks free service and part replacement. Since Criteria 11 (free service and part replacement) is very important for the dairy factory, the degree of importance assigned to that criteria is higher, which as a result affects the normalized values in Table 5, and consequently makes the Alternative 1 less competitive. Even though Alternative 3 is also offering Criteria 11, it can be seen from Table 2 that the service distance is much more than Alternative 2. Since maintenance, malfunctioning and failures of the machinery are very common in production facilities, the service distance is also very important factor for many factories. It should be kept in mind that, if production stops as a result of machinery malfunction, the respond time will be shorter if the distance is lesser.

As a conclusion, when analyzing the results, it should be kept in mind that, even though the cost of Criteria 11 (free service and part replacement) is about 3.500 TL, the assigned weight for that criteria is higher than that. Offering this option is also means that, manufacturer of the homogenizer is very confident of its machinery and believes that its machine will not generate any problems during this one year period. On the other hand, from consumer's point of view, even though Alternative 1 has the lowest price and similar technical attributes, consumers will have concerns about machinery, lacking of one year free service, which as a result makes the Alternative 1 an unreliable choice.

As for the Alternative 3, company can offer different competitive choices in order to affect consumer decision such as lesser service fees, more technical support or maximum response in case of malfunction.

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