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Article

Elicitation of the Factors Affecting Electricity Distribution Efficiency using Fuzzy AHP Method: A Case Study

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Abstract: Efficient and uninterrupted energy supply plays crucial role in the quality of the modern daily life, while it is obvious that the efficiency and performance of energy supply companies has significant impact on energy supply itself, and on determining and finetuning the future roadmap of the sector. In this study, the performance and efficiency of energy supply companies with respect to productivity is investigated over a case study of an electricity distribution company in Turkey. The factors affecting the company's performance and their corresponding weights have been determined and elicited using analytical hierarchy process (AHP) and the Fuzzy AHP methods, as two well-known multi-criteria decision-making methods, which are two well-known prominent methods widely used in the literature. The results help demonstrate that the criteria elicited to evaluate the company's energy supply performance plan a crucial role in developing strategies, policies and action plans to achieve continuous improvement and consistent development.

Keywords: Electricity Distribution, Factor Elicitation for efficiency, Fuzzy Analytical Hierarchical Process (F-AHP)

1. Introduction

With the developments that took place after the industrial revolution and the rapid grow in the world population, the need for energy consumption increases in daily basis, which enforces scientific research on this directions and new technologies to emerge. With the developing technology, electricity has gained a function beyond lighting and has become indispensable for human being in transportation, communication, industry, education, health, defense and many other fields. With the importance gained, use of energy, particularly electricity, has become one of the important criteria not only in daily life but also in the progress of civilizations. With this in mind, it is believed that electrical energy will be at the basis of many developments in the future.

The increasing demand and dependency on electricity causes the consumption share of electricity to expand rapidly among other energy sources. This shows that electrical energy is a type of energy whose demand is rapidly increasing worldwide and that must be transmitted quickly and in high quality. With the energy crises in the 1970s, the effects of energy demand on the economy, the importance of electricity production, supply and supply-demand balance have been recognized by everyone, and the work on the subject has continued [1]. Electricity consumption with ever growing importance seems to affect many different sectors directly or indirectly. It turns to be considered as one of the criteria or performance indicator in measuring the development levels and economic growth of countries as is provided by the Turkish Electricity Joint Stock Company in Turkey.

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A privatization process has started in Turkish energy sector in two decades back and finalized in 2008, where electricity distribution services to customers has been delegated to 21 distribution companies in Turkey. Despite the fact that distribution companies are in a dominant position as per the scope of their licenses, they are audited by different channels such as TEDAŞ, EPDK, Ministry of Energy and Natural Resources, and the concepts of performance and efficiency have gained importance for distribution companies [2]. In addition, electricity distribution companies serving customers have to follow the corporate strategies imposed by the Ministry of Energy and serve to reach pre-set efficiency targets by changing the perception of being a public institution and ensuring customer satisfaction. Following up this need, this study proposes an approach to identify the performance criteria of energy supply, particularly electricity distribution, companies in performance and efficiency studies extracting from companies' daily practices. It is paramount to indicate that the best performance and efficiency studies can be conducted through a bottom-up approach, which significantly involves daily practices. There are few studies done on the efficiency of energy companies in different countries using data-driven techniques such as data envelopment analysis (DEA) [37]. To the best knowledge of the authors, this is the first study conducted to take on board the performance and efficiency of electricity distribution companies in Turkey following the major privatisation using qualitative data collected from expert views.

In this paper, a study conducted to perform a comprehensive performance assessment for an electricity distribution company operating in the Eastern Anatolia Region of Turkey has been reported. It has primarily started to determine the factors affecting the efficiency such a company. Then, the determined factors were prioritized using AHP and Fuzzy AHP methods as two prominent multi-criteria decision-making approaches; AHP uniquely and primarily assists conducting assessments with criteria that can compose of sub-criteria while Fuzzy AHP facilitates encompassing more human expertise Fuzzy sets and grammar to perform much more realistic assessments. Within the scope of the study, a unique case study has been carried out for one of major energy distribution firms functions in north-east of Turkey, namely Aras Elektrik Dağıtım AŞ (EDAŞ), operating as service provider for 7 provinces; Ağrı, Ardahan, Bayburt, Erzincan, Erzurum, Iğdır and Kars.

The rest of the paper is structured as follows. A relevant literature review is provided in Section 2, while the proposed approach, the steps of Fuzzy AHP method is introduced in Section 3. The details of expert view capturing process to elicit the evaluation and assessment criteria and the use of AHP and Fuzzy AHP in conducting the efficiency study is overviewed in Section 4. Section 5 presents the results and findings with relevant discussions while Section 6 briefs the conclusions.

2. Literature Review and Background

Studies related to electricity distribution companies in Turkey generally, the history of the distribution companies, the privatization process, privatization of electricity and examinations before and after their study investigated the structure of the energy sector are [2-5]. Data Envelopment Analysis (DEA) method was generally used in studies where efficiency analysis of electricity distribution companies were made.

Filippini et al. [6] studied the efficiency of electricity distribution companies in Slovenia in which the relationship between efficiency and energy prices investigated; it was concluded that electricity distribution companies are not efficient, and a more efficient map will be formed by merging small companies. Odyakmaz [7] found that the current performance measurement systems for electricity distribution companies have been set up based on operating costs and other efficiency and productivity parameters have not been considered. The study uses a DEA approach to calculate the efficiencies and identifies that environmental, structural and quality factors are found impactful on the activities of electricity distribution companies. Duzgun [8] has used a DEA method for measuring the performance of few electricity distribution companies in Turkey in which the number of personnel, line length and operating expenses were primarily taken as inputs and then the inverse density index and line length index were added to the model in order to measure the impact of

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environmental factors up on the efficiencies. It has been concluded the companies with less than 1 million and more than 2 million customers in the optimum model are inefficient. In addition, it has also been found that socio-economic data have a direct effect on efficiency. Dönmezçelik [9] investigated the efficiency of electricity distribution companies using the DEA method. Two models have been created using 5-year data covering the years 2007-2011. In the first model, data such as operating costs, loss and leakage rates, income per subscriber are used, while in the second model, input and output values such as number of personnel, line length, number of breakdowns and interruptions, transformer power are used. Other studies evaluating the efficiency of electricity distribution companies using the DEA method; Performance evaluation of Iranian electricity distribution companies [10-12]; efficiency analysis of the electricity distribution companies in Turkey [13-14]; Efficiency analysis of East and West German electricity distribution companies [15] etc.

Winter et al. [16] have used the KEMIRA-M method to select a warehouse location for an electricity distribution company. Environmental and company-related criteria have been determined for the evaluation of 20 warehouse location alternatives. Janackovic et al. [17] have discussed the selection of key indicators using the F-AHP method to improve the occupational safety system in electricity distribution companies. The organizational factor describes the organizational specificity affecting the safety system using the following indicators: Plan of training in occupational health and safety by organizational sectors (c1); Management efficiency in occupational health and safety system (c2); Higher-risk workplace assessment (c3); Analysis of the age structure of employees (c4); Analysis of basic training on safety at work for all employees (c5); Safety assessment in the workplace (c6); Annual training plan for employees (c7); Assessment of procedural and behavioral directives (c8); Analysis of costs of occupational injuries (c9); Analysis of applicability of protection measures at work (c10); Research into causes and consequences of stressful situations (c11); Analysis of cases of mobbing at work (c12); Analysis of work of internal control services (c13); Analysis of lost work days due to injuries and illness (c14); Analysis of external labor inspection services (c15); Analysis of for first aid trainings (c16). Celen and Yalcin [18] have studied the quality of service in the electricity distribution companies in Turkey using F-AHP, TOPSIS and DEA methods. The relative importance levels of different quality indicators were determined with a F-AHP method. Then, TOPSIS method was used to create/estimate the service quality variable. Finally, this variable was used as an output in the DEA stage and the efficiency performances of electricity distribution services were determined. Saulo et al. [19] presented an overview of electricity distribution system planning by comparing the short-term planning approach with the long-term vision-oriented planning approach. In the comparison of short- and long-term plans, it has used a simple multi-attribute rating (SMART) technique as a multi-criteria decision-making methods. More recently, Zavadskas et al. [38] have considered F-AHP in procedure development for supplier selection in steel industry, while Blagojević et al. [39] have merged F-AHP with DEA in performance assessment and efficiency of a railway company. The authors of [40] have used AHP with other multi criteria decision making state-of-art approaches in display product selection.

AHP has been seen and reviewed as one of very prominent multi criteria decision making approaches offering qualitative evaluation [41]. The literature review suggests that the majority of performance assessment and efficiency studies in post-privatisation Turkish energy sector has been conducted using the variants of DEA method, which is a hard numerical assessment approach. It is known that quantifying some qualitative data may produce consistent and useful results, but, in many cases, variant types of qualitative data would not be satisfactorily converted into numbers. Particularly, evaluations based on expert views are preferred to remain in qualitative form, therefore, AHP and its fuzzy form has been usefully and easily implemented for many selection and assessment problems. In addition, AHP variants provide assessments without disregarding subcategories and it is not complicated to implement unlike many other multi-criteria decision-making approaches. All these facts and reasons have been convincing to use AHP methods, classical AHP and Fuzzy AHP, in this study since all assessment data is qualitative and heavily reliant on expert views.

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3. Materials and Methods

Case studies on AHP, fuzzy AHP, efficiency were examined, and it was seen that AHP and fuzzy AHP were used in a wide range of subjects. Decision makers making decisions without concrete data in all sectors with different dynamics poses a problem. For example, while determining the criteria that affect productivity, criteria such as operating expenses and income sources can be determined with concrete and numerical expressions, criteria such as workforce opportunities, fringe benefits, reliability level of the enterprise cannot be expressed with numerical data. Since this situation creates an obstacle for the decision maker to reach the result, it has been observed that the use of multi-criteria decision-making methods in studies on productivity contributes to the literature. In addition, reaching a single result in studies with classical AHP sometimes limits the range of action of the decision maker. For example, when the AHP application is made to decide the title of the personnel according to the performance system, the result value for a single title will be reached. However, the decision maker is not given the opportunity to take initiative in situations that may cause uncertainty, such as the optimum result of the placement of two different personnel for the same title. In case of similar situations, the solution points with upper and lower values in the solutions made with fuzzy AHP are provided to get rid of the uncertainty of the decision maker. In addition, in previous studies, it was seen that the productivity of distribution companies was measured mostly with the data envelopment method, the fuzzy AHP method was not used, and the data envelopment method was used in the current studies. For this reason, in order to determine the efficiency criteria in the study, an action was taken on the 2018-2019 data of Aras EDAŞ. In this context, the fuzzy AHP method, which is used in solving complex problems with multiple criteria, has been used.

Fuzzy AHP plays an important role in establishing a hierarchical structure consisting of main and sub-criteria, addressing the problem clearly and determining the importance of the criteria relative to each other. In addition, fuzzy AHP helps to digitize the expressions that belong to a single person or a group of experts, both subjective and objective, but have no numerical value, to reach an analytical solution. Fuzzy AHP, which is used in problem solutions in many different fields, produces simple solutions to complex criteria. In addition, fuzzy AHP accelerates the decision-making process and offers the opportunity to reach systematic results.

In the study, triangular fuzzy numbers were used to digitize verbal expressions. Since triangular fuzzy numbers allow subjective data to be digitized objectively, they are frequently used in decision problems. In addition, trapezoidal numbers are preferred in fuzzy logic problems due to the fact that they allow operations in a closer to real value range than other fuzzy numbers, and their graphical representation and operation are easy.

Unlike classical set theory, where the membership of an element in a set is represented by two terms (ie 0 or 1), fuzzy set theory allows for partial membership; this means it includes items with varying degrees of membership in the set; It monitors a range of membership functions with values [0,1]. Fuzzy Set Theory was proposed by Zadeh (1965) to reflect the reality by using approximate values in ambiguous and uncertain environments due to the nature of human reasoning [23]. Fuzzy set theory can be applied in a wide variety of fields, especially useful when information is incomplete or uncertain. Fuzzy logic is derived from fuzzy set theory. It is capable of handling concepts that are inherently imprecise (i.e. ambiguous, imprecise, vulgar, or false). Both fuzzy set theory and fuzzy logic thus have widespread applications [31].

AHP structures the problem in a hierarchical fashion, from goal to criteria, sub-criteria and alternatives at successive levels [32]. The hierarchy provides experts with an overview of the complex relationships inherent in context and helps them evaluate whether elements of the same level are comparable. The items are then compared in pairs against the 9 level scale to get their weight. However, binary comparison, which is the essence of AHP, brings uncertainty as it requires judgment from experts. In practical situations, experts may not be able to assign exact numerical values to their preferences due to limited knowledge or ability. [33], [34]. To overcome the ambiguity in AHP, the exact numbers are replaced by fuzzy numbers that represent linguistic expressions in fuzzy AHP. This tolerates ambiguous judgments by assigning degrees of membership to exact numbers to explain to what extent these numbers belong to an expression [35].

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AHP is a multi-criteria decision-making technique. In most cases, it is difficult to measure or prioritize decision-making criteria because they are subjective and not measurable. One of the advantages of AHP is that this method can systematically convert abstract and non-measurable criteria into numerical values [36]. In addition, one of the most important benefits provided by the AHP method is that this method can measure the consistency degree of binary comparisons.

In this study, AHP (F-AHP) method based on Fuzzy grammar was used in the case study decision making methods in the electricity distribution company.

Let $X=\{x_1,x_2,\ldots,x_n\}$ be an object set, and $U=\{u_1,u_2,\ldots,u_m\}$ be a goal set. According to this method, each object is taken and extent analysis for each goal is performed respectively. Therefore, m extent analysis values for each object can be obtained, with the following signs:

$$M_{gi}^1, M_{gi}^2, \ldots, M_{gi}^m, \quad i=1,2,\ldots,n \tag{1}$$

where all the $M_{gi}^j (j=1,2,\ldots,m)$ are triangular fuzzy numbers. The steps of Chang's extent analysis can be given as follows [28, 18]:

Step 1: The value of fuzzy synthetic extent with respect to the ith object is defined as in Eq. (2):

$$S_i=\sum_{j=1}^{m} M_{gi}^j \otimes \left[\sum_{i=1}^{n}\sum_{j=1}^{m} M_{gi}^j\right]^{-1} \tag{2}$$

To obtain $\sum_{j=1}^{m} M_{gi}^j$, the fuzzy addition operation of m extent analysis values for a particular matrix is performed as in Eq. (3):

$$\sum_{j=1}^{m} M_{gi}^j=\left(\sum_{j=1}^{m} l_j,\sum_{j=1}^{m} m_j,\sum_{j=1}^{m} u_j\right) \tag{3}$$

And to obtain $\left[\sum_{i=1}^{n}\sum_{j=1}^{m} M_{gi}^j\right]^{-1}$, the fuzzy addition operation of M_{gi}^j values is performed as n Eq. (4):

$$\sum_{i=1}^{n}\sum_{j=1}^{m} M_{gi}^j=\left(\sum_{i=1}^{n} l_j,\sum_{i=1}^{n} m_j,\sum_{i=1}^{n} u_j\right) \tag{4}$$

And then the inverse of the vector above is computed as in Eq. (5):

$$\left[\sum_{i=1}^{n}\sum_{j=1}^{m} M_{gi}^j\right]^{-1}=\left(\frac{1}{\sum_{i=1}^{n} u_i},\frac{1}{\sum_{i=1}^{n} m_i},\frac{1}{\sum_{i=1}^{n} l_i}\right) \tag{5}$$

Step 2: As M_1 and M_2 are two triangular fuzzy numbers, the degree of possibility of $M_2=(l_2,m_2,u_2)\geq M_1=(l_1,m_1,u_1)$ is defined as

$$V(M_2\geq M_1)=\sup_{y\geq x}(\min(\mu_{M_1}(x),\mu_{M_2}(y))) \tag{6}$$

And can be equivalently expressed as follows:

$$V(M_2\geq M_1)=hgt(M_1\cap M_2)=\mu_{M_2}(d)=\begin{cases}1 & if \quad m_2\geq m_1,\\ 0 & if \quad l_1\geq u_2,\\ \dfrac{l_1-u_2}{(m_2-u_2)-(m_1-l_1)} & otherwise\end{cases} \tag{7}$$

where d is the ordinate of the highest intersection point D between μ_{M_1} and μ_{M_2}. Eq. (8) is illustrated in Fig. 1 [18, 29]. The values of both $V(M_1\geq M_2)$ and $V(M_2\geq M_1)$ are needed to compare M_1 and M_2.

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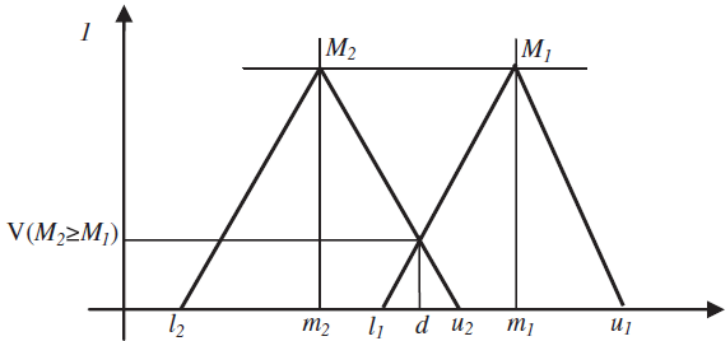

Fig. 1. The intersection between M1 and M2

Step 3: The degree possibility for a convex fuzzy number to be greater than k convex fuzzy numbers $M_i(i=1,2,\ldots,k)$ can be defined by Eq. (8):

$$V(M \geq M_1, M_2, \ldots, \mathrm{M}_k) = V\left[\left(M \geq M_1\right) and \left(M \geq M_2\right)\right] and \ldots and \left(M \geq M_k\right) = \min V\left(M \geq M_i\right), \quad i=1,2,3,\ldots,k \tag{8}$$

Assume that

$$d'(A_i) = \min V(\mathrm{S}_i \geq \mathrm{S}_k) \tag{9}$$

For $k=1,2,\ldots,n; k \neq i$. Then the weight vector is given by

$$W' = (d'(A_1), d'(A_2), \ldots, d'(A_n))^T, \tag{10}$$

Where $A_i(i=1,2,\ldots,\mathrm{n})$ are n elements.

Step 4: With normalization, the normalized weight vectors are

$$W = (d(A_1), d(A_2), \ldots, d(A_n))^T \tag{11}$$

4. Case Study

The implementation steps are as follows: Defining the problem and purpose, determining the decision-making group-experts, determining the criteria, creating a hierarchical structure, obtaining the criterion weights with AHP and F-AHP method.

4.1 Defining the problem and purpose:

Electricity is produced by power plants and transported over long distances via transmission lines and short distances via distribution lines and sold to end users by retail sales companies.

As a result of the need to manage electricity generation, transmission, distribution and trade from a single source, targets have been set for the electricity sector within the development plans.

Turkey Electricity Distribution Corporation (TEDAŞ) in 2004 on the scope of privatization by the Privatization High Council decision of 21 distribution regions have been identified. Distribution and retail sales companies were established and started to operate in 21 regions with a license period of 49 years. Aras EDAŞ constitutes one of these distribution regions (Fig.2).

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Fig. 2. Electricity distribution companies in Turkey

It was carried out in Aras EDAŞ, an electricity distribution company that provides services in 7 provinces, 58 districts, 70.554 km2 area with 1.715 personnel, allowing sample application data to be used in the academic study for the analysis of factors affecting productivity in enterprises with the F-AHP method.

Aras EDAŞ has been privatized with the Share Sales Agreement regarding the sale of 100% shares in accordance with the decision of the Privatization High Council dated 07/03/2013 and numbered 2013/37 and continues its activities under the same name.

Company's area of activity; It covers 52 districts, 2033 villages and 1,593 settlements (neighborhoods, hamlets, etc.) in an area of 71.007 km2 within the borders of Erzurum, Erzincan, Bayburt, Kars, Ağrı, Ardahan and Iğdır. There are 58 enterprises in total, 20 of which are in Erzurum, 9 in Erzincan, 3 in Bayburt, 8 in Kars, 6 in Ardahan, 8 in Ağrı and 4 in Iğdır from 7 provinces in the area of duty. The General Directorate, which is affiliated with the board of directors, serves with the Provincial Coordinators in Ağrı, Ardahan, Bayburt, Erzurum, Erzincan Iğdır and Kars provinces and the District Operation Chiefs in the districts.

As of 2018, Aras EDAŞ provides electricity distribution services with 1,715 personnel, including 462 of its own personnel, who work in service procurement. 1,001,044 subscribers in Turkey offers service to subscribers by 2.4%.

Aras EDAŞ makes investments for network improvement, technological infrastructure, quality and uninterrupted energy, which will increase efficiency in the management approach where customer satisfaction is taken into consideration. Considering the investment needs of the region and the projected investment plans, the distribution service investment expenditure for the 2011-2015 implementation period was approved by the Energy Market Regulatory Board (EPDK) as 352.180.435 TL in total. 2016-2020 III. For the implementation period, it was approved by EPDK for a total of 595.420.985 TL, 119.084.197 TL for each year. 177,308,063.02 TL in 2016, 217,549,525.21 TL in 2017, 155,239,865.11 TL investment was made in 2018, and 164,650,551.58 TL investment was planned for 2019.

Although the efficiency of distribution companies, including Aras EDAŞ, is generally focused on cost, they have been directed to work customer satisfaction-oriented by the Ministry of Energy and Natural Resources in recent years. In this context, Aras EDAŞ has moved away from being a public institution and has worked on reorganizing the existing and usual structure for years and ensuring customer satisfaction by reviewing all processes. Examining the studies conducted by Aras EDAŞ and other distribution companies, where customer satisfaction gains more importance day by

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day, it has been observed that process or person-based efficiency studies are carried out, but there is no work done to determine the basic criteria that affect the efficiency of the entire company.

As a result of the review of previous studies on AHP, Fuzzy AHP and productivity, it is concluded that data envelopment method is generally used in productivity analyzes, Fuzzy AHP method is frequently used in performance measurements, but it is not widely used for productivity in enterprises in the service sector. In addition, although there are frequent studies in the privatization process, use of different technologies, occupational health and safety in the electricity distribution companies that started to serve after privatization, it has been observed that efficiency studies are not carried out much, and the data envelopment method is generally the basis for their studies. Therefore, this study not previously encountered in the application of fuzzy AHP electricity distribution company in Turkey with the efficiency analysis will be done.

In Aras EDAŞ, which sets out with the aim of increasing productivity, it is revealed that the criteria affecting productivity and the weight of these criteria should be determined. It is aimed to shed light on the actions to be taken and to be used as a guide in the steps to be taken by the enterprise towards efficiency.

Determination of decision-making group-experts: The large area of activity of Aras EDAŞ and the high number of enterprises and personnel require the management staff to stay firm. In addition, due to the nature of the work performed, it has been observed that the personnel, who generally constitute the management staff, are graduates of technical departments and have a good command of management training. For this reason, a total of 150 managers were interviewed at the level of Chief, Chief Engineer, Manager and Coordinator in order to benefit from their experience and opinions for the hierarchical structure formed by group decision-making.

4.2 Determination of criteria:

The purpose of this study is to express the productivity in enterprises. The first criteria were expressed as Customer Satisfaction, Uninterrupted Energy and Quality Energy, which are the main criteria affecting the efficiency of distribution companies.

Customer Satisfaction (C1): There is an understanding of competition when electricity distribution companies operate for public service purposes but do not focus on profit. Each distribution company is obliged to provide infrastructure services to all its customers in its own service area. Since it is not possible for any distribution company to serve customers in the region of the other distribution company, there is no competition between companies. Although electricity distribution companies operate in a monopoly far from competition, they have adopted a customer satisfaction-oriented approach after privatization. In addition, distribution companies operating under the Ministry of Energy and Natural Resources are evaluated at certain intervals in terms of customer satisfaction criteria through surveys and analyzes conducted by authorities such as the Ministry, TEDAŞ, and EMRA. For this reason, customer satisfaction, which is accepted as an indicator of efficiency in electricity distribution companies, has been included as one of the main criteria in our study.

Uninterrupted Energy (C2): Uninterrupted energy is expressed as the capacity to provide electrical energy to customers served at economically acceptable costs and with the minimum possible downtime and frequency. Distribution companies, which have great responsibilities at the point of uninterrupted electricity supply of customers, make maximum effort for 24/7 uninterrupted energy. In addition, all interruptions that occur in all or part of the network must be recorded. It covers all outages regardless of criteria such as the recording duration and number of outages. Notified outages made within the scope of works such as maintenance and repair and shared with customers at the latest 48 hours in advance are subject to inspections by authorities such as TEDAŞ and EPDK in cases of instantaneous interruptions due to the failure. For these reasons, uninterrupted energy, which is considered to be an indicator of efficiency in electricity distribution companies, is also one of the main criteria in our study.

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Quality Energy (C3): It refers to the presentation of energy to customers without technical problems such as hormonic disorders and voltage problems with quality energy, also called Technical Quality. Electricity distribution companies must measure the technical quality of the energy they offer and record them in accordance with the relevant standards. All processes and data belonging to the records received are subject to inspections by authorities such as TEDAŞ and EPDK as efficiency criteria. For these reasons, quality energy, which is regarded as an indicator of efficiency in electricity distribution companies, is one of the main criteria in our study.

After the determination of the main criteria, sub-criteria of the main criteria were determined. Its sub-criteria are considered as Service Region, Management and Employees.

Service Area: 21 distribution companies located in each distribution company operating in Turkey and serves customers in different geographic regions. Aras EDAŞ, where the study was conducted, is one of the distribution companies serving in the widest geographical area with a service area of 71,007 km2. Geographical conditions were included in the study as one of the criteria affecting the efficiency of distribution companies due to the fact that field studies are predominant due to the nature of the study.

Similarly, after the determination of the service region criteria, other criteria belonging to the sub-criteria were obtained based on expert opinions. The sub-criteria of the Service Region criteria are determined as Number of Customers (C11), Geographical Conditions (C12), Climatic Conditions (C13), Network Size (C14), Line Length (C15), Energy Losses (C16) and Investment Amount (C17).

Management: Although many definitions have been made about management staff and managers in businesses, if we summarize, managers play an auxiliary role in reaching the targets of the enterprise by using all resources with high performance and thus increasing the productivity. For this reason, "Management" has been considered as one of the sub-criteria, based on the importance of the role of managers in order for businesses to be successful.

Following the determination of the management criteria, similarly, other criteria belonging to the sub-criteria were obtained based on expert opinions. Sub-criteria of management criteria Determination of Goals (C21), Participation of Personnel in Decision Processes (C22), Ensuring Ergonomic Conditions (C23), Supporting Employee Development (C24), Giving Importance to Occupational Health and Safety (C25), Flexible Working Hours (C26), Existence of Integrated Management System Certificates (C27) is determined as Employee Promotion and Advancement Opportunity (C28).

Employees: No matter how high the technological and technical investments are in the enterprises, it will not be possible to increase productivity unless there are personnel managing these investments and technological infrastructures. As a result of similar opinions expressed by experts, employees were included in the study as one of the sub criteria.

After the determination of the employee criteria, similarly, other criteria belonging to the sub-criteria were obtained based on expert opinions. Sub-criteria of the employee criteria Employee Adoption of Goals (C31), Staff Education Level (C32), Employee Motivation (C33), Wages and Benefits (C34), Teamwork (C35), Awareness of Responsibility (C36), Average Service Time of Personnel (C37), Number of Personnel (C38).

4.3 Creating the hierarchical structure:

A hierarchical structure was created as a result of the criteria determined by the group decision making method and explained in detail. It is specified in Figure 3.

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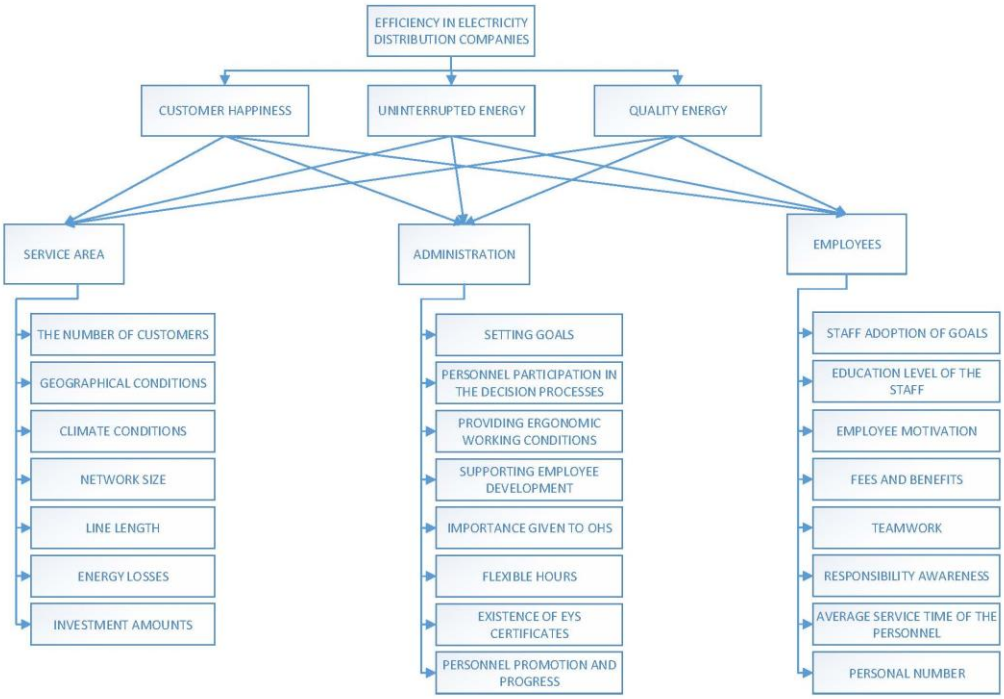

Fig. 3. Problem hierarchical structure

The questionnaire method was used to compare the criteria and sub criteria whose hierarchical structure was determined. The questionnaire was sent online to 150 managers at the level of Chief, Chief Engineer, Manager and Coordinator, who previously contributed to the creation of the hierarchical structure by obtaining expert opinion. While filling the questionnaire, Aras EDAŞ's internal software survey system was used.

While determining the number of questionnaires to be made, similar studies have been examined and it is seen that although care has been taken to select the sample representing the main population, no special study has been done for the number of questionnaires. For example, in the shipyard efficiency study conducted by Kırdağlı in 2010, the study was completed with only 9 expert opinions [27]. In this study, it was thought that the survey conducted with 150 managers at Aras EDAŞ, when all the personnel at the executive level who were involved in the projects related to efficiency measurements and had an impact on the decision processes were interviewed.

In the survey, managers were asked to make pairwise comparisons of the criteria. Verbal expressions, which correspond to fuzzy numbers, were used when taking opinions from the managers. Fuzzy triangle numbers used in binary comparison are given in Table 1.

Table 1. Fuzzy triangular numbers table used for binary comparison

		FUZZY TRIANGLE NUMBERS					
POINT	VERBAL EXPRESSION	NUMBER			PAIR		
1	Equally Important	1,000	1,000	1,000	1,000	1,000	1,000
2	A little more important	0,667	1,000	1,500	0,667	1,000	1,500
3	Strongly Important	1,500	2,000	2,500	0,400	0,500	0,667
4	Very Strongly Important	2,500	3,000	3,500	0,286	0,333	0,400
5	Absolutely Important	3,500	4,000	4,500	0,222	0,250	0,286

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When the studies conducted with Order Analysis Management were examined, it was seen that the geometric mean was preferred because the arithmetic mean was not sufficient to create comparison matrices. It was observed that geometric mean methods were used to make the survey results similar to triangle fuzzy number values and to include conjugate expressions in the study [30]. Therefore, the views of 150 managers are combined with the geometric mean.

Expert opinions taken for the main criteria were combined using geometric mean and the decision matrix formed is given in Table 2.

Table 2. Pairwise comparison matrix for key criteria

	C1 (S_{C_1})	C2 (S_{C_2})	C3 (S_{C_3})
C1 (S_{C_1})	(1.000, 1.000, 1.000)	(1.500, 2.000, 2.500)	(1.500, 2.000, 2.500)
C2 (S_{C_2})	(0.400, 0.500, 0.667)	(1.000, 1.000, 1.000)	(0.667, 1.000, 1.500)
C3 (S_{C_3})	(0.400, 0.500, 0.667)	(0.667, 1.000, 1.500)	(1.000, 1.000, 1.000)

The operations performed according to the Rank Analysis method steps of Chang (1996) are given below.

Step 1: The value of fuzzy synthetic extent with respect to the i[th] object has been determined in Equation 2 form by using Equation 3-4-5. Calculation of the value of C1 criterion is as follows:

$$S_{C_1} = (4.000, 5.000, 6.000) \otimes [8.134, 10.000, 12.334]^{-1} = (0.324, 0.500, 0.738)$$

The S_{C_2} and S_{C_3} values calculated in the same way are as follows:

$$S_{C_2} = (0.168, 0.250, 0.389)$$

$$S_{C_3} = (0.168, 0.250, 0.389)$$

Step 2: For triangular fuzzy numbers, the degree of possibility is expressed equivalently in Equation 7 and is determined using Equation 6:

- Conditions that satisfy the $V(M_2 \geq M_1) = 1$ property for $m_2 \geq m_1$;

$$V\left(S_{C_1} \geq S_{C2}\right) = 1$$

$$V\left(S_{C_1} \geq S_{C_3}\right) = 1$$

$$V\left(S_{C_2} \geq S_{C3}\right) = 1$$

$$V\left(S_{C3} \geq S_{C2}\right) = 1$$

- It is seen that there is no case that satisfies the $V(M_2 \geq M_1) = 0$ property for $l_1 \geq u_2$.
- For other cases, the $\dfrac{l_1 - u_2}{(m_2 - u_2) - (m_1 - l_1)}$ value was calculated using the formula $V(M_2 \geq M_1)$.

$$V\left(S_{C_2} \geq S_{C_1}\right) = V\left(S_{C_3} \geq S_{C_1}\right) = (0.324 - 0.389) / ((0.250 - 0.389) - (0.500 - 0.327)) = 0.206$$

Step 3: The degree possibility for a convex fuzzy number to be greater than k convex fuzzy numbers using Equation 8:

$$\min V\left(S_{C_1} \geq S_{C_2}, S_{C_3}\right) = 1$$

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$$\min V\left(S_{C_2} \geq S_{C_1}, S_{C_3}\right) = 0.206$$

$$\min V\left(S_{C_3} \geq S_{C_1}, S_{C_2}\right) = 0.206$$

Step 4: With normalization, the normalized weight vectors are shown as:
$W = (0.708, 0.146, 0.146)^T$

The F-AHP steps given above have been repeated for the decision matrices given in Table 3-11.

Table 3. Paired comparison matrix of 'service area' sub criteria for customer satisfaction

	C_{11}	C_{12}	C_{13}	C_{14}	C_{15}	C_{16}	C_{17}
C_{11}	(1.000, 1.000, 1.000)	(2.500, 3.000, 3.500)	(1.500, 2.000, 2.500)	(0.667, 1.000, 1.500)	(1.500, 2.000, 2.500)	(0.286, 0.333, 0.400)	(0.222, 0.250, 0.286)
C_{12}	(0.286, 0.333, 0.400)	(1.000, 1.000, 1.000)	(0.667, 1.000, 1.500)	(0.667, 1.000, 1.500)	(0.667, 1.000, 1.500)	(0.286, 0.333, 0.400)	(0.667, 1.000, 1.500)
C_{13}	(0.400, 0.500, 0.667)	(0.667, 1.000, 1.500)	(1.000, 1.000, 1.000)	(0.667, 1.000, 1.500)	(0.400, 0.500, 0.667)	(0.400, 0.500, 0.667)	(0.667, 1.000, 1.500)
C_{14}	(0.667, 1.000, 1.500)	(0.667, 1.000, 1.500)	(0.667, 1.000, 1.500)	(1.000, 1.000, 1.000)	(0.667, 1.000, 1.500)	(0.400, 0.500, 0.667)	(0.400, 0.500, 0.667)
C_{15}	(0.400, 0.500, 0.667)	(0.667, 1.000, 1.500)	(1.500, 2.000, 2.500)	(0.667, 1.000, 1.500)	(1.000, 1.000, 1.000)	(0.667, 1.000, 1.500)	(2.500, 3.000, 3.500)
C_{16}	(2.500, 3.000, 3.500)	(2.500, 3.000, 3.500)	(1.500, 2.000, 2.500)	(1.500, 2.000, 2.500)	(0.667, 1.000, 1.500)	(1.000, 1.000, 1.000)	(0.667, 1.000, 1.500)
C_{17}	(3.500, 4.000, 4.500)	(0.667, 1.000, 1.500)	(0.667, 1.000, 1.500)	(1.500, 2.000, 2.500)	(2.500, 3.000, 3.500)	(0.667, 1.000, 1.500)	(1.000, 1.000, 1.000)

Table 4. Paired comparison matrix of 'management' sub criteria for customer satisfaction

	C_{21}	C_{22}	C_{23}	C_{24}	C_{25}	C_{26}	C_{27}	C_{28}
C_{21}	(1.000, 1.000, 1.000)	(1.500, 2.000, 2.500)	(0.400, 0.500, 0.667)	(1.500, 2.000, 2.500)	(0.667, 1.000, 1.500)	(2.500, 3.000, 3.500)	(0.667, 1.000, 1.500)	(0.667, 1.000, 1.500)
C_{22}	(0.400, 0.500, 0.667)	(1.000, 1.000, 1.000)	(0.400, 0.500, 0.667)	(0.400, 0.500, 0.667)	(0.667, 1.000, 1.500)	(2.500, 3.000, 3.500)	(0.667, 1.000, 1.500)	(0.400, 0.500, 0.667)
C_{23}	(1.500, 2.000, 2.500)	(1.500, 2.000, 2.500)	(1.000, 1.000, 1.000)	(1.500, 2.000, 2.500)	(0.667, 1.000, 1.500)	(2.500, 3.000, 3.500)	(1.500, 2.000, 2.500)	(0.667, 1.000, 1.500)
C_{24}	(0.400, 0.500, 0.667)	(1.500, 2.000, 2.500)	(0.400, 0.500, 0.667)	(1.000, 1.000, 1.000)	(1.500, 2.000, 2.500)	(0.400, 0.500, 0.667)	(1.500, 2.000, 2.500)	(1.500, 2.000, 2.500)
C_{25}	(0.667, 1.000, 1.500)	(0.667, 1.000, 1.500)	(0.667, 1.000, 1.500)	(0.400, 0.500, 0.667)	(1.000, 1.000, 1.000)	(0.667, 1.000, 1.500)	(2.500, 3.000, 3.500)	(2.500, 3.000, 3.500)
C_{26}	(0.286, 0.333, 0.400)	(0.286, 0.333, 0.400)	(0.286, 0.333, 0.400)	(1.500, 2.000, 2.500)	(0.667, 1.000, 1.500)	(1.000, 1.000, 1.000)	(1.500, 2.000, 2.500)	(0.667, 1.000, 1.500)
C_{27}	(0.667, 1.000, 1.500)	(0.667, 1.000, 1.500)	(0.400, 0.500, 0.667)	(0.400, 0.500, 0.667)	(0.286, 0.333, 0.400)	(0.400, 0.500, 0.667)	(1.000, 1.000, 1.000)	(0.400, 0.500, 0.667)
C_{28}	(0.667, 1.000, 1.500)	(1.500, 2.000, 2.500)	(0.667, 1.000, 1.500)	(0.400, 0.500, 0.667)	(0.286, 0.333, 0.400)	(0.667, 1.000, 1.500)	(1.500, 2.000, 2.500)	(1.000, 1.000, 1.000)

Table 5. Paired comparison matrix of 'employees' sub criteria for customer satisfaction

	C_{31}	C_{32}	C_{33}	C_{34}	C_{35}	C_{36}	C_{37}	C_{38}
C_{31}	(1.000, 1.000, 1.000)	(0.667, 1.000, 1.500)	(0.667, 1.000, 1.500)	(0.667, 1.000, 1.500)	(1.500, 2.000, 2.500)	(0.667, 1.000, 1.500)	(2.500, 3.000, 3.500)	(2.500, 3.000, 3.500)
C_{32}	(0.667, 1.000, 1.500)	(1.000, 1.000, 1.000)	(0.400, 0.500, 0.667)	(1.500, 2.000, 2.500)	(0.400, 0.500, 0.667)	(1.500, 2.000, 2.500)	(1.500, 2.000, 2.500)	(2.500, 3.000, 3.500)
C_{33}	(0.667, 1.000, 1.500)	(1.500, 2.000, 2.500)	(1.000, 1.000, 1.000)	(1.500, 2.000, 2.500)	(0.667, 1.000, 1.500)	(0.400, 0.500, 0.667)	(2.500, 3.000, 3.500)	(2.500, 3.000, 3.500)
C_{34}	(0.667, 1.000, 1.500)	(0.400, 0.500, 0.667)	(0.400, 0.500, 0.667)	(1.000, 1.000, 1.000)	(0.400, 0.500, 0.667)	(0.400, 0.500, 0.667)	(0.400, 0.500, 0.667)	(0.400, 0.500, 0.667)
C_{35}	(0.400, 0.500, 0.667)	(1.500, 2.000, 2.500)	(0.667, 1.000, 1.500)	(1.500, 2.000, 2.500)	(1.000, 1.000, 1.000)	(0.667, 1.000, 1.500)	(1.500, 2.000, 2.500)	(2.500, 3.000, 3.500)
C_{36}	(0.667, 1.000, 1.500)	(0.400, 0.500, 0.667)	(1.500, 2.000, 2.500)	(1.500, 2.000, 2.500)	(0.667, 1.000, 1.500)	(1.000, 1.000, 1.000)	(1.500, 2.000, 2.500)	(1.500, 2.000, 2.500)
C_{37}	(0.286, 0.333, 0.400)	(0.400, 0.500, 0.667)	(0.286, 0.333, 0.400)	(1.500, 2.000, 2.500)	(0.400, 0.500, 0.667)	(0.400, 0.500, 0.667)	(1.000, 1.000, 1.000)	(1.500, 2.000, 2.500)
C_{38}	(0.286, 0.333, 0.400)	(0.286, 0.333, 0.400)	(0.286, 0.333, 0.400)	(1.500, 2.000, 2.500)	(0.286, 0.333, 0.400)	(0.400, 0.500, 0.667)	(0.400, 0.500, 0.667)	(1.000, 1.000, 1.000)

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Table 6. Paired comparison matrix of 'service area' sub criteria for uninterrupted energy

	C_{11}	C_{12}	C_{13}	C_{14}	C_{15}	C_{16}	C_{17}
C_{11}	(1.000, 1.000, 1.000)	(0.667, 1.000, 1.500)	(0.667, 1.000, 1.500)	(0.400, 0.500, 0.667)	(0.400, 0.500, 0.667)	(0.400, 0.500, 0.667)	(0.400, 0.500, 0.667)
C_{12}	(0.667, 1.000, 1.500)	(1.000, 1.000, 1.000)	(0.667, 1.000, 1.500)	(0.667, 1.000, 1.500)	(0.400, 0.500, 0.667)	(0.286, 0.333, 0.400)	(0.286, 0.333, 0.400)
C_{13}	(0.667, 1.000, 1.500)	(0.667, 1.000, 1.500)	(1.000, 1.000, 1.000)	(2.500, 3.000, 3.500)	(2.500, 3.000, 3.500)	(0.400, 0.500, 0.667)	(2.500, 3.000, 3.500)
C_{14}	(1.500, 2.000, 2.500)	(0.667, 1.000, 1.500)	(0.286, 0.333, 0.400)	(1.000, 1.000, 1.000)	(0.667, 1.000, 1.500)	(0.667, 1.000, 1.500)	(0.667, 1.000, 1.500)
C_{15}	(1.500, 2.000, 2.500)	(1.500, 2.000, 2.500)	(0.286, 0.333, 0.400)	(0.667, 1.000, 1.500)	(1.000, 1.000, 1.000)	(0.400, 0.500, 0.667)	(0.400, 0.500, 0.667)
C_{16}	(1.500, 2.000, 2.500)	(2.500, 3.000, 3.500)	(1.500, 2.000, 2.500)	(0.667, 1.000, 1.500)	(1.500, 2.000, 2.500)	(1.000, 1.000, 1.000)	(0.286, 0.333, 0.400)
C_{17}	(1.500, 2.000, 2.500)	(2.500, 3.000, 3.500)	(0.286, 0.333, 0.400)	(0.667, 1.000, 1.500)	(1.500, 2.000, 2.500)	(2.500, 3.000, 3.500)	(1.000, 1.000, 1.000)

Table 7. Paired comparison matrix of 'management' sub criteria for uninterrupted energy

	C_{21}	C_{22}	C_{23}	C_{24}	C_{25}	C_{26}	C_{27}	C_{28}
C_{21}	(1.000, 1.000, 1.000)	(1.500, 2.000, 2.500)	(0.667, 1.000, 1.500)	(0.400, 0.500, 0.667)	(0.667, 1.000, 1.500)	(0.286, 0.333, 0.400)	(1.500, 2.000, 2.500)	(2.500, 3.000, 3.500)
C_{22}	(0.400, 0.500, 0.667)	(1.000, 1.000, 1.000)	(1.500, 2.000, 2.500)	(0.400, 0.500, 0.667)	(0.667, 1.000, 1.500)	(0.286, 0.333, 0.400)	(0.667, 1.000, 1.500)	(0.400, 0.500, 0.667)
C_{23}	(0.667, 1.000, 1.500)	(0.400, 0.500, 0.667)	(1.000, 1.000, 1.000)	(0.400, 0.500, 0.667)	(0.667, 1.000, 1.500)	(0.667, 1.000, 1.500)	(0.400, 0.500, 0.667)	(1.500, 2.000, 2.500)
C_{24}	(1.500, 2.000, 2.500)	(1.500, 2.000, 2.500)	(1.500, 2.000, 2.500)	(1.000, 1.000, 1.000)	(0.667, 1.000, 1.500)	(0.667, 1.000, 1.500)	(2.500, 3.000, 3.500)	(2.500, 3.000, 3.500)
C_{25}	(0.667, 1.000, 1.500)	(0.667, 1.000, 1.500)	(0.667, 1.000, 1.500)	(0.667, 1.000, 1.500)	(1.000, 1.000, 1.000)	(0.667, 1.000, 1.500)	(0.667, 1.000, 1.500)	(2.500, 3.000, 3.500)
C_{26}	(2.500, 3.000, 3.500)	(2.500, 3.000, 3.500)	(0.667, 1.000, 1.500)	(0.667, 1.000, 1.500)	(0.667, 1.000, 1.500)	(1.000, 1.000, 1.000)	(1.500, 2.000, 2.500)	(2.500, 3.000, 3.500)
C_{27}	(0.400, 0.500, 0.667)	(0.667, 1.000, 1.500)	(1.500, 2.000, 2.500)	(0.286, 0.333, 0.400)	(0.667, 1.000, 1.500)	(0.400, 0.500, 0.667)	(1.000, 1.000, 1.000)	(0.400, 0.500, 0.667)
C_{28}	(0.286, 0.333, 0.400)	(1.500, 2.000, 2.500)	(0.400, 0.500, 0.667)	(0.286, 0.333, 0.400)	(0.286, 0.333, 0.400)	(0.286, 0.333, 0.400)	(1.500, 2.000, 2.500)	(1.000, 1.000, 1.000)

Table 8. Paired comparison matrix of 'employees' sub criteria for uninterrupted energy

	C_{31}	C_{32}	C_{33}	C_{34}	C_{35}	C_{36}	C_{37}	C_{38}
C_{31}	(1.000, 1.000, 1.000)	(0.400, 0.500, 0.667)	(1.500, 2.000, 2.500)	(0.667, 1.000, 1.500)	(1.500, 2.000, 2.500)	(1.500, 2.000, 2.500)	(2.500, 3.000, 3.500)	(2.500, 3.000, 3.500)
C_{32}	(1.500, 2.000, 2.500)	(1.000, 1.000, 1.000)	(0.667, 1.000, 1.500)	(2.500, 3.000, 3.500)	(0.667, 1.000, 1.500)	(1.500, 2.000, 2.500)	(2.500, 3.000, 3.500)	(2.500, 3.000, 3.500)
C_{33}	(0.400, 0.500, 0.667)	(0.667, 1.000, 1.500)	(1.000, 1.000, 1.000)	(1.500, 2.000, 2.500)	(0.667, 1.000, 1.500)	(0.667, 1.000, 1.500)	(1.500, 2.000, 2.500)	(1.500, 2.000, 2.500)
C_{34}	(0.667, 1.000, 1.500)	(0.286, 0.333, 0.400)	0.400, 0.500, 0.667)	(1.000, 1.000, 1.000)	(0.667, 1.000, 1.500)	(0.400, 0.500, 0.667)	(0.400, 0.500, 0.667)	(0.400, 0.500, 0.667)
C_{35}	(0.400, 0.500, 0.667)	(0.667, 1.000, 1.500)	(0.667, 1.000, 1.500)	(0.667, 1.000, 1.500)	(1.000, 1.000, 1.000)	(0.667, 1.000, 1.500)	(0.667, 1.000, 1.500)	(0.667, 1.000, 1.500)
C_{36}	(0.400, 0.500, 0.667)	(0.400, 0.500, 0.667)	(0.667, 1.000, 1.500)	(1.500, 2.000, 2.500)	(0.667, 1.000, 1.500)	(1.000, 1.000, 1.000)	(0.667, 1.000, 1.500)	(1.500, 2.000, 2.500)
C_{37}	(0.286, 0.333, 0.400)	(0.286, 0.333, 0.400)	(0.400, 0.500, 0.667)	(1.500, 2.000, 2.500)	(0.667, 1.000, 1.500)	(0.667, 1.000, 1.500)	(1.000, 1.000, 1.000)	(0.400, 0.500, 0.667)
C_{38}	(0.286, 0.333, 0.400)	(0.286, 0.333, 0.400)	(0.400, 0.500, 0.667)	(1.500, 2.000, 2.500)	(0.667, 1.000, 1.500)	(0.400, 0.500, 0.667)	(1.500, 2.000, 2.500)	(1.000, 1.000, 1.000)

Table 9. Paired comparison matrix of 'service area' sub criteria for quality energy

	C_{11}	C_{12}	C_{13}	C_{14}	C_{15}	C_{16}	C_{17}
C_{11}	(1.000, 1.000, 1.000)	(0.667, 1.000, 1.500)	(0.667, 1.000, 1.500)	(0.400, 0.500, 0.667)	(0.400, 0.500, 0.667)	(0.400, 0.500, 0.667)	(0.400, 0.500, 0.667)
C_{12}	(0.667, 1.000, 1.500)	(1.000, 1.000, 1.000)	(0.286, 0.333, 0.400)	(0.400, 0.500, 0.667)	(0.400, 0.500, 0.667)	(0.667, 1.000, 1.500)	(0.286, 0.333, 0.400)
C_{13}	(0.667, 1.000, 1.500)	(2.500, 3.000, 3.500)	(1.000, 1.000, 1.000)	(0.667, 1.000, 1.500)	(0.400, 0.500, 0.667)	(0.400, 0.500, 0.667)	(0.400, 0.500, 0.667)
C_{14}	(1.500, 2.000, 2.500)	(1.500, 2.000, 2.500)	(0.667, 1.000, 1.500)	(1.000, 1.000, 1.000)	(0.400, 0.500, 0.667)	(0.400, 0.500, 0.667)	(0.400, 0.500, 0.667)

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C_{15}	(1.500, 2.000, 2.500)	(1.500, 2.000, 2.500)	(1.500, 2.000, 2.500)	(1.500, 2.000, 2.500)	(1.000, 1.000, 1.000)	(0.667, 1.000, 1.500)	(0.400, 0.500, 0.667)
C_{16}	(0.667, 1.000, 1.500)	(0.667, 1.000, 1.500)	(1.500, 2.000, 2.500)	(1.500, 2.000, 2.500)	(0.667, 1.000, 1.500)	(1.000, 1.000, 1.000)	(1.500, 2.000, 2.500)
C_{17}	(1.500, 2.000, 2.500)	(2.500, 3.000, 3.500)	(1.500, 2.000, 2.500)	(1.500, 2.000, 2.500)	(1.500, 2.000, 2.500)	(0.400, 0.500, 0.667)	(1.000, 1.000, 1.000)

Table 10. Binary comparison matrix of 'management' sub criteria for quality energy

	C_{21}	C_{22}	C_{23}	C_{24}	C_{25}	C_{26}	C_{27}	C_{28}
C_{21}	(1.000, 1.000, 1.000)	(0.667, 1.000, 1.500)	(0.400, 0.500, 0.667)	(0.400, 0.500, 0.667)	(0.667, 1.000, 1.500)	(0.400, 0.500, 0.667)	(2.500, 3.000, 3.500)	(1.500, 2.000, 2.500)
C_{22}	(0.667, 1.000, 1.500)	(1.000, 1.000, 1.000)	(0.400, 0.500, 0.667)	(0.667, 1.000, 1.500)	(0.400, 0.500, 0.667)	(0.286, 0.333, 0.400)	(0.667, 1.000, 1.500)	(0.667, 1.000, 1.500)
C_{23}	(1.500, 2.000, 2.500)	(1.500, 2.000, 2.500)	(1.000, 1.000, 1.000)	(0.400, 0.500, 0.667)	(0.286, 0.333, 0.400)	(0.400, 0.500, 0.667)	(0.286, 0.333, 0.400)	(1.500, 2.000, 2.500)
C_{24}	(1.500, 2.000, 2.500)	(0.667, 1.000, 1.500)	(1.500, 2.000, 2.500)	(1.000, 1.000, 1.000)	(0.667, 1.000, 1.500)	(1.500, 2.000, 2.500)	(2.500, 3.000, 3.500)	(2.500, 3.000, 3.500)
C_{25}	(0.667, 1.000, 1.500)	(1.500, 2.000, 2.500)	(2.500, 3.000, 3.500)	(0.667, 1.000, 1.500)	(1.000, 1.000, 1.000)	(0.400, 0.500, 0.667)	(0.667, 1.000, 1.500)	(2.500, 3.000, 3.500)
C_{26}	(1.500, 2.000, 2.500)	(2.500, 3.000, 3.500)	(1.500, 2.000, 2.500)	(0.400, 0.500, 0.667)	(1.500, 2.000, 2.500)	(1.000, 1.000, 1.000)	(0.667, 1.000, 1.500)	(1.500, 2.000, 2.500)
C_{27}	(0.286, 0.333, 0.400)	(0.667, 1.000, 1.500)	(2.500, 3.000, 3.500)	(0.286, 0.333, 0.400)	(0.667, 1.000, 1.500)	(0.667, 1.000, 1.500)	(1.000, 1.000, 1.000)	(0.286, 0.333, 0.400)
C_{28}	(0.400, 0.500, 0.667)	(0.667, 1.000, 1.500)	(0.400, 0.500, 0.667)	(0.286, 0.333, 0.400)	(0.286, 0.333, 0.400)	(0.400, 0.500, 0.667)	(2.500, 3.000, 3.500)	(1.000, 1.000, 1.000)

Table 11. Paired comparison matrix of 'employees' sub criteria for quality energy

	C_{31}	C_{32}	C_{33}	C_{34}	C_{35}	C_{36}	C_{37}	C_{38}
C_{31}	(1.000, 1.000, 1.000)	(0.400, 0.500, 0.667)	(1.500, 2.000, 2.500)	(1.500, 2.000, 2.500)	(1.500, 2.000, 2.500)	(1.500, 2.000, 2.500)	(2.500, 3.000, 3.500)	(2.500, 3.000, 3.500)
C_{32}	(1.500, 2.000, 2.500)	(1.000, 1.000, 1.000)	(2.500, 3.000, 3.500)	(0.667, 1.000, 1.500)	(0.667, 1.000, 1.500)	(1.500, 2.000, 2.500)	(0.667, 1.000, 1.500)	(2.500, 3.000, 3.500)
C_{33}	(0.400, 0.500, 0.667)	(0.286, 0.333, 0.400)	(1.000, 1.000, 1.000)	(0.667, 1.000, 1.500)	(1.500, 2.000, 2.500)	(1.500, 2.000, 2.500)	(2.500, 3.000, 3.500)	(2.500, 3.000, 3.500)
C_{34}	(0.400, 0.500, 0.667)	(0.667, 1.000, 1.500)	(0.667, 1.000, 1.500)	(1.000, 1.000, 1.000)	(0.400, 0.500, 0.667)	(0.400, 0.500, 0.667)	(0.286, 0.333, 0.400)	(0.286, 0.333, 0.400)
C_{35}	(0.400, 0.500, 0.667)	(0.667, 1.000, 1.500)	(0.400, 0.500, 0.667)	(1.500, 2.000, 2.500)	(1.000, 1.000, 1.000)	(0.667, 1.000, 1.500)	(1.500, 2.000, 2.500)	(1.500, 2.000, 2.500)
C_{36}	(0.400, 0.500, 0.667)	(0.400, 0.500, 0.667)	(0.400, 0.500, 0.667)	(1.500, 2.000, 2.500)	(0.667, 1.000, 1.500)	(1.000, 1.000, 1.000)	(2.500, 3.000, 3.500)	(2.500, 3.000, 3.500)
C_{37}	(0.286, 0.333, 0.400)	(0.667, 1.000, 1.500)	(0.286, 0.333, 0.400)	(2.500, 3.000, 3.500)	(0.400, 0.500, 0.667)	(0.286, 0.333, 0.400)	(1.000, 1.000, 1.000)	(0.400, 0.500, 0.667)
C_{38}	(0.286, 0.333, 0.400)	(0.286, 0.333, 0.400)	(0.286, 0.333, 0.400)	(2.500, 3.000, 3.500)	(0.400, 0.500, 0.667)	(0.286, 0.333, 0.400)	(1.500, 2.000, 2.500)	(1.000, 1.000, 1.000)

After applying the F-AHP method steps, criterion weights were obtained in three separate groups: These are; Weights of "Service Region", "Management" and "Employees" sub-criteria for customer satisfaction (1), uninterrupted energy service (2) and quality energy service provision. In Table 12, "Service Area", "Management" and "Employees" sub-criteria are given weights to ensure customer satisfaction in electricity distribution companies. In Table 13, the weights of "Service Area", "Management" and "Employees" sub-criteria for providing uninterrupted energy service in electricity distribution companies are given.

Table 12. Weights of efficiency criteria for customer satisfaction in electricity distribution companies

In terms of customer satisfaction								
'Service region' sub criteria	Weight	Rank	'Management' Sub-criteria	Weight	Rank	'Employees' sub-criteria	Weight	Rank
The number of customers (C_{11})	0.173	4	Setting goals (C_{21})	0.184	2	Staff adoption of goals (C_{31})	0.189	2

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Geographical conditions (C_{12})	0.050	5	Staff participation in decision processes (C_{22})	0.102	6	Training level of staff (C_{32})	0.167	5
Climatic conditions (C_{13})	0.040	6	Ensuring ergonomic working conditions (C_{23})	0.236	1	Employee motivation (C_{33})	0.198	1
Network size (C_{14})	0.036	7	Supporting employee development (C_{24})	0.129	4	Wages and benefits (C_{34})	0.028	7
Line length (C_{15})	0.177	3	The importance given to OHS (C_{25})	0.137	3	Teamwork (C_{35})	0.179	3-4
Energy losses (C_{16})	0.262	1-2	Flexible hours (C_{26})	0.081	7	Responsibility awareness (C_{36})	0.179	3-4
Investment amounts (C_{17})	0.262	1-2	Presence of EYS certificates (C_{27})	0.006	8	Average service time of the staff (C_{37})	0.046	6
			Employee promotion and advancement opportunity (C_{28})	0.122	5	personal number (C_{38})	0.015	8

Table 13. Weights of efficiency criteria for uninterrupted energy service in electricity distribution companies

In terms of providing uninterrupted energy service								
'Service region' sub criteria	Weight	Rank	'Management' Sub-criteria	Weight	Rank	'Employees' sub-criteria	Weight	Rank
The number of customers (C_{11})	0.011	6	Setting goals (C_{21})	0.122	4	Staff adoption of goals (C_{31})	0.226	2
Geographical conditions (C_{12})	0.024	5	Staff participation in decision processes (C_{22})	0.078	5-6	Training level of staff (C_{32})	0.259	1
Climatic conditions (C_{13})	0.280	1	Ensuring ergonomic working conditions (C_{23})	0.057	7	Employee motivation (C_{33})	0.153	3
Network size (C_{14})	0.074	4	Supporting employee development (C_{24})	0.211	1-2	Wages and benefits (C_{34})	0.009	8
Line length (C_{15})	0.114		The importance given to OHS (C_{25})	0.191	3	Teamwork (C_{35})	0.097	5
Energy losses (C_{16})	0.249	2-3	Flexible hours (C_{26})	0.211	1-2	Responsibility awareness (C_{36})	0.105	4
Investment amounts (C_{17})	0.249	2-3	Presence of EYS certificates (C_{27})	0.078	5-6	Average service time of the staff (C_{37})	0.066	7
			Employee promotion and advancement opportunity (C_{28})	0.053	8	personal number (C_{38})	0.087	6

In Table 14, the weights of "Service Area", "Management" and "Employees" sub-criteria for providing quality energy service in electricity distribution companies are given.

Table 14. Weights of efficiency criteria for quality energy service in electricity distribution companies

In terms of providing quality energy service								
'Service region' sub criteria	Weight	Rank	'Management' Sub-criteria	Weight	Rank	'Employees' sub-criteria	Weight	Rank
The number of customers (C_{11})	0.026	6	Setting goals (C_{21})	0.109	5	Staff adoption of goals (C_{31})	0.235	1

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Geographical conditions (C_{12})	0.002	7	Staff participation in decision processes (C_{22})	0.045	8	Training level of staff (C_{32})	0.203	2
Climatic conditions (C_{13})	0.136	4	Ensuring ergonomic working conditions (C_{23})	0.084	6	Employee motivation (C_{33})	0.171	3
Network size (C_{14})	0.074	5	Supporting employee development (C_{24})	0.214	1	Wages and benefits (C_{34})	0.029	7
Line length (C_{15})	0.240	2	The importance given to OHS (C_{25})	0.163	3	Teamwork (C_{35})	0.124	5
Energy losses (C_{16})	0.228	3	Flexible hours (C_{26})	0.204	2	Responsibility awareness (C_{36})	0.133	4
Investment amounts (C_{17})	0.293	1	Presence of EYS certificates (C_{27})	0.115	4	Average service time of the staff (C_{37})	0.057	6
			Employee promotion and advancement opportunity (C_{28})	0.064	7	Personal number (C_{38})	0.007	8

5. Results and Discussions

In this study, the criteria that affect electricity distribution companies and the weights of these criteria are emphasized. Fuzzy logic has been used in distribution companies because efficiency is only understandable with its reflections on customer behavior, and their behavior is complex due to human nature and does not show a clear and linear tendency. However, in order to compare the results with classical AHP, AHP results were determined and discussed on the methods.

First of all, a hierarchical structure has been established by making interviews with Aras EDAŞ managers, which are the subject of the implementation, and determine the main and sub-criteria affecting productivity. The criteria determined were evaluated on the same group by using the questionnaire method and verbal expressions. Weights were obtained by using unified decision matrices obtained by combining decision maker's opinions with geometric mean and Chang's Order Analysis Method.

Considering customer satisfaction, uninterrupted energy and quality energy main criterion weights, it is seen that uninterrupted and high-quality energy is equal, but rather less important than customer satisfaction. Fig. As seen in (4), Customer Satisfaction has the highest importance in the efficiency of electricity distribution companies. It is observed that the company focuses on customer satisfaction in the studies conducted by the company, and it is aimed to measure customer satisfaction in continuous meetings with customers. In addition, in independent surveys conducted outside of the company, it has been observed that the most important criterion in the measurement of efficiency in distribution companies is customer satisfaction.

Fig. As seen in (4), it has been revealed that the customer satisfaction criterion has a much higher importance compared to the other two criteria in the solutions made with AHP. However, uninterrupted and quality energy criteria are not equal to each other as in F-AHP, and uninterrupted energy is at a higher level of importance than quality energy.

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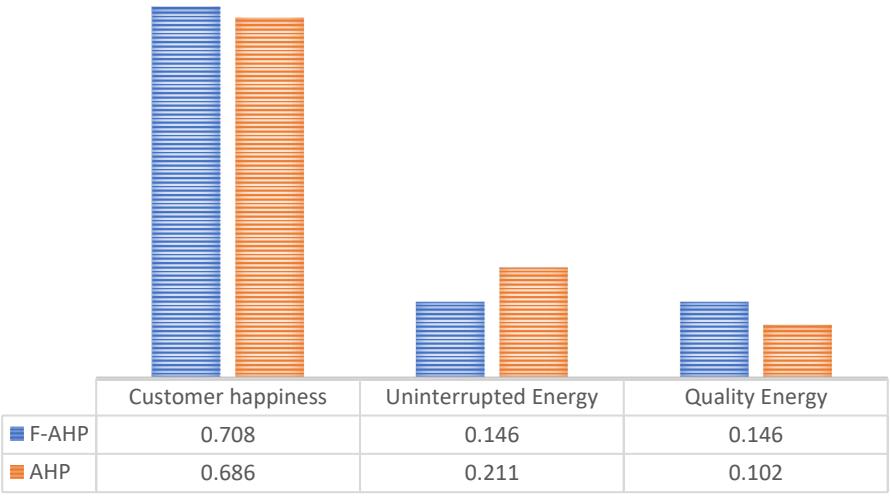

	Customer happiness	Uninterrupted Energy	Quality Energy
F-AHP	0.708	0.146	0.146
AHP	0.686	0.211	0.102

Fig. 4. Main criterion weights comparison

Paired comparisons of the service region, management and employees criteria, which are the main customer satisfaction criteria affecting the productivity in distribution companies, were made with the analysis. Fig. As seen in 5-7, the most important criteria in customer satisfaction criteria are investment amounts and loss and leakage rates. It is seen that the investments made in technical and technological infrastructure work have a priority in ensuring efficiency in customer satisfaction. In addition to the technical investments made in the field services offered to the customers, ensuring that customers can reach the relevant person quickly to solve their problems by increasing the communication channels, appointment systems and online payment facility that will prevent the loss of time in the busy life pace and waiting in business for long hours, the establishment of systems where online requests, complaints and suggestions can be received It has been observed that technological investments such as the establishment of management information systems where customer information is kept and customer experiences and trends can be analyzed have an important priority in customer satisfaction.

The issue that the loss and illegal electricity costs are reflected to customers who pay their bills regularly, is frequently mentioned in the press today and causes criticism on social media platforms. This situation creates a prejudice against the service offered by electricity distribution companies in customers and causes a question mark in the minds of the customers, no matter how good the service quality is. In addition, the high rate of loss and leakage causes dissatisfaction in regions where the use of illegal use is intense, while technical scans and technological investments in the field to reduce leakage cause fluctuations in energy demands. For this reason, high loss and leakage rates become one of the primary criteria affecting customer satisfaction.

Another criterion that has priority is the ergonomic working conditions belonging to the management criterion. Employees of the electricity distribution sector, where field work is intensely carried out, have to work at height in order to perform breakdown, repair and maintenance works on the lines. Depending on the type of the pole, it is important to climb from time to time and to provide ergonomic conditions in works using basket vehicles from time to time. In addition to working with the help of basket vehicles, most of the employees need to improve the ergonomic conditions in order to provide customer satisfaction to the 75 personnel working in the call centers established to provide faster solutions to customers.

In the electricity distribution sector, field personnel work in shifts, ensuring continuity in field work in order to instantly respond to breakdowns and customer demands, and overtime from time to time causes lack of motivation in employees. One of the conditions affecting field workers is that

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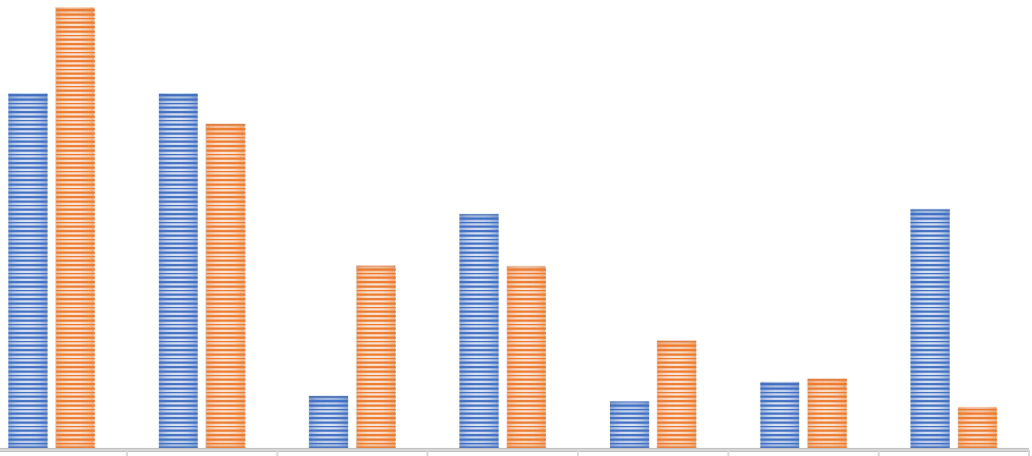
the winter season in provinces such as Erzurum, Ardahan and Kars is difficult. In these provinces, the temperature drops down to -30 degrees in winter, as well as difficult access to households due to heavy snowfall, making it necessary for the households that cannot be reached by vehicles by tracked vehicles or by walking. Employee motivation has a priority, as the work carried out in electricity distribution services can be achieved by transferring employees who are in direct contact with customers to customers through correct communication. It is expected that electricity distribution companies will show a positive tendency to increase their efficiency with employee motivation-oriented management approaches.

The results of AHP were analyzed with the analysis performed to compare the dual comparisons of the service area, management and employees criteria, which is the main customer satisfaction criterion affecting the efficiency of distribution companies, with F-AHP. Fig. As seen in 5, the results of the service area sub-criterion examination for the main criterion of customer satisfaction show similar characteristics with AHP, while the investment amount, climatic conditions, grid size criteria are more important than F-AHP data, energy losses, number of customers and line length are less important. determined as. The geographical conditions criterion seems to have approximately the same value in both methods. Fig. As seen in 6, for the main criterion of customer satisfaction, the results of the management sub-criterion examination, ensuring ergonomic conditions, determining flexible working hours, and the existence of IMS certificates are more important than F-AHP data, while determining targets, importance given to OHS, giving promotion opportunities to personnel, the criteria for participation in decision-making processes were determined to be less important. The criterion of supporting employee development seems to have approximately the same importance in both methods. Fig. As can be seen in 7, as a result of the examination of the employee sub-criteria for the main criterion of customer satisfaction, while the personnel not adopting the targets, the average number of personnel, the average service time criteria are more important than the F-AHP data, the employee motivation, team spirit, personnel responsibility awareness, and the education level of the personnel are more important. determined to be less important. Staff wages and benefits criteria have been found to be equally important in both methods.



	Investment Amount	Energy Losses	Climatic Conditions	The number of customers	Network Size	Geographical Conditions	Line Length
F-AHP	0.262	0.262	0.040	0.173	0.036	0.050	0.177
AHP	0.325	0.240	0.136	0.135	0.080	0.052	0.031

Fig. 5. Comparison of 'service area' sub criterion weights for customer satisfaction

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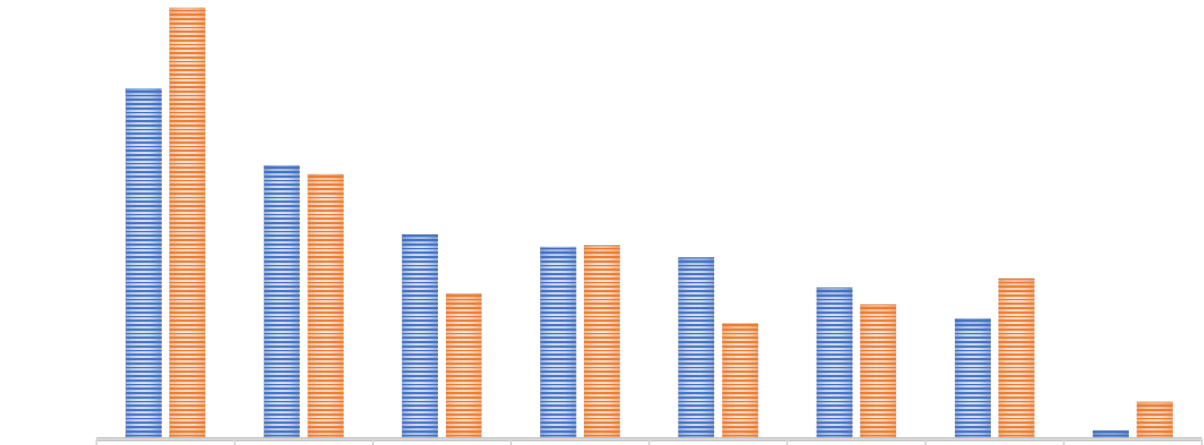
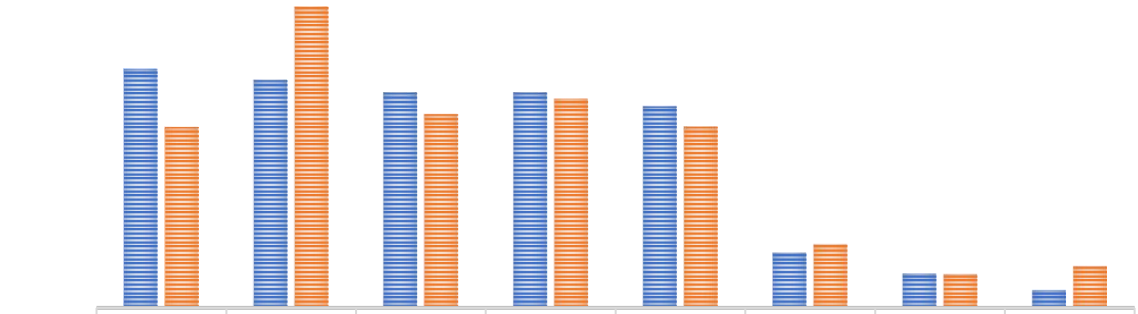


	Ensuring Ergonomic Working Conditions	Setting Goals	Importance Attached to OHS	Supporting Employee Development	Giving Promotion and Advancement Opportunities to Personnel	Personnel Participation in Decision Processes	Flexible hours	Existence of EYS Certificates
F-AHP	0.236	0.184	0.138	0.130	0.122	0.102	0.082	0.006
AHP	0.290	0.178	0.098	0.131	0.078	0.091	0.108	0.025

Fig. 6. Comparison of 'management' sub criterion weights for customer satisfaction



	Employee Motivation	Staff Adoption of Goals	Team spirit	Responsibility of Personnel	Education Level of Personnel	Average Service Time	Personnel Wages and Benefits	Average Number of Employees
F-AHP	0.198	0.189	0.179	0.179	0.167	0.046	0.028	0.015
AHP	0.150	0.250	0.161	0.174	0.150	0.053	0.028	0.035

Fig. 7. Comparison of 'employees' sub criterion weights for customer satisfaction

Binary comparisons of the main criteria of uninterrupted energy affecting efficiency in distribution companies with the criteria of service region, management and employees were made. Fig. As seen in 8-10, the most important criteria in the uninterrupted energy criterion are climatic conditions, investment amount and loss and leakage ratios, personnel's adoption of the targets, the education level of the personnel and the support of employee development with equally weighted flexible working hours. Network improvement studies, the work of taking the cables underground are among the areas where meticulous work has been carried out by the electricity distribution companies in order to meet the demands of the customers and to provide uninterrupted energy.

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Heavy rain and snowfall, strong winds, increased soil water level as a result of melting snow constitute an obstacle to uninterrupted energy. In order to deal with these situations completely independent of human influence, the underground network is emphasized and it is aimed to eliminate the malfunctions in a short time by using cable and route detection devices. However, factors such as the height of snow and the number of days the soil spends under the snow negatively affect the uninterrupted energy criteria. For this reason, the primary weighted criterion of uninterrupted energy criteria is climatic conditions.

Investment amount and leakage rate have a significant impact on uninterrupted energy criteria as well as customer satisfaction criteria. Since the increase in illegal usage causes excessive load in the network and imbalances in energy demand, it creates an obstacle to uninterrupted energy. For this reason, distribution companies focus on field scans and technological investments in combating illegal electricity. With the increase in investments, it is aimed to reduce the use of illegal electricity and to provide uninterrupted energy. In Aras EDAŞ, where the application is carried out, with the PLC project based on communication over electricity lines, investments aimed at both protecting the rights of customers, preventing the damage to the country's economy and reducing the use of illegal electricity are realized.

The lack of employee participation in the enterprises or the lack of knowledge of the targets by the personnel makes it difficult for the enterprises to reach their goals. Although uninterrupted energy is the basic criterion of electricity distribution companies, they have frameworks drawn in accordance with legislation. For example, notifying customers in advance of a certain scheduled hour and not taking any interruptions without notice for more than a certain hour. However, since these requirements are not adopted by the personnel, it will be reflected in the practices in the field, and it becomes difficult to reach the targets set in the enterprise or to act in accordance with the legislation. For this reason, the adoption of the rules to be followed or the goals created by the personnel has priority weighting.

In order to provide uninterrupted energy, it is necessary to increase the maintenance work and to intervene in the uninterrupted energy instantly. This situation requires the employees to keep up with the developing technologies and to intervene with solution-oriented approaches. This can only be achieved by increasing the technical and personal training of the personnel and supporting their vocational training with trainings suitable for today's conditions. When all these reasons are taken into consideration, it has been observed that besides the importance of the education levels of the employees, it adopts a parallel approach with the emphasis on supporting employee development over other criteria. In addition, as the standards set the requirement for instant repair of malfunctions and respond to customer requests 24/7, flexible working hours are prioritized for uninterrupted energy.

With the analysis made, the AHP results were examined in order to compare the dual comparisons of the uninterrupted energy main criterion that affect efficiency in distribution companies with F-AHP and the dual comparisons of the service region, management and employees criteria. Fig. As seen in 8, the results of the service region sub-criterion examination for the uninterrupted energy main criterion are similar to AHP, while the geographical conditions and the number of customers criteria are more important than the F-AHP data, while the criteria for line length and network size are determined to be less important. It is seen that the criteria for climatic conditions, energy losses and investment amount have approximately the same values in both methods. Fig. The results of management sub-criterion review for the main criterion of uninterrupted energy, which is seen in 9, are more important than F-AHP data, while supporting employee development, providing ergonomic working conditions and providing personnel with promotion and advancement opportunities, flexible working hours, importance given to OHS, goals determination, participation in decision-making processes, existence of IMS certificates were determined as less important. Fig. As seen in 10, as a result of the examination of the employee sub-criteria for the main criterion of uninterrupted energy, the education level of the personnel, personnel wages and benefits, and the criteria not to adopt the personnel targets are more important than the F-AHP data, while the employee motivation, team spirit, personnel responsibility awareness, average personnel number and average service time are less important.

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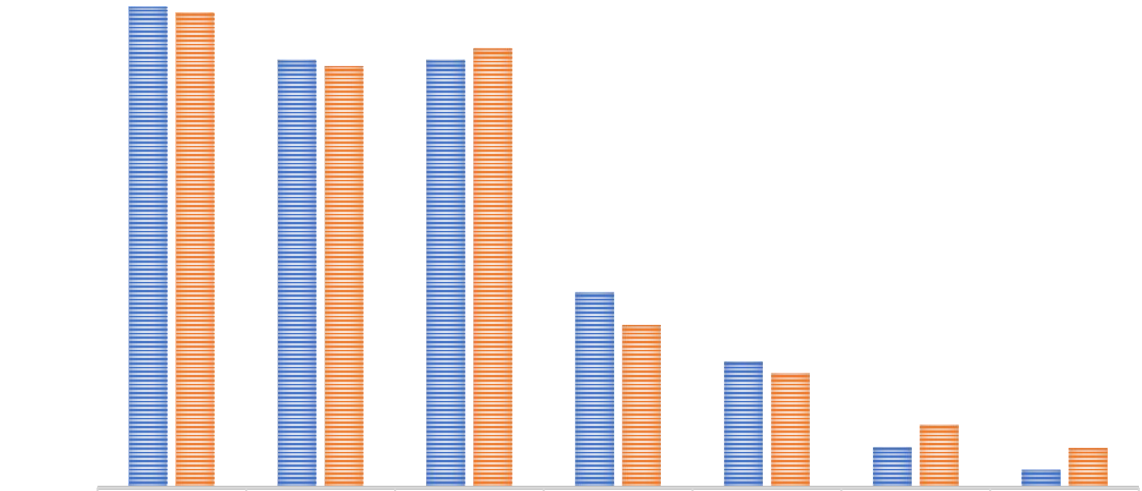
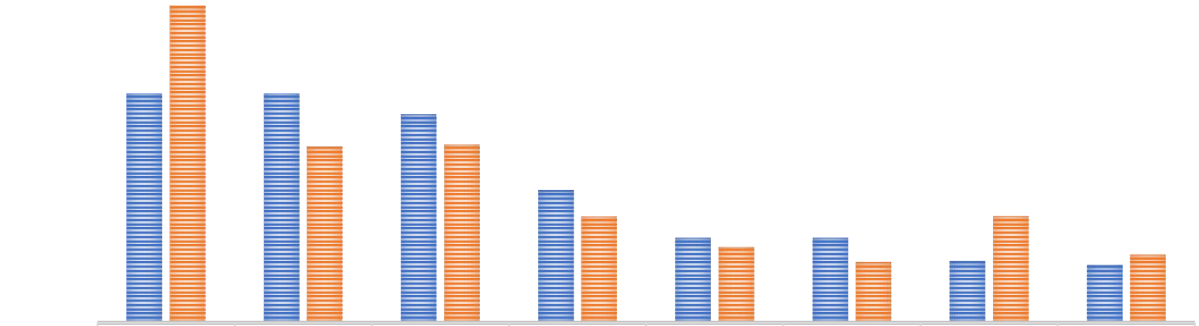


	Climatic Conditions	Energy Losses	Investment Amount	Line Length	Network Size	Geographical Conditions	The number of customers
F-AHP	0.280	0.249	0.249	0.114	0.074	0.024	0.011
AHP	0.277	0.246	0.256	0.095	0.067	0.037	0.023

Fig. 8. 'Service zone' sub criterion weights comparison for uninterrupted energy



	Supporting Employee Development	Flexible hours	Importance Attached to OHS	Setting Goals	Personnel Participation in Decision Processes	Existence of EYS Certificates	Ensuring Ergonomic Working Conditions	Giving Promotion and Advancement Opportunities to Personnel
F-AHP	0.211	0.211	0.191	0.122	0.078	0.078	0.057	0.053
AHP	0.291	0.162	0.164	0.098	0.070	0.056	0.098	0.063

Fig. 9. 'Management' sub criterion weights for uninterrupted energy

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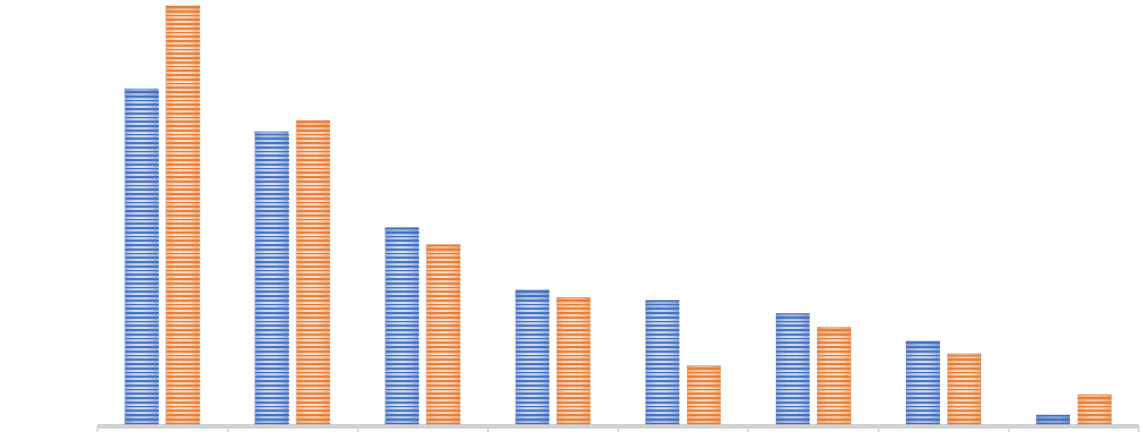

	Education Level of Personnel	Staff Adoption of Goals	Employee Motivation	Responsibility of Personnel	Team spirit	Average Number of Employees	Average Service Time	Personnel Wages and Benefits
F-AHP	0.259	0.226	0.153	0.105	0.097	0.087	0.066	0.009
AHP	0.323	0.235	0.139	0.099	0.047	0.076	0.056	0.024

Fig. 10. Comparison of 'employees' sub criterion weights for uninterrupted energy

Binary comparisons of the main criterion of quality energy affecting efficiency in distribution companies with the criteria of service region, management and employees were made. Fig. As seen in 11-13, the most important criteria in quality energy criteria are weighted as investment amount, line length, energy losses, staff's adoption of goals, support of employee development, training level of the staff and flexible working hours, respectively, similar to other comparisons.

In order to compare the dual comparisons of the service region, management and employees criteria, which is the main criterion of quality energy that affects efficiency in distribution companies, the AHP results were analyzed with the F-AHP. Fig. As can be seen in 11, the results of the service region sub-criterion examination for the uninterrupted energy main criterion show similar characteristics with AHP, while the energy losses, grid size, geographical conditions criteria are more important than the F-AHP data, while the investment amount and climatic conditions criteria are determined as less important. It is seen that the criteria of line length and number of customers have approximately the same values in both methods. Fig. While the criteria for supporting employee development, flexible working hours, the importance given to OHS, ensuring ergonomic working conditions are more important than the F-AHP data, as seen in the 12th, giving the personnel the opportunity to promote and progress, the existence of IMS certificates, the criteria have been determined as less important. Fig. As seen in 13, while the training level of the personnel, personnel wages and benefits criteria are more important than the F-AHP data as a result of the examination of the employee sub-criteria for the main criterion of uninterrupted energy, the personnel's failure to adopt the targets, employee motivation, team spirit, personnel responsibility awareness, average personnel number and average service time are less important.

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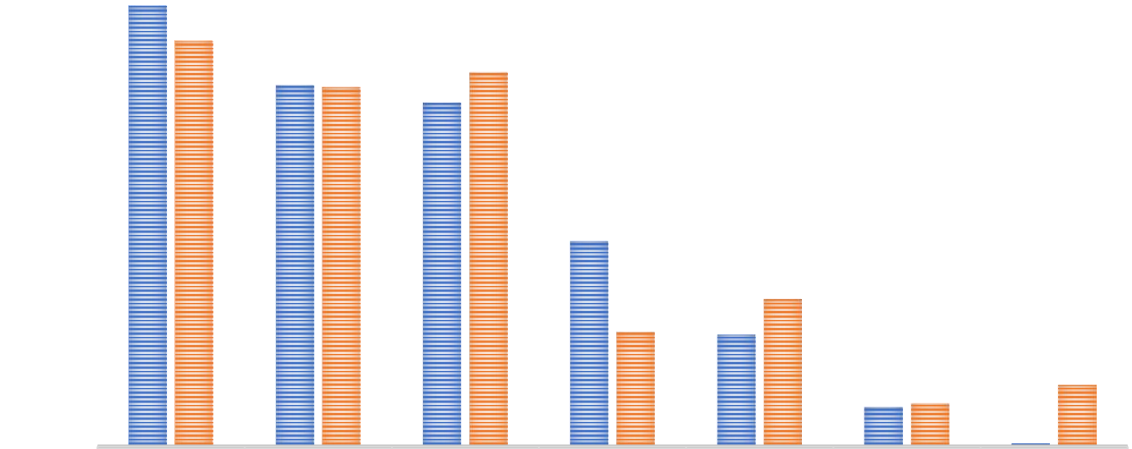
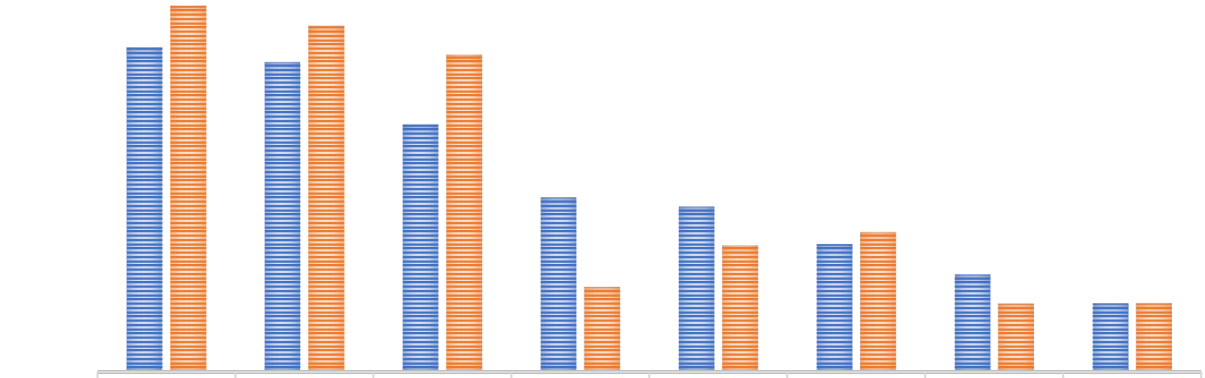


	Investment Amount	Line Length	Energy Losses	Climatic Conditions	Network Size	The number of customers	Geographical Conditions
F-AHP	0.293	0.240	0.228	0.136	0.074	0.026	0.002
AHP	0.269	0.239	0.248	0.076	0.098	0.029	0.041

Fig. 11. Comparison of 'service region' sub criterion weights for quality energy



	Supporting Employee Development	Flexible hours	Importance Attached to OHS	Existence of EYS Certificates	Setting Goals	Ensuring Ergonomic Working Conditions	Giving Promotion and Advancement Opportunities to Personnel	Personnel Participation in Decision Processes
F-AHP	0.214	0.204	0.163	0.115	0.109	0.084	0.064	0.045
AHP	0.241	0.228	0.209	0.056	0.083	0.092	0.045	0.045

Fig. 12. Comparison of 'management' sub criterion weights for quality energy

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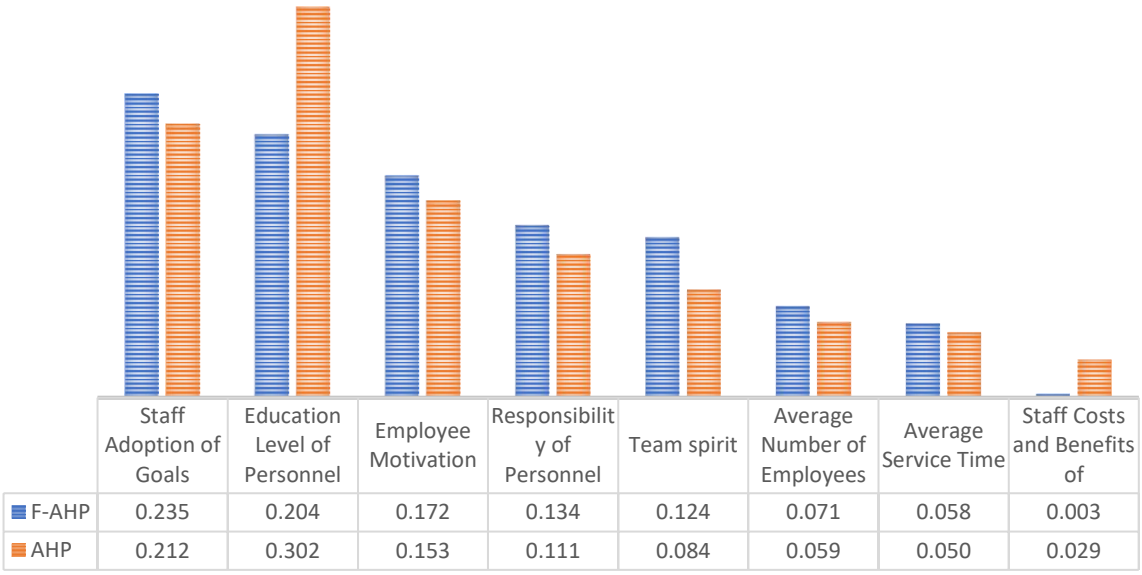

	Staff Adoption of Goals	Education Level of Personnel	Employee Motivation	Responsibility of Personnel	Team spirit	Average Number of Employees	Average Service Time	Staff Costs and Benefits of
F-AHP	0.235	0.204	0.172	0.134	0.124	0.071	0.058	0.003
AHP	0.212	0.302	0.153	0.111	0.084	0.059	0.050	0.029

Fig. 13. 'Employees' sub criterion weights for quality energy

6. Conclusions

This study has aimed to investigate the best performance measurement approach and identification of factors affecting the efficiency of electricity distribution companies operating in post privatisation era in Turkey. The main concern was how to set up a competition among the companies operating in Turkish energy market and to enforce the change in public perception towards distribution companies. Performance assessment with respect to customer satisfaction plays the most crucial role in this process. The study has been conducted with an energy supply firm, which operates in north-eastern region of Turkey using AHP and F-AHP methods as a renown qualitative assessment approach and its fuzzified version. Each method has been separately implemented and used for the case undertaken and the results are compared, where F-AHP demonstrates and exhibits better qualitative assessment as it lets to encompass more expertise within the process.

The results obtained with F-AHP reveals that topmost criterion affecting the efficiency of electricity distribution companies is “customer satisfaction” while the next most prominent one is “sustainable and uninterrupted energy supply”, which shows a slight inferiority the first one. Besides, the other highly prioritised criteria have been observed as “the amount of investments”, “loss and leakage rates”, “climatic conditions”, “support provided to employees for education and development”, “employee motivation” and “flexible working hours”. Similarly, it has been determined that criteria such as “employee wages and benefits”, “average service duration”, “presence of IMS certificates” have exhibited lower priorities. This study has been conducted over a typical energy supply company operating in Turkey, which can be generalised for all companies in this kind. It can guide to apply the same approaches to the firms similarly operating, taking the case-specific details, e.g. hierarchies etc., into account and identify the impactful factors efficiency and performance assessment.

The study can be extended with integrating more expert-view supplying approaches and incorporating with other renown multi criteria decision making approaches and their fuzzified forms such as DEMANTEL, TOPSIS etc.

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