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AN INTEGRATED MODEL APPROACH WITH FUZZY MULTI CRITERIA DECISION MAKING METHODS FOR THE SELECTION OF THIRD PARTY LOGISTICS FIRM IN THE FOOD INDUSTRY

GIDA SEKTÖRÜNDE ÜÇÜNCÜ PARTİ LOJİSTİK FİRMA SEÇİMİNDE BULANIK ÇOK KRİTERLİ KARAR VERME TEKNİKLERİYLE ENTEGRE BİR MODEL YAKLAŞIMI

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Abstract

The purpose of this study was to determine third party logistics company selection and evaluation criteria and to help make the most suitable selection among the alternatives in the food sector. Another purpose was to present a mixed model by integrating fuzzy multi criteria decision making methods in third-party logistics company selection process. The combination of fuzzy DEMATEL, fuzzy ANP and fuzzy TOPSIS methods were used in this study. A decision network was created by evaluating the interactions between the criteria determined depending on the decision goal. This study was conducted in a large scale company producing milk and dairy products in food sector. As a result of the analyses made and the findings obtained, technology, delivery performance and quality were found as the criteria having the highest scores in terms of effectiveness. In addition, it was also determined that the most affected criterion among the criteria was the company image. As a result of the evaluation of alternatives, the best logistics company was suggested to the food company. This study is among the first studies to integrate fuzzy DEMATEL, fuzzy ANP and fuzzy TOPSIS methods in the selection of third party logistics suppliers. In terms of the food industry, three new criteria that have not been encountered in the literature before were determined and a small contribution was made to the relevant literature. These are porter cost, hygiene and vehicle supply ability.

Keywords: Supplier Selection, Third-Party Logistics, Multi Criteria Decision Making Methods, Food Sector.

Öz

Bu çalışmanın amacı, üçüncü parti lojistik firma seçimi ve değerlendirme kriterlerini belirlemek ve gıda sektöründeki alternatifler arasından en uygun seçimin yapılmasına yardımcı olmaktır. Diğer bir amaç ise, üçüncü parti lojistik firma seçim sürecinde bulanık çok kriterli karar verme yöntemlerini entegre ederek karma bir model sunmaktır. Bu çalışmada bulanık DEMATEL, bulanık ANP ve bulanık TOPSIS yöntemlerinin kombinasyonu kullanılmıştır. Karar amacına bağlı olarak belirlenen kriterler arasındaki etkileşimler değerlendirilerek bir karar ağı oluşturulmuştur. Bu çalışma gıda sektöründe süt ve süt ürünleri üreten büyük ölçekli bir firmada yapılmıştır. Yapılan analizler ve elde edilen bulgular sonucunda teknoloji, teslimat performansı ve kalite en çok etkileyen kriterler olarak bulunmuştur. Bununla birlikte kriterler arasından en çok etkilenen kriterin de firma imajı olduğu tespit edilmiştir. Alternatiflerin değerlendirilmesi sonucunda firmaya en iyi üçüncü parti lojistik firma önerisi yapılmıştır. Bu çalışma, üçüncü parti lojistik tedarikçi seçimi ve değerlendirilmesinde bulanık DEMATEL, bulanık ANP ve bulanık TOPSIS yöntemlerini ilk kez bütünleşik olarak kullanan çalışmalar arasında yer almaktadır. Ayrıca bu çalışmada gıda sektörü açısından literatürde rastlanmamış üç adet yeni kriter tespit edilmiş ve ilgili literatüre ufak da olsa katkıda bulunulmaya çalışılmıştır. Bu kriterler; hamaliye bedeli, hijyen ve araç tedarik yeteneğidir.

Anahtar Kelimeler: Tedarikçi Seçimi, Üçüncü Parti Lojistik, Çok Kriterli Karar Verme Teknikleri, Gıda Sektörü.

GENİŞLETİLMİŞ ÖZET

Çalışmanın Amacı

Bu çalışmanın temel amacı, tedarikçi seçim ve değerlendirme sürecini oluşturmaya yönelik entegre bir bulanık yaklaşım kullanılarak büyük ölçekli bir gıda firmasına üçüncü parti lojistik firma seçim önerisinde bulunmaktır. Alt amaç olarak ise bu tür çalışmaların gıda sektöründe yeterli görülmemesi nedeniyle bu sektörde önemli olan kriterlerin belirlenmesidir.

Araştırma Soruları

Gıda sektöründe faaliyet gösteren firma için üçüncü parti lojistik firma seçiminde dikkat edilen kriterler nelerdir? Sektörde uygulayıcılar tarafından dikkate alınan ancak literatürde yer almayan kriterler var mıdır?

Literatür Araştırması

Üçüncü parti lojistik (3PL), tedarik zinciri yönetiminde oldukça önemlidir. 3PL sağlayıcıları, şirketlerin müşteri memnuniyeti sağlamaları, maliyetleri optimize etmeleri ve rekabet avantajı yakalaması noktasında büyük bir role sahiptir (Govindan vd., 2016). Bu kapsamda günümüz iş dünyasında tedarik zincirinin entegre bir şekilde yürütülmesinde 3PL faaliyetlerine talep artmaktadır. Bununla birlikte, en uygun bir 3PL hizmet sağlayıcısının seçimi ve değerlendirmesi, birçok kriter dikkate alındığından çok kriterli karar verme problemi olarak görülmektedir (Sahu vd., 2015).

Yöntem

Çalışmada Bulanık DEMATEL, Bulanık ANP ve Bulanık TOPSIS yöntemleri kullanmıştır. Bulanık olan üç yöntem entegre edilirken öncelikle Bulanık DEMATEL yöntemiyle kriterlerin iç bağımlıkları elde edilmiştir. Daha sonra kriterlerin sadece kendi aralarında değil aynı zamanda farklı küme elemanlarıyla da doğrudan ya da dolaylı olarak etkileşimde olabileceği düşüncesiyle Bulanık ANP yöntemi kullanılmıştır. Dolayısıyla Bulanık ANP yöntemiyle dış bağımlılıklar belirlenmiştir. Bulanık DEMATEL ve Bulanık ANP yöntemleriyle elde edilen iç ve dış bağımlılıklar Bulanık ANP'nin süper matris oluşturma aşamasında entegre edilmiştir. Son olarak da bu şekilde elde edilen ağırlıklar Bulanık TOPSIS'de kullanılarak alternatifler arasından seçim yapılmıştır.

Sonuç ve Değerlendirme

Araştırmada, gıda sektöründe süt ve süt ürünleri üreten bir işletme için en önemli kriterlerin sırasıyla özel uzmanlık, tecrübe ve firma ünü olduğu belirlenmiştir. Yapılan analizler ve elde edilen bulgular sonucunda teknoloji, teslimat performansı ve kalite en çok etkileyen kriterler olarak bulunmuştur. Bununla birlikte kriterler arasından en çok etkilenen kriter ise firma imajı olarak tespit edilmiştir. S2 olarak isimlendirilen firma, alternatiflerin değerlendirilmesi sonucunda en iyi üçüncü parti lojistik firması olarak önerilmiştir. Ayrıca çalışmada literatürde rastlanmamış olan hamaliye bedeli, hijyen ve araç tedarik yeteneği kriterleri tespit edilmiştir.

1. INTRODUCTION

The key to succeed in any business is how well and efficiently the entrepreneur can use resources and how much the entrepreneur can achieve maximum efficiency. Scientists and industrialists consider how business operation may be managed more efficiently in this competitive field. The gap between product quality and performance has begun to close with the intense competition in the global market (Sarmah et al., 2006). In today's global markets increasing competition, marketing short-lasting products, and chancing customer expectations have attracted the attention of companies on the supply chains and forced them to invest in these chains (Sell, 1999). Supply chain means the process in which the information and products are transferred from the supplier to producer, wholesaler, retailer and customer. A well-designed Supply Chain Management (SCM) system is important in terms of improving the competitive advantage in international economics and in the rapidly growing Information Technology Age (Li and Wang, 2007). Correct supplier decisions help businesses to find suitable supply chain partners; and as a result, they increase their organizational performance. In many companies, accurate supplier decisions are important components for production and logistics direction, and such a decision becomes more and more important especially for food industry, which has low product durability.

The success or failure of SCM depends on a proper SCM system and selecting correct suppliers. Experts accept that supplier selection is one of the most important functions of a purchase department and that businesses to decrease their product costs and increase their competitive advantage (Saen, 2007). In an efficient supply chain, as the first step, businesses must find prominent suppliers, and then establish long-term partnerships with these suppliers to increase their competitiveness. The business environment in today's world emphasizes that the supplier relations are developed for sustainable corporate management. For this reason, supplier selection decision is of great importance for a successful supply chain management.

Supply chain includes the order of each element which plays roles in the journey of a product starting from raw material supply to production and end-user in the chain. Right at this point, it is understood that there is a whole and integrated activity in the production of a product. Therefore, at this point, the importance of an activity appears clearly in the chain. It is the Logistics Management, which includes these activities in the supply chain. Logistics Management has an important role in carrying out the supply chain without interruptions. For this reason, there are companies that are only responsible for logistics management. These companies are called third-party logistics companies. As these logistics companies affect the overall performance of the supply chain directly, their selection process becomes an important issue.

Third-party logistics (3PL) involves external firms performing logistics activities that traditionally managed by manufacturing firms. In other words, outsourcing of logistics activities of firms that produce goods or services is defined as third-party logistics. The 3PL firm selection is basically a complex analytical process. In general, a supplier selection problem involves more than one criterion; and often, the criteria are in conflict with each other (Yang et al., 2008). Basically, the nature of the supplier selection is a Multi Criteria Decision Making (MCDM) problem that is based on relative priority attained for each selection criterion (Hwang and Shen, 2015).

In MCDM, it is generally hypothesized that the criteria are independent. However, in real life, the information that is available in a decision-making process is often not clear, and criteria are not independent (Yang et al., 2008). The traditional MCDM methods that are used to determine the importance of selection criteria generally accept the effect or relation weights and independence among criteria (Wang et al., 1999). However, using a single selection model is not always proper because of the interaction at varying levels between the selection criteria. Rather, fuzzy criteria do not acknowledge the independence between criteria. The fuzzy integral method, which is called "Nonadditive", and which is based on fuzzy criteria, was developed to deal with the degree of the interaction among the diversified criteria and the uncertainty in the subjective judgments of humans.

The main aim of this study is to propose a third-party logistics supplier selection framework to a large-scale food company by using an integrated fuzzy approach and to the determine the importance of existing and/or new criteria/factors in the 3PL selection in food sector in Turkey. Fuzzy DEMATEL, fuzzy ANP and fuzzy TOPSIS methods were preferred in the study. The reason behind this choice is that the integration of these three methods would complement the missing aspects of each other. The fuzzy scale that consisted of 11 propositions (Chen 2000, Büyüközkan and Çifçi, 2012; Hwang and Shen, 2015) was used in the study. In the context of methodology framework firstly, the internal dependencies of the criteria were obtained using the fuzzy DEMATEL method. Then the fuzzy ANP method was employed to identify the external dependencies of the criteria. The internal and external dependencies obtained via the fuzzy DEMATEL and fuzzy ANP methods were than integrated in the super matrix formation stage of the fuzzy ANP. Finally, the weights were used within the scope of the fuzzy TOPSIS method and selection process among the alternatives was performed. It is hoped that this study will help researchers who will work on similar issues in the future, provide information to industry experts. The rest of the study is organized as follows: Section 2 reviews the literature. Section 3 presents the methodology and scope of the research. Section 4 gives the findings and finally section 5 concludes.

2. LITERATURE

Third-Party Logistics (3PL) plays a significant role in supply chain management. The demand for 3PL providers has been fundamental approach to provide better customer services, lower costs, and to achieve competitive advantage for firms (Govindan et al., 2016). Outsourcing has been a global trend in today's market to provide a wide range of services like logistics, transportation, distribution, packaging, labeling, storage and shipping. 3PL provider demand is now an increasingly important issue for businesses in terms of increasing customer services, operational efficiency, and reducing logistics costs and capital expenditures. However, the selection of a proper 3PL provider is considered as a sort of multi criteria decision making problem which needs to take the hierarchy of complex criteria into consideration (Sahu et al., 2015). Table 1 gives an extensive summary of the studies conducted by using the multi criteria decision making methods (MCDM) in 3PL provider selection problem.

Table 1. Summary of the studies about 3PL provider selection using MCDM Methods

Method	Researcher
AHP	Zhang et al., (2004); Kulak and Kahraman (2005); Göl and Çatay (2007); Karagül and Albayrakoğlu (2007); Meng (2008); Çakır et al., (2009); Chiang and Tzeng (2009); Singh et al., (2010); Soh (2010); Vijayvargiya and Dey (2010); Fu et al., (2010); Daim et al., (2012); Özbek and Eren (2012); Özçifçi and Arsu (2013), Gürcan et al., (2016)
AAS	Meade and Sarkis (2002); Jharkharia and Shankar (2007); Çelebi et al., (2010); Sun et al., (2010); Özbek (2013)
TOPSIS	Qureshi et al., (2007)
ELECTRE	Aguezzoul et al., (2006)
DEMATEL	Govindan et al., (2016)
Fuzzy AHP	Akman and Alkan (2006), Yadav et al., (2020)
Fuzzy TOPSIS	Bottani and Rizzi (2006); Qureshi et al., (2007), Soba and Şimşek (2019)
Fuzzy ELECTRE	Govindan et al., (2010)
Fuzzy DEMATEL	Li et al., (2018)
IRP	Narkhede et al., (2017)
ANP and DEA	Raut et al., (2018)
ANP and VIKOR	Lixin et al., (2008)
AHP and VIKOR	Shan (2011)
AHP and TOPSIS	Bianchini (2018), Tabares et al., (2020)
AHP and DEA	Bajec and Suban (2019)
Fuzzy AHP and TOPSIS	Jovˇci´c et al., (2019)
Fuzzy DEMATEL and Fuzzy TOPSIS	Altan and Aydın (2015)
Fuzzy AHP and Distance from Average Solution (EDAS)	Ecer (2018)
Fuzzy Evaluation	Samantra et al., (2013); Sahu Datta and Mahapatra, (2015)
Literature Research	Gümüşay and Berberoğlu (2011); Alkhatib et al., (2015)

As one can see from the literature review in Table 1, there is considerable research in the literature but this study differs from the related literature by introducing the integrated fuzzy DEMATEL, fuzzy ANP and fuzzy TOPSIS methodology to 3PL provider selection problem. It is hoped that this study will contribute to the literature in terms of its methodological approach and sectoral orientation.

3. METHODOLOGY

As mentioned in the previous sections, the purpose of this study is to provide an approach based on a mixed model by integrating fuzzy MCDM methods to help the decision-making process of the firms in 3PL provider selection. To measure the validity of the model, a real case study was done in a large-scale company operating in the food sector. An evaluation model was proposed to help the company to evaluate the suitability of logistics firms. In this study, the fuzzy DEMATEL, fuzzy ANP and fuzzy TOPSIS methods were used together. These methods are explained in the following sub-sections.

3.1. Fuzzy DEMATEL Method

DEMATEL is a comprehensive method that is employed to construct and analyze a structural model including causal relations among mixed factors (Wu and Lee, 2007). It explains the interdependency among the factors of system that is ignored in traditional techniques by using a causal diagram. The steps of fuzzy DEMATEL are as follows:

1) Determining the evaluation criteria and creating direct relation matrix: in this method, experts perform a dual comparison of the factors to determine the degree and direction of the interactive relation among the criteria. $a=[Aij]nxn$ in a matrix of size nxn refers to the degree of influence of i. criteria on j. criteria (Chang, Chang and Wu, 2011). In addition, if there are p experts, the decision matrix is created in an equal number, namely p. This creates the average Z matrix as shown in Equation (2) and Equation (3). If the Fuzzy Direct Relation is expressed by $\hat{Z}$, the $\hat{Z}_{ij}= (k_{ij}, l_{ij}, m_{ij})$ triangular fuzzy numbers are linguistic expressions, and show the effect of *i*. criterion on *j*. criterion.

$$A = \begin{bmatrix} 0 & \cdots & a_{1n} \\ \vdots & \ddots & \vdots \\ a_{n1} & \cdots & 0 \end{bmatrix} \tag{1}$$

$$\hat{Z} = \hat{Z}_{ij(nxn)} = \left[\left(\frac{\hat{Z}_{ij1} + \hat{Z}_{ij2} + \dots + \hat{Z}_{ijp}}{p}\right)\right]_{nxn} \tag{2}$$

$$\hat{Z} = \begin{bmatrix} 0 & \cdots & a_{1n} \\ \vdots & \ddots & \vdots \\ a_{n1} & \cdots & 0 \end{bmatrix} \tag{3}$$

2) Creating normalized direct relation matrix: the direct relation matrix (A) is normalized using Equation (4). λ is calculated by applying Equation (5).

$$\tilde{E}= \lambda.A \tag{4}$$

$$\lambda = min\left\{\frac{1}{max\sum_{j=1}^{n}|a_{ij}|}, \frac{1}{max\sum_{j=1}^{n}|a_{ij}|}\right\} \tag{5}$$

The weight of each criterion is determined as based on its total effect on all other criteria. The total effect (r) of the criterion which has the greatest effect among the all criteria is used to determine the weight of this criterion (Equation (6)). In this way, *"0≤a_ij≤1"* condition is provided for all the elements of the matrix (Paksoy, 2017).

$$\tilde{E}_{ij} = \frac{\hat{z}_{ij}}{r} = \left(\frac{l_{ij}}{r}, \frac{m_{ij}}{r}, \frac{u_{ij}}{r}\right) \; ; \quad (6)$$

3) Creating the total relation matrix: after the normalized direct relation matrix is obtained, the total relation matrix $\tilde{Y}$ is calculated using Equation (7).

$$\tilde{Y} = \tilde{E}(I\text{-}\tilde{E})\text{-}1 \qquad (I: \text{Unit Matrix}) \quad (7)$$

4) Determining the degree of effectiveness and influence (Sender and Recipient Group) of the criteria: the row sums D_i and column sums R_i of the matrix $\tilde{Y}$ expressing the total relationship matrix, D_i refers to the total degree of influence of i criteria on other criteria. R_i value refers to the degree of *j*. criterion is affected by other criteria (Chen and Chen, 2010). After D_j and R_i are obtained, D_j+R_i and D_j-R_i values are calculated. According to these calculations, the D_j+R_i value expresses the sum of received and sent effects and indicates the degree of influence of the i criterion in the system (Gök and Perçin, 2016). Information on the relationship direction between the criteria is obtained by using the D_j-R_i indicator (Liou et al., 2007; Tzeng et al., 2007; Chen and Chen, 2010; Paksoy, 2017).

5) Clarification: since the values found were still consisted of triangular fuzzy numbers, they contained three values. The clarification method is applied to convert these into one single value. The clarification is calculated using Equation (8) (Organ, 2013; Ocampo et al., 2018).

$$\tilde{Y}_{ij} = 1/4 \; (l_{ij} + 2m_{ij} + u_{ij}) \quad (8)$$

6) Drawing the cause-result graphic: finally, a threshold value is identified by the experts group. The threshold value (α) may be used to exclude the minor effects from the evaluation (Kashi, 2015). This process is essential to protect the criteria relation structure, which is the most important element. In this way, the confusion in the relation map is also eliminated (Chen and Chen, 2010); and the total relation matrix T is arranged as T_α while clarifying from insignificant effects (Paksoy, 2017; Liou et al., 2007).

3.2. Fuzzy ANP Method

Saaty (1996) proposed the Analytic Network Process (ANP) by improving the Analytic Hierarchy Process (AHP) to solve the interdependency problems. Generally, the decision-maker considers the intermittent evaluation to be more reliable than evaluation that includes definite values. There are many fuzzy ANP methods in the literature introduced by various researchers. In this study, the fuzzy ANP method developed by Ramik (2007) and proposed by Büyüközkan and Çifçi (2012) was used. The fuzzy ANP process steps are as follows.

1) Creating the paired comparison matrices: the dependencies between the criteria are determined through the fuzzy ANP. After these dependencies are identified, the paired comparison

matrix is created by making comparisons. A fuzzy scale is used when this matrix is created (Büyüközkan and Çifçi, 2012).

2) Calculating the weights: priority vectors are needed for each paired comparison matrix to complete the sub-matrices of various super matrices. The triangular fuzzy priorities are estimated when *k=1, 2, 3, … n* of the evaluation matrix ($\grave{w}_k$). The Logarithmic Least Squares method may be used to calculate these weights (Equation (9)) (Ramik, 2007; Büyüközkan and Çifçi, 2012) and it was also used in the present study.

$$\grave{w}_k = \left(w^l k;\ w^m k;\ w^u k\right),\ k = 1, 2, \ldots, n$$

$$w_k^s = \frac{\left(\prod_{i=1}^{n} a_{kj}^s\right)^{1/n}}{\sum_{i=1}^{n}\left(\prod_{i=1}^{n} a_{ij}^m\right)^{1/n}},\ s \in \{l, m, u\} \qquad (9)$$

For all *i* and *j*'s; $0<a\leq 1$, $i= 1, 2, \ldots, n$ and $j= 1, 2, \ldots, n$

3) Clarification of the weights: clarification is made using Equation (8)

4) Creation of super matrix: the weights obtained previous steps are placed in relevant places in the super matrix.

5) Normalizing the super matrix: the cell values in each column are divided by the sum of the related column within the context of normalization process (Ramik, 2007).

6) Calculating the limit matrix: to find the limit super matrix, the power of the normalized weighted super-matrix is raised until the column values that correspond to the same line becomes equal to each other; in other words, the matrix lines become stationary. The new matrix obtained in this way is called the limit super matrix (Saaty, 2008) and it is found at $(2n+1)^{th}$ power (Büyüközkan and Çifçi, 2012).

3.3. Fuzzy TOPSIS Method

There are various fuzzy TOPSIS approaches in the literature, which differ in terms of the calculation methods used. Although some studies preferred the triangular fuzzy numbers, other trapezoidal fuzzy numbers. In this study, the model proposed by Chen (2000) was used. Chen (2000) aimed to protect the values of the scores in the *[0-1]* range with the normalization technique he proposed (Değermenci and Ayvaz, 2016). Fuzzy TOPSIS steps are listed and described below.

1) Comparison of the criteria according to the alternatives: in this step, the criteria are compared by using fuzzy scale. The matrix *D* obtained for *m* criterion and *n* alternative is as follows (Equation (10)):

$$D = \begin{bmatrix} x_{11} & \cdots & x_{1n} \\ \vdots & \ddots & \vdots \\ x_{m1} & \cdots & x_{mn} \end{bmatrix} \qquad (10)$$

2) Normalizing the decision matrix: the following equations are used for normalizing the decision matrix ($\hat{R}$) using Equation (11).

$$\hat{R} = [r_{ij}]_{m*n} \quad ; i = 1, 2, \ldots, m; \quad j = 1, 2, \ldots, n; \tag{11}$$

$$r_{ij} = \left(\frac{a_{ij}}{c_j^+} + \frac{b_{ij}}{c_j^+} + \frac{c_{ij}}{c_j^+}\right) \qquad ; c_j = max\ c_{ij} \tag{12}$$

$$r_{ij} = \left(\frac{a_j^-}{c_{ij}} + \frac{a_j^-}{b_{ij}} + \frac{a_j^-}{c_{ij}}\right) \qquad ; a_j = min\ a_{ij} \tag{13}$$

According to the approach proposed by Chen (2000), if it is desired that the fuzzy decision matrix is in benefits' direction (i.e. the corresponding criterion is high) each value in the column is divided by the maximum value (Equation 12). Conversely, if it is desired that the relevant criterion in the fuzzy decision matrix is cost-oriented (i.e. low), then, the minimum value is found in each column and each value in the column is divided by the minimum value (Equation 13).

3) Crating the weighted decision matrix: after the normalized matrix obtained, the weighted standard (normalized) matrix ($\tilde{Y}_{ij}$) is created by multiplying each value by the weights using Equation (14). If the weights of the criteria is wi, and the normalized matrix is rij, the weighted decision matrix is found as follows;

$$\tilde{Y}_{ij} = w_i\ x\ r_{ij} \quad ; \quad i = 1, 2, \ldots, m; \quad j = 1, 2, \ldots, n; \tag{14}$$

4) Calculating the fuzzy positive ideal solution and negative ideal solution points: after the weighted decision matrix is created, the distances to the fuzzy positive ideal solution and the negative ideal solution points (A^+, A^-) are calculated using Equation (15) and Equation (16).

$$A^+ = (y_1^+, y_2^+, \ldots, y_n^+) \tag{15}$$

$$A^- = (y_1^-, y_2^-, \ldots, y_n^-) \tag{16}$$

$$y_j^+ = (1,1,1) \ \ and \ \ y_j^- = (0,0,0)$$

5) Calculation of distances: after A^+ and A^- are obtained, the distances (D_J^+, D_J^-) are calculated using Equation (17), Equation (18) and Equation (19).

$$D_J^+ = \sum_{j=1}^{m} d(y_{ij}, y_i^+), j = 1, 2, \ldots, n \tag{17}$$

$$D_J^- = \sum_{j=1}^{m} d(y_{ij}, y_i^-), j = 1, 2, \ldots, n \tag{18}$$

$$d(m,n) = \sqrt{\frac{1}{3}(m_1 - n_1)^2 + (m_2 - n_2)^2 + (m_3 - n_3)^2} \tag{19}$$

6) Ranking the alternatives: after the distances are calculated, the ranking of the alternatives are made using Equation (20). The distance C_i^+ is calculated in relation to the ideal solution (Equation (20)).

$$C_i^+ = \frac{d_i^-}{d_i^- + d_i^+} \qquad 0 \leq C_i^+ \leq 1 \tag{20}$$

The C_i^+ value shows the value of the alternative. The alternative with maximum C_i^+ value is preferred. $C_i^+ = 1$ shows the proximity of the relevant alternative to the ideal solution, and $C_i^+ = 0$ shows the distance of the alternative to the ideal solution.

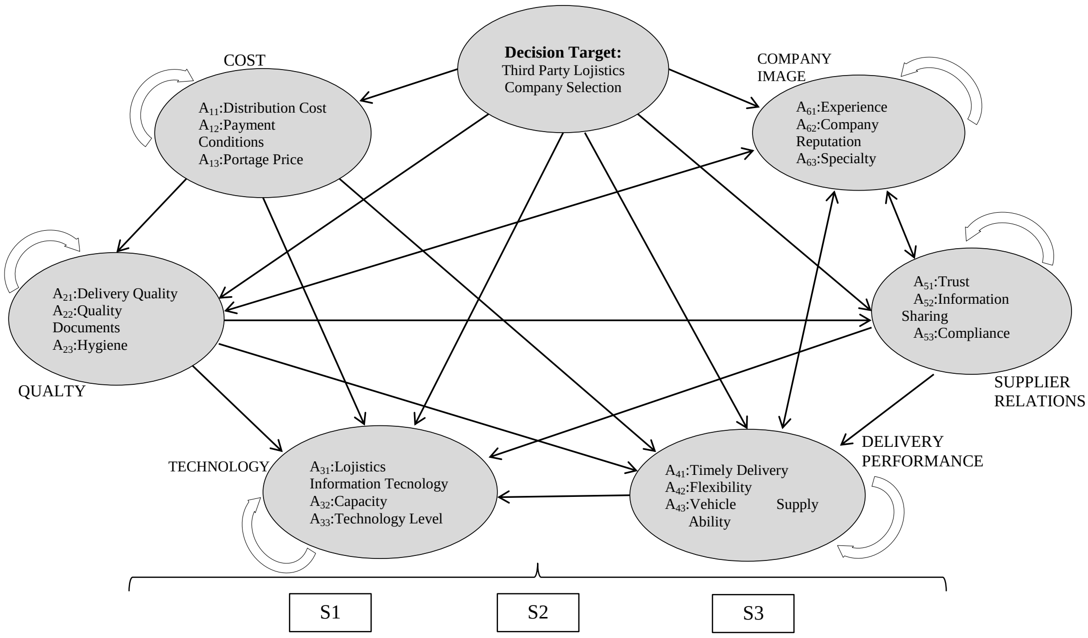
3.4. Data Analysis and Procedure

In this study, a comprehensive literature review and field research was conducted in order to determine the criteria concerning the 3PL provider selection and/or evaluation process. As a result of making detailed assessments and obtaining expert opinions , the most prominent criteria for 3PL firm selection in the food sector were determined consequently six main criteria, eighteen sub-criteria and three alternative logistics companies were included in this study. Table 2 shows the main and sub criteria. Then, a decision network (Figure 1) was formed with the expert group.

Table 2. 3PL Company Selection Criteria in the Food Sector

Main Criteria	Sub-Criteria
COST (A_1)	Transport cost (A_{11}) Payment conditions (A_{12}) Portage price (A_{13})
QUALITY (A_2)	Delivery quality (A_{21}) Quality certificates (A_{22}) Hygiene (A_{23})
TECHNOLOGY (A_3)	Logistics information technology (A_{31}) Capacity (A_{32}) Technology level (A_{33})
DELIVERY PERFORMANCE (A_4)	Timely delivery (A_{41}) Flexibility (A_{42}) Vehicle supply ability (A_{43})
SUPPLIER RELATIONS (A_5)	Trust (A_{51}) Information sharing(A_{52}) Compliance (A_{53})
COMPANY IMAGE (A_6)	Experience (A_{61}) Company reputation (A_{62}) Specialty (A_{63})

Figure 1. Third-Party Logistics Company Selection Decision Network



In order to measure the relations among the criteria, a fuzzy evaluation scale was used (Chen, 2000). Table 3 shows the fuzzy evaluation scale.

Table 3. Fuzzy Evaluation Scale

Linguistic Expressions	**Fuzzy Scale**
None	(0; 0; 1)
Almost none	(0; 0,1; 0,2)
Low	(0,1; 0,2; 0,3)
Extremely low	(0,2; 0,3; 0,4)
Tolerable/moderate	(0,3; 0,4; 0,5)
Moderate	(0,4; 0,5; 0,6)
A little above average	(0,5; 0,6; 0,7)
Good at Acceptable Level	(0,6; 0,7; 0,8)
Good	(0,7; 0,8; 0,9)
Very good	(0,8; 0,9; 1)
Perfect	(0,9; 1; 1)

Source: (Chen, 2000)

The most commonly used fuzzy number set in the literature is the triangular fuzzy number set because of ease of calculation (Chen, 2000; Büyüközkan and Çifçi, 2012; Kang et al., 2012; Kuo, et al., 2015; Hwang and Shen, 2015). In this study, the triangular fuzzy number set was also preferred due to its simplicity. The triangular fuzzy number set may be represented as (l, m, u). Here; l, m and u parameters represent the smallest possible number defining a fuzzy event, the most appropriate value, and the largest possible number, respectively.

4. RESULTS

While applying the steps of three methods and analyzing the data the Microsoft Excel and the MATLAB softwares were used.

4.1. Fuzzy DEMATEL

The interactions between the criteria, and their internal dependencies were identified using the fuzzy DEMATEL method. The findings are as follows:

Creating and normalizing the direct relation matrix: this matrix was organized separately for the main criteria and sub-criteria. Then, it was normalized by using Equation (4). Table 4 shows the normalized direct relation matrix.

Table 4. Normalized Direct Relation Matrix

	A_1	**A_2**	**A_3**	**A_4**	**A_5**	**A_6**
A_1	0,00;0,00; 0,00	0,05 ; 0,08 ; 0,15	0,00 ; 0,00 ; 0,03	0,00 ; 0,00 ; 0,03	0,00 ; 0,00 ; 0,03	0,05 ; 0,08 ; 0,11
A_2	0,21; 0,24 ; 0,26	0,00 ; 0,00 ; 0,00	0,00 ; 0,00 ; 0,03	0,08 ; 0,11 ; 0,26	0,03 ; 0,05 ; 0,08	0,24 ; 0,26 ; 0,26
A_3	0,11 ; 0,13 ; 0,16	0,21 ; 0,24 ; 0,23	0,00 ; 0,00 ; 0,00	0,24 ; 0,26 ; 0,38	0,00 ; 0,03 ; 0,05	0,21 ; 0,24 ; 0,26
A_4	0,00 ; 0,03 ; 0,05	0,18 ; 0,21 ; 0,24	0,00 ; 0,00 ; 0,03	0,00 ; 0,00 ; 0,00	0,21 ; 0,24 ; 0,26	0,24 ; 0,26 ; 0,26
A_5	0,00 ; 0,00 ; 0,03	0,00 ; 0,03 ; 0,05	0,00 ; 0,00 ; 0,03	0,00 ; 0,00 ; 0,03	0,00 ; 0,00 ; 0,00	0,11 ; 0,13 ; 0,16
A_6	0,00 ; 0,00 ; 0,03	0,00 ; 0,00 ; 0,03	0,00 ; 0,00 ; 0,03	0,00 ; 0,00 ; 0,03	0,00 ; 0,03 ; 0,05	0,00 ; 0,00 ; 0,00

Creating total relation matrix: total relation matrix was created using Equation (7). Table 5 shows the total relation matrix.

Table 5. Total Relation Matrix [$X(I\text{-}X)^{-1}$]

	A_1	**A_2**	**A_3**	**A_4**	**A_5**	**A_6**
A_1	0,01 ; 0,02 ; 0,05	0,05; 0,08; 0,15	0,00 ; 0,00 ; 0,04	0,00 ; 0,01 ; 0,06	0,00 ; 0,01 ; 0,07	0,07 ; 0,11 ; 0,19
A_2	0,22 ; 0,25 ; 0,33	0,03; 0,05; 0,11	0,00 ; 0,00 ; 0,06	0,08 ; 0,11 ; 0,19	0,04 ; 0,09 ; 0,17	0,28 ; 0,35 ; 0,42
A_3	0,16 ; 0,22 ; 0,32	0,27 ; 0,32 ; 0,42	0,00 ; 0,00 ; 0,05	0,26 ; 0,30 ; 0,36	0,06 ; 0,12 ; 0,22	0,35 ; 0,43 ; 0,55
A_4	0,04 ; 0,08 ; 0,17	0,19 ; 0,23 ; 0,32	0,00 ; 0,00 ; 0,06	0,01 ; 0,02 ; 0,08	0,22 ; 0,26 ; 0,34	0,31 ; 0,37 ; 0,46
A_5	0,00 ; 0,01 ; 0,07	0,00 ; 0,03 ; 0,09	0,00 ; 0,00 ; 0,04	0,00 ; 0,00 ; 0,06	0,00 ; 0,01 ; 0,04	0,11 ; 0,14 ; 0,22
A_6	0,00 ; 0,00 ; 0,05	0,00 ; 0,00 ; 0,06	0,00 ; 0,00 ; 0,03	0,00 ; 0,00 ; 0,05	0,00 ; 0,03 ; 0,08	0,00 ; 0,00 ; 0,05

Clarification was made according to Equation (8) to interpret the Total Relation Matrix. Clarified total relation matrix is given in Table 6.

Table 6. Clarified Total Relation Matrix

	A_1	A_2	A_3	A_4	A_5	A_6
A_1	0,03	0,09	0,01	0,02	0,02	0,12
A_2	0,26	0,06	0,01	0,12	0,10	0,34
A_3	0,23	0,33	0,01	0,30	0,13	0,44
A_4	0,09	0,24	0,02	0,04	0,27	0,38
A_5	0,02	0,04	0,01	0,02	0,01	0,15
A_6	0,01	0,01	0,01	0,01	0,03	0,02

When the effect values in Table 6 are considered, the criteria that have the highest effect values are A_3 (technology) with a value of 0,44; A_4 (delivery performance) with a value of 0,38; and A_2 (quality) with a value of 0,34 on the A_6 (company image) criterion. At this point, it is seen that the most affected criterion by the other criteria is the company image.

According to Table 6, the criterion that affected the other criteria was the A_3 (technology). Technology (A_3) was followed by company image (A_6: 0,44), quality (A_2: 0,33), delivery performance (A_4: 0,30), cost (A_1: 0,23) and supplier relations (A_5: 0,13). Another interesting point in the table is that although the company image (A_6) criterion was the most affected criterion, it was the criterion that had the least effect on other criteria.

4.2. Fuzzy ANP

The results that were obtained applying the fuzzy DEMATEL were then integrated into the fuzzy ANP. The relevant steps are as follows:

Creating the paired comparison matrix: an example is given in Table 7. Table 7 includes the evaluation of the effect of timely delivery, flexibility and vehicle supply ability on the distribution cost element.

Table 7. Paired Comparison Matrix

	A_{41}	A_{42}	A_{43}
A_{41}	1,00; 1,00; 1,00	0,5; 0,6; 0,7	0,6; 0,7; 0,8
A_{42}	1,43; 1,67; 2,00	1,0; 1,0; 1,0	2,0; 2,5; 3,33
A_{43}	1,25; 1,43; 1,67	0,3; 0,4; 0,5	1,0; 1,0; 1,0

Determining the weights: the least squares method was used to calculate the weights according to Equation (9). When the weight values of the elements are examined in Table 8, it is seen that the highest value is 0,774 belongs to vehicle supply ability (A_{43}) criterion. It is also seen that the weight values of flexibility (A_{42}: 0,167) and timely delivery (A_{41}: 0,119) are close to each other. In this case, it may be argued that the most effective factor among the sub-criteria of delivery performance criteria for distribution cost is vehicle supply ability.

Table 8. Weights of the Effect of Timely Delivery (A_{41}), Flexibility (A_{42}) and Vehicle Supply Ability (A_{43}) on Delivery Cost (A_{41})

Criterion	Denominator	Share			Share/Denominator			Clarification
		l	m	u	l	M	u	
A_{41}	0,4932	0,3684	0,4932	0,5944	0,0896	0,1200	0,1446	0,119
A_{42}	0,6934	0,5228	0,6934	0,8434	0,1272	0,1687	0,2052	0,167
A_{43}	2,9240	2,2314	2,9240	4,6416	0,5428	0,7113	1,1292	0,774
Total	4,1106							

Creating unweighted (initial) super matrix: the unweighted super matrix includes internal and external effects between sets and between elements. Super matrix was created by integrating internal dependencies that were obtained via Fuzzy DEMATEL. Table 9 shows the unweighted (initial) super matrix.

Table 9. Weightless (Initial) Super Matrix

		Cost			Quality			Technology			Delivery performance			Supplier relations			Company image		
		A_{11}	**A_{12}**	**A_{13}**	**A_{21}**	**A_{22}**	**A_{23}**	**A_{31}**	**A_{32}**	**A_{33}**	**A_{41}**	**A_{42}**	**A_{43}**	**A_{51}**	**A_{52}**	**A_{53}**	**A_{61}**	**A_{62}**	**A_{63}**
Cost	**A_{11}**	0,410	0,523	0,532	0,000	0,000	0,000	0,000	0,000	0,000	1,000	0,000	0,000	0,000	0,000	0,000	0,000	1,000	0,000
	A_{12}	0,106	0,087	0,095	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	1,000	1,000	0,000	0,000	0,000
	A_{13}	0,485	0,390	0,374	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
Quality	**A_{21}**	1,000	0,000	0,000	0,111	0,309	0,251	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	1,000	0,000
	A_{22}	0,000	0,000	0,000	0,248	0,107	0,392	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
	A_{23}	0,000	0,000	0,000	0,641	0,584	0,357	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
Technology	**A_{31}**	0,000	0,000	0,000	0,000	0,320	0,000	0,039	0,287	0,331	0,229	0,000	0,000	0,000	1,000	0,000	0,000	0,000	0,000
	A_{32}	0,374	0,000	0,000	0,000	0,372	0,000	0,046	0,026	0,257	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
	A_{33}	0,628	0,000	0,000	0,000	0,310	0,000	0,914	0,687	0,412	0,787	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
Delivery Perform.	**A_{41}**	0,119	0,000	0,000	0,309	0,282	0,000	0,000	0,000	0,000	0,021	0,030	0,032	0,151	0,000	0,000	0,000	0,332	0,000
	A_{42}	0,167	0,000	0,000	0,305	0,314	0,000	0,000	0,000	0,000	0,443	0,360	0,588	0,241	0,000	0,411	0,000	0,672	0,000
	A_{43}	0,774	0,000	0,000	0,388	0,407	0,000	0,000	1,000	0,000	0,536	0,610	0,380	0,634	0,000	0,591	0,000	0,000	0,000
Supp. Relations	**A_{51}**	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,320	0,496	0,401	0,000	0,295	0,000
	A_{52}	0,000	0,000	0,000	0,229	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,632	0,450	0,558	0,000	0,300	0,000
	A_{53}	0,000	0,000	0,000	0,787	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,048	0,054	0,041	0,000	0,407	0,000

Company image	**A61**	0,000	0,000	0,000	0,285	0,000	0,672	0,000	0,000	0,000	0,000	0,000	0,332	0,461	0,000	0,000	0,377	0,475	0,526
	A62	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	1,000	1,000	0,672	0,254	0,000	0,000	0,045	0,038	0,047
	A63	0,000	0,000	0,000	0,723	0,000	0,332	1,000	1,000	1,000	0,000	0,000	0,000	0,289	0,000	0,000	0,578	0,487	0,428
	Total	4,062	1,000	1,000	4,025	3,004	2,004	2,000	3,000	2,000	4,016	2,000	2,004	3,030	3,000	3,002	1,000	5,007	1,000

Normalizing super matrix: the normalizing matrix was obtained by dividing the cell values in each column by the total of the corresponding column.

Table 10. Normalizing Super Matrix

	A11	**A12**	**A13**	**A21**	**A22**	**A23**	**A31**	**A32**	**A33**	**A41**	**A42**	**A43**	**A51**	**A52**	**A53**	**A61**	**A62**	**A63**
A11	0,101	0,523	0,532	0,000	0,000	0,000	0,000	0,000	0,000	0,249	0,000	0,000	0,000	0,000	0,000	0,000	0,200	0,000
A12	0,026	0,087	0,095	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,333	0,333	0,000	0,000	0,000
A13	0,119	0,390	0,374	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
A21	0,246	0,000	0,000	0,027	0,103	0,125	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,200	0,000
A22	0,000	0,000	0,000	0,062	0,036	0,196	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
A23	0,000	0,000	0,000	0,159	0,194	0,178	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
A31	0,000	0,000	0,000	0,000	0,106	0,000	0,020	0,096	0,165	0,057	0,000	0,000	0,000	0,333	0,000	0,000	0,000	0,000
A32	0,092	0,000	0,000	0,000	0,124	0,000	0,023	0,009	0,129	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
A33	0,155	0,000	0,000	0,000	0,103	0,000	0,457	0,229	0,206	0,196	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
A41	0,029	0,000	0,000	0,077	0,094	0,000	0,000	0,000	0,000	0,005	0,015	0,016	0,050	0,000	0,000	0,000	0,066	0,000
A42	0,041	0,000	0,000	0,076	0,104	0,000	0,000	0,000	0,000	0,110	0,180	0,293	0,080	0,000	0,137	0,000	0,134	0,000
A43	0,190	0,000	0,000	0,096	0,135	0,000	0,000	0,333	0,000	0,134	0,305	0,190	0,209	0,000	0,197	0,000	0,000	0,000
A51	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,106	0,165	0,134	0,000	0,059	0,000
A52	0,000	0,000	0,000	0,057	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,209	0,150	0,186	0,000	0,060	0,000
A53	0,000	0,000	0,000	0,195	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,016	0,018	0,014	0,000	0,081	0,000
A61	0,000	0,000	0,000	0,071	0,000	0,335	0,000	0,000	0,000	0,000	0,000	0,166	0,152	0,000	0,000	0,377	0,095	0,526
A62	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,249	0,500	0,335	0,084	0,000	0,000	0,045	0,008	0,047
A63	0,000	0,000	0,000	0,180	0,000	0,166	0,500	0,333	0,500	0,000	0,000	0,000	0,095	0,000	0,000	0,578	0,097	0,428

Creating limit super matrix: the limit matrix (Table 11) was obtained for the main criteria at the 9th power; and at the 47th power for the sub-criteria.

Table 11. Limit Super Matrix

A11	0,026	0,026	0,026	0,026	0,026	0,026	0,026	0,026	0,026	0,026	0,026	0,026	0,026	0,026	0,026	0,026	0,026	0,026
A12	0,008	0,008	0,008	0,008	0,008	0,008	0,008	0,008	0,008	0,008	0,008	0,008	0,008	0,008	0,008	0,008	0,008	0,008
A13	0,010	0,010	0,010	0,010	0,010	0,010	0,010	0,010	0,010	0,010	0,010	0,010	0,010	0,010	0,010	0,010	0,010	0,010
A21	0,020	0,020	0,020	0,020	0,020	0,020	0,020	0,020	0,020	0,020	0,020	0,020	0,020	0,020	0,020	0,020	0,020	0,020
A22	0,002	0,002	0,002	0,002	0,002	0,002	0,002	0,002	0,002	0,002	0,002	0,002	0,002	0,002	0,002	0,002	0,002	0,002
A23	0,004	0,004	0,004	0,004	0,004	0,004	0,004	0,004	0,004	0,004	0,004	0,004	0,004	0,004	0,004	0,004	0,004	0,004
A31	0,006	0,006	0,006	0,006	0,006	0,006	0,006	0,006	0,006	0,006	0,006	0,006	0,006	0,006	0,006	0,006	0,006	0,006
A32	0,004	0,004	0,004	0,004	0,004	0,004	0,004	0,004	0,004	0,004	0,004	0,004	0,004	0,004	0,004	0,004	0,004	0,004

A_{33}	0,012	0,012	0,012	0,012	0,012	0,012	0,012	0,012	0,012	0,012	0,012	0,012	0,012	0,012	0,012	0,012	0,012	0,012
A_{41}	0,008	0,008	0,008	0,008	0,008	0,008	0,008	0,008	0,008	0,008	0,008	0,008	0,008	0,008	0,008	0,008	0,008	0,008
A_{42}	0,025	0,025	0,025	0,025	0,025	0,025	0,025	0,025	0,025	0,025	0,025	0,025	0,025	0,025	0,025	0,025	0,025	0,025
A_{43}	0,026	0,026	0,026	0,026	0,026	0,026	0,026	0,026	0,026	0,026	0,026	0,026	0,026	0,026	0,026	0,026	0,026	0,026
A_{51}	0,007	0,007	0,007	0,007	0,007	0,007	0,007	0,007	0,007	0,007	0,007	0,007	0,007	0,007	0,007	0,007	0,007	0,007
A_{52}	0,009	0,009	0,009	0,009	0,009	0,009	0,009	0,009	0,009	0,009	0,009	0,009	0,009	0,009	0,009	0,009	0,009	0,009
A_{53}	0,009	0,009	0,009	0,009	0,009	0,009	0,009	0,009	0,009	0,009	0,009	0,009	0,009	0,009	0,009	0,009	0,009	0,009
A_{61}	0,362	0,362	0,362	0,362	0,362	0,362	0,362	0,362	0,362	0,362	0,362	0,362	0,362	0,362	0,362	0,362	0,362	0,362
A_{62}	0,059	0,059	0,059	0,059	0,059	0,059	0,059	0,059	0,059	0,059	0,059	0,059	0,059	0,059	0,059	0,059	0,059	0,059
A_{63}	0,403	0,403	0,403	0,403	0,403	0,403	0,403	0,403	0,403	0,403	0,403	0,403	0,403	0,403	0,403	0,403	0,403	0,403

According to the weight values that were obtained with the limit matrix (Table 11), the criterion with the highest weight value for the sub-criteria is specialty (A_{63}). The criteria that interact at the highest level with other criteria are the company reputation and specialty criteria. They are the sub-criteria of company image main criterion. Right at this point, it was seen that the results obtained from the fuzzy DEMATEL and the limit matrix were similar. For this reason, the criterion that is highly affected by other criteria directly or indirectly is the company image.

4.3. Fuzzy TOPSIS

Finally the fuzzy TOPSIS method is applied. Its steps are as follows:

Creating fuzzy decision matrix: fuzzy decision matrix was created by using Equation (10). While making interviews with the experts, three logistics companies were evaluated separately according to each criterion. The evaluations and analyzes made separately for the main criteria and sub-criteria are shown in Table 12 and Table 13, respectively.

Normalizing fuzzy decision matrix: the normalization process for fuzzy decision matrix was made using Equation (11) (Chen, 2000).

Table 12. Main Criteria Fuzzy Decision Matrix

	A_1	**A_2**	**A_3**	**A_4**	**A_5**	**A_6**
S_1	0,5; 0,6; 0,7	0,6; 0,7; 0,8	0,6; 0,7; 0,8	0,6; 0,7; 0,8	0,7; 0,8; 0,9	0,6; 0,7; 0,8
S_2	0,8; 0,9; 1	0,8; 0,9; 1	0,8; 0,9; 1	0,8; 0,9; 1	0,7; 0,8; 0,9	0,9; 1; 1
S_3	0,6; 0,7; 0,8	0,7; 0,8; 0,9	0,6; 0,7; 0,8	0,6; 0,7; 0,8	0,7; 0,8; 0,9	0,7; 0,8; 0,9
Max/Min	0,5	1,0	1,0	1,0	0,9	1,0

Table 13. Sub-Criteria Fuzzy Decision Matrix

	A_{11}	A_{12}	A_{13}	A_{21}	A_{22}	A_{23}	A_{31}	A_{32}	A_{33}	A_{41}	A_{42}	A_{43}	A_{51}	A_{52}	A_{53}	A_{61}	A_{62}	A_{63}
S_1	0,5; 0,6; 0,7	0,5; 0,6; 0,7	0,5; 0,6; 0,7	0,7; 0,8; 0,9	0,7; 0,8; 0,9	0,6; 0,7; 0,8	0,7; 0,8; 0,9	0,7; 0,8; 0,9	0,6; 0,7; 0,8	0,6; 0,7; 0,8	0,5; 0,6; 0,7	0,6; 0,7; 0,8	0,7; 0,8; 0,9	0,7; 0,8; 0,9	0,6; 0,7; 0,8	0,6; 0,7; 0,8	0,7; 0,8; 0,9	0,8; 0,9; 1,0
S_2	0,7; 0,8; 0,9	0,7; 0,8; 0,9	0,7; 0,8; 0,9	0,9; 1,0; 1,0	0,7; 0,8; 0,9	0,8; 0,9; 1,0	0,8; 0,9; 1,0	0,7; 0,8; 0,9	0,8; 0,9; 1,0	0,7; 0,8; 0,9	0,7; 0,8; 0,9	0,9; 1,0; 1,0	0,7; 0,8; 0,9	0,7; 0,8; 0,9	0,8; 0,9; 1,0	0,9; 1,0; 1,0	0,9; 1,0; 1,0	0,8; 0,9; 1,0
S_3	0,7; 0,8; 0,9	0,6; 0,7; 0,8	0,6; 0,7; 0,8	0,7; 0,8; 0,9	0,7; 0,8; 0,9	0,7; 0,8; 0,9	0,7; 0,8; 0,9	0,7; 0,8; 0,9	0,7; 0,8; 0,9	0,6; 0,7; 0,8	0,5; 0,6; 0,7	0,6; 0,7; 0,8	0,7; 0,8; 0,9	0,7; 0,8; 0,9	0,7; 0,8; 0,9	0,7; 0,8; 0,9	0,7; 0,8; 0,9	0,8; 0,9; 1,0
Max / Min	0,5	0,5	0,5	1,0	0,9	1,0	1,0	0,9	1,0	0,9	0,9	1,0	0,9	0,9	1,0	1,0	1,0	1,0

Creating weighted standardized (normalized) decision matrix: to create the weighted standardized decision matrix, firstly, the weight values of the criteria must be obtained (Equation 14). The weight values were previously obtained using the Fuzzy ANP and Table 14 shows these weights.

Table 14. Weight Values of the Main and Sub-Criteria

Main criteria	W_i	Direction	Sub-criteria	W_i	Direction
Cost	0,094	N	A_{11}	0,026	N
			A_{12}	0,008	N
			A_{13}	0,010	N
Quality	0,205	P	A_{21}	0,020	P
			A_{22}	0,002	P
			A_{23}	0,004	P
Technology	0,348	N	A_{31}	0,006	P
			A_{32}	0,004	P
			A_{33}	0,012	P
Delivery performance	0,222	P	A_{41}	0,008	P
			A_{42}	0,025	P
			A_{43}	0,026	P
Supplier relations	0,075	N	A_{51}	0,007	P
			A_{52}	0,009	P
			A_{53}	0,009	P
Company image	0,058	P	A_{61}	0,362	P
			A_{62}	0,059	P
			A_{63}	0,403	P
Total	1,000		Total	1,000	

Creating the positive ideal and negative ideal solution points: after weighted normalized matrix was obtained, the direction of each criterion was determined according to the property of each criterion and the weights in Table 14.

Calculating the distance to the positive and negative ideal points: after determining the positive and negative ideal solution points, the distances to the fuzzy positive and negative ideal point are identified (Equation 15 and 16).

Calculating the distance according to the ideal solution and selecting the alternatives: this process is applied for each alternative. Then, the ideal solution distances are found using Equation 17 and 18. According to Table 15, Company S2 received the highest value of 0,2892. In this respect, the firm should prefer S_2. In Table 16, when an evaluation is made according to the sub-criteria, again, S_2 is the first company to be preferred with the value of 0,2078.

Table 15. Distance of the Main Criteria According to Ideal Solution and Ranking of the Alternatives

D_i^+		D_i^-		C_i^*		Ranking	
S_1^+	4,4730	S_1^-	1,5472	C_1^*	0,2570	S_1	3
S_2^+	4,2819	S_2^-	1,7420	C_2^*	0,2892	S_2	1
S_3^+	4,4281	S_3^-	1,5933	C_3^*	0,2646	S_3	2

Table 16. Distance of the Sub-Criteria According to Ideal Solution and Ranking of the Alternatives

D_i^+		D_i^-		C_i^*		Ranking	
S_1^+	14,5520	S_1^-	3,5817	C_1^*	0,1975	S_1	3
S_2^+	14,3748	S_2^-	3,7697	C_2^*	0,2078	S_2	1
S_3^+	14,4958	S_3^-	3,6348	C_3^*	0,2005	S_3	2

According to the main criteria and the sub-criteria, the S2 Company ranked the first with only a slight difference compared to the other two companies. It was seen that the difference between the alternatives in terms of sub-criteria was less when compared with the main criteria. The difference in this case shows that the factors, which are important in the logistics company selection, were considered while the effect of some factors was not considered. However, it is made sure that all important criteria that may affect the evaluation are taken into consideration when the evaluation is made according to the sub-criteria. For this reason, it may be stated that the company which seems to be not advantageous according to some main criteria has in fact some advantageous sub-factors.

5. DISCUSSION AND CONCLUSIONS

The purpose of the present study was to create a mixed evaluation model by integrating fuzzy MCDM methods to help the decision-making process of businesses during 3PL provider company selection. The criteria were weighted and/or evaluated using the fuzzy DEMATEL and fuzzy ANP methods, and selection of alternative 3PL providers was made via the fuzzy TOPSIS method.

According to the findings obtained through the fuzzy DEMATEL method, the most affecting and the most affected criterions among the main criteria were found as technology and firm image, respectively. However, while firm image was found as the most affected criterion, it was also the criterion that had the lowest effect on the other criteria. Therefore, it can be stated that each factor in the logistics firms' activities implicitly or explicitly, positively or negatively affects the firm image. Moreover, the most affecting criteria among the sub-criteria were found as distribution cost, hygiene, technology level and vehicle supply ability. This result indicates that the 3PL firms can take competitive advantage by considering these factors. In this study, in addition to the aforementioned issues; three new criteria which were not encountered in the literature before, were determined: porterage price, hygiene and the ability to supply vehicles. It is possible to say that hygiene and ability to supply vehicles have important potential effects.

The weights obtained by integrated methods of fuzzy DEMATEL and fuzzy ANP were used in the fuzzy TOPSIS method and a selection was made among the alternatives. The second logistics firm was selected as the most suitable one according to the food company and this result was supported by both the main and the sub criteria.

For an enterprise producing milk and dairy products in the food sector, it was determined that the importance order of the criteria as a result of the integrated model was special expertise, experience and company reputation, respectively. According to this result, it is suggested that the relevant company should first set two prerequisites for the selection of a logistics company. These prerequisites are; to operate only in the food sector and to have a minimum duration of the activity. With this proposal, it is aimed to pay attention to special expertise with the prerequisite of operating only in the food sector, and pay attention to experience with the prerequisite of minimum activity period. Therefore, the company will have the opportunity to evaluate the expert and stronger third-party logistics companies. Since the cold chain should not be broken in the food sector, third-party logistics companies that provide services in this field may be recommended to go to special expertise. It is thought that special expertise will increase the trust in logistics companies, which have an important place in the supply chain. Specialization of logistics companies in a certain area will enable them to gain experience and manage the risk better in this area.

When similar studies conducted on 3PL selection in the cold chain in the food sector are considered, Rijswijk and Frewer (2008) reported that traceability was an important criterion for food safety and quality. About the traceability problem, Montanari (2008) reported the need for reliable information technology infrastructure for the cold-chain. Moberg and Speh (2004) reported that responding to service requirements, management quality, registry with ethical importance, and ability to provide value-added services were the 4 most important criteria for the selection of 3PL. Özçakar and Demir (2011) ranked the criteria as the cost advantage, flexibility, payment terms, quality, supplier reliability and timely delivery from the largest to the smallest. Similar to the studies that are mentioned in the present study, experience, specialty, timely delivery, flexibility, quality, reliability and information technology criteria are the leading criteria. However, as a different item, criteria like vehicle supply ability, distribution cost, company image, technology level, and information sharing criteria were also determined among the most weighted criteria.

As it is the case in any study, the present study also had some limitations. Firstly, the fact that the present study was conducted in only one company operating in the food sector was one of the limitations of it. Secondly, it may not be accepted as a correct approach to generalize the findings of the study, which was conducted on a small sampling, to all business and logistics companies in the food sector.

In this study, the 3PL provider selection in food industry, and determination of relevant evaluation criteria were dealt with. It may be recommended to researchers to conduct future studies on making comparisons or integrations in businesses that operate with different products in the food sector. In addition, the 3PL provider selection still expects different methods to be used. In the integration that was made in the present study, VIKOR, Electre, etc. methods may be used instead of fuzzy TOPSIS. Similar methods may be used by making comparisons without integration. Finally, it is hoped that conducting this kind of studies in different sectors may contribute greatly to the literature.

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