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AN INTEGRATED FUZZY AHP/DEA APPROACH FOR PERFORMANCE EVALUATION OF TERRITORIAL UNITS IN TURKEY

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Abstract. Due to the differences between regions and sub-regions in the countries, some problems come out especially in economic and social life. The issue of differences of regions has been widely implemented to evaluate the economic performance of Turkey in many disciplines. The objective of this paper is to evaluate the efficiency of 26 sub-regions of NUTS-2 classification using integration Fuzzy Analytic Hierarchy Process (FAHP) with Data Envelopment Analysis (DEA). The integrated FAHP/DEA method comprises two stages. In the first stage, linguistic terms are used to determine the decision makers' opinion and are converted to quantitative forms by using FAHP methods. Subsequently, in the second stage, DEA method is applied to obtain relative efficiency of sub-regions in Turkey. The integrated FAHP/DEA method is illustrated with a real case study.

Keywords: Fuzzy Analytic Hierarchy Process, Data Envelopment Analysis, NUTS-2 classification.

JEL Classification: D81, P48, C44, D70.

Introduction

In the 21st century, a major change, that affects every aspects of life, has taken place, this process is called globalization and it requires continuous renewal and variation due to the occurrence of transformations. As a result of globalization, innovations and developments have increased; furthermore, efficiency and productivity concepts have gained importance. Development differences between regions are one of the important problems that raise attention of the most researchers in the world. As well as, there are developed and less developed countries in the world; there are also regions that are developed and less developed, within those countries. Differences between these regions affect the country in every aspect and governments want to reduce the differences between those regions.

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In regards to economic and social criteria, Turkey has important differences between the regions. These differences among regions have lead into serious problems. For the industrial sector, the western provinces of the country are more effective than the middle and eastern provinces. Turkey has the world's 18th largest nominal Gross Domestic Product (GDP), and 17th largest GDP by Purchasing Power Parity (PPP). The country is a founding member of the Organization for Economic Co-operation and Development (OECD) and the G-20 major economies (Wikipedia 2014). Despite economic crises Turkey had, Turkey's economy has taken big steps towards being a reliable economy in the last decade. In 2010, the agricultural sector accounts for 9% of GDP, while the industrial sector accounts for 26% and the services sector accounts for 65% (CIA 2010).

The aim of this study is to propose an integrated FAHP/DEA method for the performance evaluation of the sub-regions in Turkey. The performance evaluation of the sub-regions is an essentially MCDM problem, which involves both qualitative and quantitative criteria. One of the MCDM approaches FAHP, can be used to evaluate both qualitative and quantitative criteria. However, if number of criteria and alternatives increase, decision makers cannot obtain consistent evaluations due to the large scale dimension of pairwise comparison matrices. To overcome these difficulties we integrated FAHP methods with DEA models. In addition, there is no study considering the performance evaluation of regions or sub-regions in Turkey. Most researchers have been focused on specific studies such as operational performance of the thermal power plant, performance of manufacturing firms, and evaluation of government investments in higher education and so on. To address this gap, we measure the performance evaluation of sub-regions in Turkey by integrated FAHP/DEA method.

The remainder of this study is organized as follows: Section 1 deals with an overview of the FAHP methods, DEA models and integrated FAHP-DEA method. Section 2 discusses the details of the proposed FAHP-DEA methodology. Section 3 shows a real case study that provides an application of the proposed FAHP/DEA method. Section 4 presents the conclusion of the study.

1. Literature review

Since the 1960s, Multi-Criteria Decision Making (MCDM) has been a popular decision-making tool including quantitative and qualitative criteria/factors. The MCDM methods divided into two main approaches: Multi Attribute Decision Making (MADM) methods and Multi Objective Decision Making (MODM) methods. MADM problems contain the finite set of alternatives, whereas MODM problems contain the infinite set of alternatives (Kahraman 2008). The MCDM method includes following stages: (1) determination of the alternatives/criteria, (2) evaluation of the alternatives according to the criteria, (3) an evaluation score of the alternatives on the criteria, and (4) determination of criteria weights (Thokala, Duenas 2012). Fuzzy MCDM methods have been used to assess alternatives according to the several criteria by decision maker(s). Therefore, fuzzy MCDM methods are a growing area that integrates MCDM methods and fuzzy sets. Various approaches have been proposed to solve MCDM and fuzzy MCDM problems (Celik *et al.* 2015; Kahraman *et al.* 2015). In recent years, many review articles have been published on methods of MCDM and fuzzy MCDM, such as Ho (2008), Zavadskas and Turskis (2011), Liou and Tzeng (2012), Zavadskas *et al.* (2014b), Mardani *et al.* (2015), Kahraman *et al.* (2015) and Celik *et al.* (2015). Several studies have carried out using the MCDM and fuzzy MCDM methods in different fields, construction (Brauers *et al.* 2013; Zavadskas *et al.* 2014a), energy (Abid, Bahloul 2011; Erol, Kılkış 2012), supplier selection (Govindan *et al.*2013; Shaw *et al.* 2012), management (Baležentis, A., Baležentis, T. 2011; Liu *et al.* 2012).

1.1. Fuzzy Analytic Hierarchy Process Method

Analytic Hierarchy Process (AHP) proposed by Saaty (1980) method is an extensively used MCDM method to help decision makers and researchers since 1980s (Vaidya, Kumar 2006). Although AHP method has been widely used, it cannot really reflect the human thinking. In real world problems, decision making process could be consisted of uncertain situations. To overcome uncertainties, fuzzy set theory is combined with AHP and several FAHP methods are proposed by various authors. The first study is proposed by Van Laarhoven and Pedrycz (1983) using triangular fuzzy numbers and logarithmic regression method. Buckley (1985) extended AHP with trapezoidal fuzzy numbers and used the geometric mean method to derive fuzzy weights. Chang (1996) presented extent analysis method by using triangular fuzzy numbers. Mikhailov (2002) presented fuzzy preference programming method which based on α-cuts decomposition of the fuzzy judgements. Mikhailov (2003) proposed a non-linear method that decision makers can find crisp values using triangular fuzzy numbers. Applications of FAHP methods in different fields can be found the literature, such as engineering (Akadiri *et al.* 2013; Pan 2008; Tansel İç *et al.* 2013), management and business (Durán 2011; Lin *et al.* 2009), science and technology (Gao, Hailu 2012; Najafi *et al.* 2014). In recent years, AHP methods and FAHP methods have been applied for many studies regarding to Turkey. Ecer (2014) proposed a hybrid approach based on AHP and COPRAS-G to assess the website quality of banks in Turkey. Taylan *et al.* (2014) presented a novel tool to evaluate the construction projects by by fuzzy AHP and fuzzy TOPSIS methodologies. Kahraman *et al.* (2013) used FAHP to take the criteria into account in government investment in higher education in Turkey. Baysal *et al.* (2015) evaluated the ranking of the nine sub-municipal projects in Konya, Turkey with FAHP. Deveci *et al.* (2015) compared the performance of fuzzy MCDM methods for solving the carbon dioxide geological storage location selection problem in Turkey.

1.2. Data Envelopment Analysis Method

Data envelopment analysis (DEA) initially proposed by Charnes *et al.* (1978) and Banker *et al.* (1984) is a linear programming approach to obtain the relative efficiencies of decision making units (DMUs). DEA methods have been extensively used for many disciplines in operational research and decision making problems: Shafer and Byrd (2000) measured the relative efficiency of organizational investments in information technology, Camanho and Dyson (2005) and Chen *et al.* (2005) investigated the bank efficiency, Johnes (2006) and Nazarko and Šaparauskas (2014) evaluated the efficiency of higher education institutions, Ramanathan (2006b) handled comparative performance analysis of governments, Sun *et al.*

(2012) measured regional environmental performance of eight western regions in China, Wang *et al.* (2013) computed the energy and environmental efficiency of 29 administrative regions of China. The performance of countries are handled with different DEA models by various authors (Kou *et al.* 2016; Meng *et al.* 2014; Vlontzos *et al.* 2014; Yang *et al.* 2016). Also, DEA method is applied in different research areas in Turkey: Sarıca and Or (2007) applied the DEA method for the performance evaluation of electricity generation plants in Turkey. Köksal and Aksu (2007) compared the 24 A-Group Travel agencies in Turkey with DEA method. Düzakın, E. and Düzakın, H. (2007) applied the slacks based model of DEA to measure performance of manufacturing firms in Turkey. Sözen *et al.* (2010) calculated the efficiency of thermal power plants in Turkey by using DEA method.

1.3. Applications of Integrated Fuzzy Analytic Hierarchy Process (FAHP) and Data Envelopment Analysis Method

In the literature, there have been limited on integration of FAHP and DEA methods. Sinuany-Stern *et al.* (2000) presented two-stage ranking model, AHP/DEA, for ranking units. Yang and Kuo (2003) applied AHP/DEA methodology for solving a multiple objective layout design problem. Saen *et al.* (2005) measured relative weights slightly non-homogeneous DMUs by AHP and relative efficiency of DMUs by chance-constrained DEA. Ertay *et al.* (2006) combined DEA and AHP methods to solve facility layout design (FLD) problem. Ramanathan (2006a) proposed Data Envelopment Analytic Hierarchy Process (DEAHP) method, which is a hybrid methodology of DEA and AHP. Sevkli *et al.* (2007) applied the DEAHP methodology developed by Ramanathan (2006a) in supplier selection of well-known Turkish company operating in appliance industry. Korpela *et al.* (2007) handled warehouse operator selection with integrated AHP-DEA approach. Giokas and Pentzaropoulos (2008) compared and ranked of 30 OECD members with two quantitative instruments as AHP and DEA. Azadeh *et al.* (2008) proposed an integrated model by integration of DEA, AHP and computer simulation for railway system improvement and optimization. Wang *et al.* (2008) used an integrated AHP–DEA methodology for evaluating bridge risks structures. Tseng and Lee (2009) investigated human resource practices and their influence on organizational performance by AHP/DEA model. Che *et al.* (2010) proposed a FAHP–DEA methodology for solving bank loan decision problems. Lee *et al.* (2010) used an integrated fuzzy AHP-DEA to measure the relative efficiency of the national hydrogen energy technology development. Lee *et al.* (2011) measured the relative efficiency of hydrogen energy technologies with integrated fuzzy AHP/DEA approach. Azadeh *et al.* (2011) applied an integrated AHP and DEA method to evaluate personnel productivity in banking institutions. Lin *et al.* (2011) evaluated the economic performance of local governments in China by integrated DEA/AHP model. Lee *et al.* (2013) developed an integrated two-stage MCDM approach. In the approach, relative weights of criteria are calculated by FAHP method and the relative efficiency of energy technologies are measured by DEA method. Do and Chen (2014) applied the FAHP and the DEA model with an assurance region (AR) for measuring the efficiency scores of universities. Kumar *et al.* (2015) used a

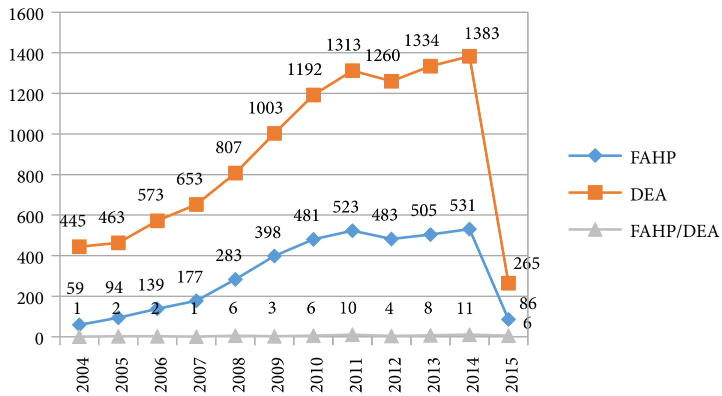

Figure 1. Distribution of the FAHP, DEA and FAHP/DEA publications (2004–2015)

hybrid FAHP/DEA model for benchmarking the quality of service in Indian mobile sector.

Figure 1 presents a comprehensive review in this field despite the vast number of published papers according to the Scopus database Publications on FAHP and DEA have been used more extensively than integrated FAHP/DEA for the years between 2004 and 2015. Although there are some research studies to handle the Turkey's performance in different fields by FAHP and/or DEA, there are no studies on performance evaluation of sub-regions in Turkey. According to the literature review, an integrated FAHP/DEA approach can be used for obtaining the performance evaluation of sub-regions in Turkey.

2. Proposed methodology

Two main steps are considered to apply the proposed methodology: The first step starts with defining the goal of the problem. In the second step, a data collection should be performed to define the qualitative and quantitative variables. After the data collection, the qualitative variables should be converted to quantitative ones using different FAHP methods, i.e. FAHP-EA, FAHP-GM, FAHP-FPP. After that, these weights are combined with the quantitative variables and finally, ranking the DMUs are obtained by DEA method. The hierarchical framework of the proposed methodology illustrated in Figure 2.

2.1. Fuzzy Analytic Hierarchy Process

Analytic Hierarchy Process (AHP) which is a MCDM method, have used a hierarchical structure to represent a decision problem. In the method, weights of the criteria and alternatives are produced according to the decision makers' opinions. FAHP is a fuzzy extension of AHP in order to solve MCDM problems under fuzzy environment. Judgments and preferences of decision makers are affected by uncertainty, so that the use of definite and precise numbers in linguistic judgments is not very reasonable (Calabrese *et al.* 2013).

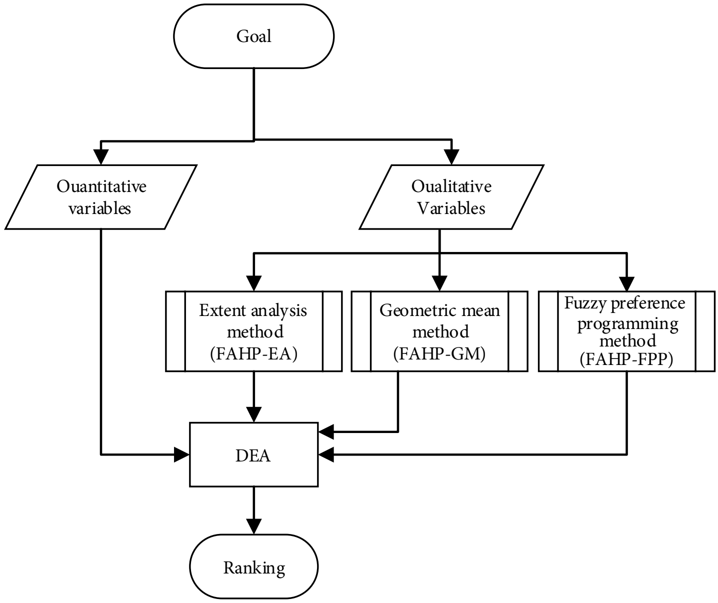

Figure 2. Hierarchical framework of the proposed methodology

2.1.1. Extent analysis method (FAHP-EA)

Chang (1996) proposed Extent Analysis method (FAHP-EA) by using triangular fuzzy numbers for pairwise comparison scale. In the method, fuzzy synthetic extent values of the pairwise comparisons are computed and then crisp weights are calculated (Büyüközkan *et al.* 2008; Kahraman *et al.* 2006).

Step 1: The value of fuzzy synthetic extent with respect to the i^{th} object is defined as:

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

where:

$$\sum_{j=1}^{m} M_{g_i}^{j} = \left(\sum_{j=1}^{m} l_j, \sum_{j=1}^{m} m_j, \sum_{j=1}^{m} u_j \right);$$

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

Step 2: To compare of the fuzzy numbers, the degree of possibility of $S_2 \geq S_1$ is defined as:

$$V(S_2 \geq S_1) = \sup_{y \geq x}\left[\min\left(\mu_{S_1(x)}, \mu_{S_2(y)}\right)\right] = hgt\left(S_1 \cap S_2\right) = \mu_{S_2(d)} = \begin{cases} 1, \text{ if } m_2 \geq m_1 \\ 0, \; l_1 \geq u_2 \\ \dfrac{(l_1 - u_2)}{(m_2 - u_2) - (m_1 - l_1)}, \text{ otherwise,} \end{cases} \tag{2}$$

where: $S_1 = (l_1, m_1, u_1)$ and $S_2 = (l_2, m_2, u_2)$ and d is the ordinate of the highest intersection point D between μ_{S_1} and μ_{S_2} (see Figure 3).

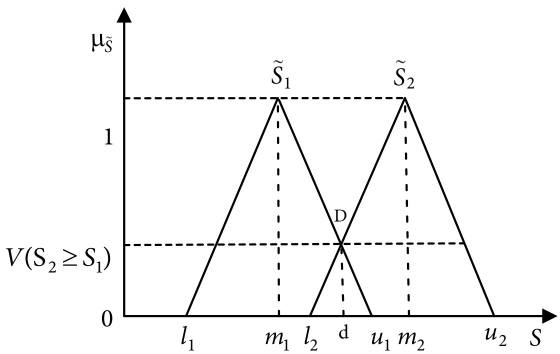

Figure 3. The intersection between $\tilde{S}_1$ and $\tilde{S}_2$

Step 3: The degree of possibility for a fuzzy number greater than k fuzzy S_i, $(i = 1,2,...,k)$ numbers is defined by the following equations:

$$V(S \geq S_1, S_2, ..., S_k) = \min V\left(S \geq S_i\right), \; i = 1,2,...,k. \tag{3}$$

Assume that,

$$d'(A_i) = \min V(S_i \geq S_k), \; k = 1,2,...,n; \; k \neq i. \tag{4}$$

Then the weight vector is defined by

$$W' = \left(d'(A_1), d'(A_2), ..., d'(A_n)\right)^T. \tag{5}$$

Step 4: After normalization, the normalized weight vectors can be defined as follows:

$$W = \left(d(A_1), d(A_2), ..., d(A_n)\right)^T, \tag{6}$$

where: W is not a fuzzy number (Chang 1996; Kahraman *et al.* 2006).

2.1.2. Geometric mean method (FAHP-GM)

The Geometric Mean Method (FAHP-GM) which is extension of AHP, was first employed by Buckley (1985) to derive fuzzy weights and performance scores. The method can be summarized as follows:

Step 1: A fuzzy pairwise comparison matrix ($\tilde{A} = [a_{ij}]$) is given by:

$$\tilde{A} = \begin{bmatrix} 1 & \cdots & \tilde{a}_{1j} & \cdots & \tilde{a}_{1n} \\ \vdots & & \vdots & & \vdots \\ \tilde{a}_{i1} & \cdots & 1 & \cdots & \tilde{a}_{in} \\ \vdots & & \vdots & & \vdots \\ \tilde{a}_{n1} & & \tilde{a}_{nj} & \cdots & 1 \end{bmatrix} = \begin{bmatrix} 1 & \cdots & \tilde{a}_{1j} & \cdots & \tilde{a}_{1n} \\ \vdots & & \vdots & & \vdots \\ 1/\tilde{a}_{i1} & \cdots & 1 & \cdots & \tilde{a}_{in} \\ \vdots & & \vdots & & \vdots \\ 1/\tilde{a}_{n1} & & 1/\tilde{a}_{nj} & \cdots & 1 \end{bmatrix},$$

where $\tilde{a}_{ij} = (l_{ij}, m_{ij}, u_{ij})$ is a triangular fuzzy numbers $(i = 1,2,...,n,\ j = 1,2,...,m)$

Step 2: The fuzzy weight matrix and the fuzzy weights of each criterion/alternative calculated as

$$\tilde{a}_i = (\tilde{a}_{i1} \otimes \tilde{a}_{i2} \otimes ... \otimes \tilde{a}_{in})^{1/n};$$

$$\tilde{w}_i = \tilde{a}_i \otimes (\tilde{a}_1 \oplus \tilde{a}_2 \oplus ... \oplus \tilde{a}_n)^{-1},$$

where: $\tilde{a}_i$ is the geometric mean of fuzzy comparison value; $\tilde{w}_i$ is a triangular fuzzy number and it should be defuzzified by any defuzzification method (Tzeng, Huang 2011).

2.1.3. Fuzzy preference programming method (FAHP-FPP)

Fuzzy preference programming method (FAHP-FPP) proposed by Mikhailov (2002) for deriving weights from fuzzy comparison judgements. The linear programming based method is formulated as follows:

$$\begin{aligned} &\text{Max } \lambda \\ &d_k\lambda + R_k w \le d_k \\ &\sum_{i=1}^{n} w_i = 1,\ w_i > 0,\ i = 1,2,...,n,\ \ k = 1,2,...,2m, \end{aligned} \tag{7}$$

where: λ denotes the degree of satisfaction is a tolerance parameter, d_k is a tolerance parameter (Mikhailov 2003).

In Eq. (7):

$$R_k w = \begin{cases} w_i - w_j u_{ij}(\alpha) \tilde{\le} 0 \\ -w_i + w_j l_{ij}(\alpha) \tilde{\le} 0 \end{cases} \tag{8}$$

and its membership function is defined as

$$\mu_k(R_k w) = \begin{cases} 1 - \dfrac{R_k w}{d_k},\ R_k w \le d_k \\ 0,\ R_k w \ge d_k. \end{cases} \tag{9}$$

In Eq. (8), the priority ratios at each α-cut level should satisfy $l_{ij}(\alpha) \le w_i / w_j \le u_{ij}(\alpha)$ and the bounds of α-cut the intervals are defined:

$$\begin{aligned} l_{ij}(\alpha) &= \alpha(m_{ij} - l_{ij}) + l_{ij}, \\ u_{ij}(\alpha) &= \alpha(m_{ij} - u_{ij}) + u_{ij}. \end{aligned} \tag{10}$$

2.2. Data Envelopment Analysis (DEA)

Data Envelopment Analysis (DEA) is a linear programming based method to evaluate the relative efficiency of DMUs. There are four basic DEA models in the literature: Charnes, Cooper, Rhodes (CCR) model, Banker, Charnes, Cooper (BCC) model, the multiplicative model and additive model. Also DEA model can be divided according to the orientation: output-oriented DEA models or input-oriented DEA models (Azadeh *et al.* 2011). The input oriented CCR model and the output oriented CCR model is given in Eq. (11) and Eq. (12):

$$
\begin{aligned}
\text{Max } z = & \sum_{r=1}^{s} u_r y_{r0}, \\
& \sum_{r=1}^{s} u_r y_{rj} - \sum_{i=1}^{m} v_i x_{ij} \le 0 \quad j = 1,\ldots,n, \\
& \sum_{i=1}^{m} v_i x_{io} = 1, \\
& v_i \ge 0,\ i = 1,\ldots,m, \\
& u_r \ge 0,\ r = 1,\ldots,s;
\end{aligned} \tag{11}
$$

$$
\begin{aligned}
\text{Min } q = & \sum_{i=1}^{m} v_i x_{io}, \\
& \sum_{i=1}^{m} v_i x_{ij} - \sum_{r=1}^{s} u_r y_{rj} \le 0 \ \ j = 1,2,\ldots,n, \\
& \sum_{r=1}^{s} u_r y_{ro} = 1, \\
& v_i \ge 0 \ \ i = 1,\ldots,m, \\
& u_r \ge 0 \ \ r = 1,\ldots,s.
\end{aligned} \tag{12}
$$

In the Eq. (11) and Eq. (12), y_{rj} is the value of output r for the DMU j; x_{ij} is the value of input i for the DMU j; u_r, $r = 1, 2, \ldots, s$ is the weight given to the output r and v_i, $i = 1, 2, \ldots, m$ is the weight given to the input i.

If the constraint $\sum_{j=1}^{n} \lambda_j = 1$ is added to the CCR model, it is known as BCC (Banker *et al.* 1984) model. The input oriented and output oriented BCC models are formulated as follows, respectively (Cooper *et al.* 2004).

$$
\begin{aligned}
\text{Max}\, z = & \sum_{r=1}^{s} u_r y_{ro} - u_o, \\
& \sum_{r=1}^{s} u_r y_{rj} - \sum_{i=1}^{m} v_i x_{ij} - u_o \le 0 \ \ j = 1,2,\ldots,n,
\end{aligned}
$$

$$\sum_{i=1}^{m} v_i x_{io} = 1,$$
$$u_o \text{ free in sign},$$
$$v_i \geq \varepsilon,\ i = 1,2,\ldots,m,$$
$$u_r \geq \varepsilon,\ r = 1,2,\ldots,s; \tag{13}$$

$$\text{Min } q = \sum_{i=1}^{m} v_i x_{io} - v_o,$$
$$\sum_{r=1}^{s} u_r y_{ro} = 1,$$
$$\sum_{i=1}^{m} v_i x_{ij} - \sum_{r=1}^{s} \mu_r y_{rj} - v_o \geq 0 \ \ j = 1,2,\ldots,n,$$
$$v_o \text{ free in sign},$$
$$v_i \geq \varepsilon,\ i = 1,2,\ldots,m,$$
$$\mu_r \geq \varepsilon,\ r = 1,2,\ldots,s. \tag{14}$$

In Eq. (13) and Eq. (14), u_o indicates returns to scale (Cooper *et al.* 2000).

3. A real case study

In this section, a case study is handled to specify the efficiency of NUTS-2 sub-regions in Turkey. A survey was conducted for the years 2009 and 2010 in order to perform the integrated FAHP/DEA method. Framework of the study is shown in Figure 4.

3.1. Variables and Decision Making Units

In this study, qualitative and quantitative variables were collected related to sub-regions of Turkey and shown in Table 1. In the FAHP analysis, three qualitative variables are used and other nine quantitative variables are used for DEA analysis.

Table 1. Quantitative and qualitative variables used in the study

Quantitative variables	Qualitative variables
Crude suicide rate	Security
College or university graduate rate	Earthquake risk
Exports per capita	Tourism
Value of crop production per capita	
Per capita electricity consumption	
Number of enterprises	
Literacy rate	
Imports per capita	
Number of benefit from the libraries thousands per capita	

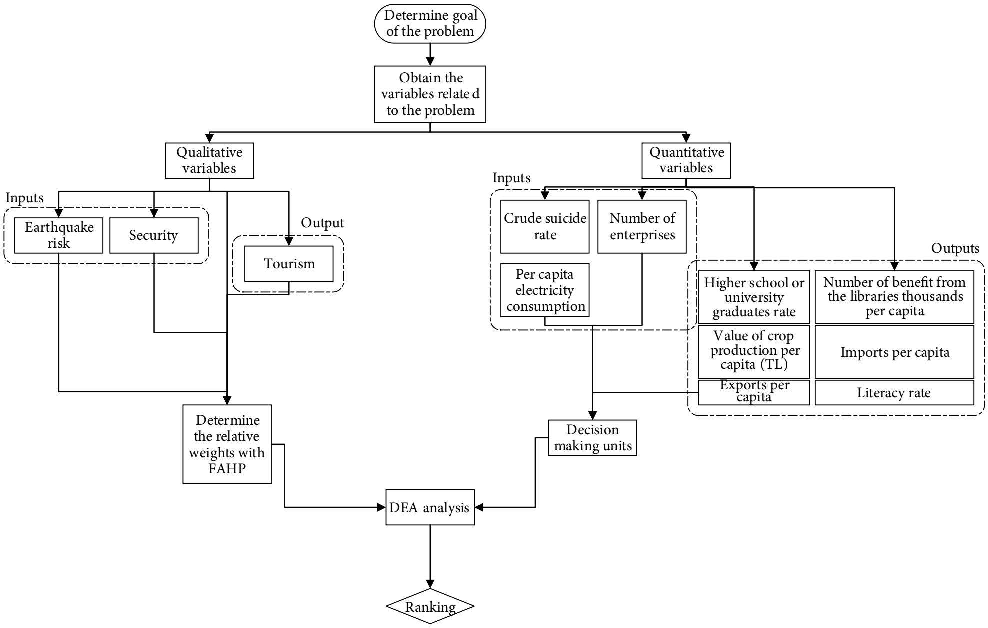

Figure 4. Framework of the integrated FAHP/DEA method

Turkey was divided into 12 regions and 26 sub-regions and 81 provinces according to the "Nomenclature of Territorial Units for Statistics (NUTS)" classification which is developed by the European Union (EU) to obtain a standard between for statistical purposes. The NUTS-2 classifications of Turkey and its related sub-regions are given in Table 2 (Wikipedia 2015).

Table 2. NUTS-2 sub-regions of Turkey

NUTS-2 classification	Sub-regions
TR10	Istanbul
TR21	Tekirdağ, Edirne, Kırklareli
TR22	Balıkesir, Çanakkale
TR31	İzmir
TR32	Aydın, Denizli, Muğla
TR33	Manisa, Afyon, Kütahya, Uşak
TR41	Bursa, Eskişehir, Bilecik
TR42	Kocaeli, Sakarya, Düzce, Bolu, Yalova
TR51	Ankara
TR52	Konya, Karaman
TR61	Antalya, Isparta, Burdur
TR62	Adana, Mersin
TR63	Hatay, Kahramanmaraş, Osmaniye
TR71	Kırıkkale, Aksaray, Niğde, Nevşehir, Kırşehir

End of Table 2

NUTS-2 classification	Sub-regions
TR72	Kayseri, Sivas, Yozgat
TR81	Zonguldak, Karabük, Bartın
TR82	Kastamonu, Çankırı, Sinop
TR83	Samsun, Tokat, Çorum, Amasya
TR90	Trabzon, Ordu, Giresun, Rize, Artvin, Gümüşhane
TRA1	Erzurum, Erzincan, Bayburt
TRA2	Ağrı, Kars, Iğdır, Ardahan
TRB1	Malatya, Elazığ, Bingöl, Tunceli
TRB2	Van, Muş, Bitlis, Hakkari
TRC1	Gaziantep, Adıyaman, Kilis
TRC2	Şanlıurfa, Diyarbakır
TRC3	Mardin, Batman, Şırnak, Siirt

3.2. FAHP analysis

In the solution process, the weights of the qualitative variables are determined by FAHP methods. A committee was constituted to perform FAHP methods in order to make a comprehensive decision. Thus, a meeting was organized with a committee consists of four experts for evaluating the qualitative variables: an administrator and an expert working at Konya regional office of TUIK, and two academicians (a statistician an industrial engineer) are chosen for the determination and evaluation of qualitative variables. Committee who have more than three years' knowledge in this field was constituted according to their profession. The experts used a nine point scale for the evaluation of the criteria as given in Table 3.

Table 3. Fuzzy evaluation scale for FAHP (Kaya, Kahraman 2011)

Linguistic terms	Fuzzy scale	Linguistic terms	Fuzzy scale
Absolutely strong (AS)	(2, 5/2, 3)	Slightly weak (SW)	(2/3, 1, 1)
Very strong (VS)	(3/2, 2, 5/2)	Fairly weak (FW)	(1/2, 2/3, 1)
Fairly strong (FS)	(1, 3/2, 2)	Very weak (VW)	(2/5, 1/2, 2/3)
Slightly strong (SS)	(1, 1, 3/2)	Absolutely weak (AW)	(1/3, 2/5, 1/2)
Equal (E)	(1, 1, 1)		

The fuzzy comparison matrices of qualitative criteria were obtained by questionnaire. The pair-wise comparisons are obtained by using triangular fuzzy evaluation scale given in Table 3. The fuzzy pair-wise comparisons matrices of qualitative criteria, Security, Earthquake Risk, Tourism, are given in detailed in (Çalık 2012). After the fuzzy pair-wise comparisons matrices are constructed, the criteria weights are calculated with using FAHP-EA, FAHP-GM and FAHP-FPP methods. The solution algorithms of the considered methods are coded in MATLAB R2010a for obtaining the criteria weights. The weights of the each alternative, i.e. DMUs, with respect to the criteria are given in Table 4.

Table 4. FAHP priorities of the 26 sub-regions with respect to the Earthquake Risk (ER), Security (S) and Tourism (T)

Alternatives	FAHP-EA			FAHP-GM			FAHP-FPP		
	ER	S	T	ER	S	T	ER	S	T
TR10	0.0813	0.0974	0.1218	0.0648	0.0483	0.0728	0.0642	0.0429	0.0528
TR21	0.0000	0.1374	0.0703	0.0234	0.0617	0.0423	0.0426	0.0587	0.0286
TR22	0.0815	0.1187	0.0570	0.0669	0.0574	0.0470	0.0644	0.0652	0.0400
TR31	0.0727	0.1650	0.0777	0.0606	0.0722	0.0498	0.0683	0.0660	0.0535
TR32	0.0659	0.1094	0.0761	0.0543	0.0554	0.0555	0.0386	0.0502	0.0667
TR33	0.0552	0.0481	0	0.0461	0.0392	0.0370	0.0214	0.0394	0.0582
TR41	0.0699	0.0018	0.0373	0.0587	0.0341	0.0422	0.0683	0.0365	0.0582
TR42	0.0958	0.0133	0.0496	0.0718	0.0362	0.0453	0.0645	0.0365	0.0582
TR51	0.0000	0.0000	0.03912	0.0170	0.0344	0.0379	0.0277	0.0365	0.0217
TR52	0.0000	0.0032	0	0.0134	0.0338	0.0210	0.0203	0.0457	0.0217
TR61	0.0434	0.1035	0.1380	0.0450	0.0519	0.0848	0.0387	0.0331	0.0176
TR62	0.0000	0.0821	0.0675	0.0245	0.0472	0.0507	0.0359	0.0392	0.0652
TR63	0.0544	0.0159	0.0653	0.0469	0.0353	0.0520	0.0359	0.0301	0.0506
TR71	0.0000	0.0199	0	0.0166	0.0367	0.0241	0.0215	0.0394	0.0286
TR72	0.0000	0.0234	0	0.0190	0.0371	0.0275	0.0215	0.0365	0.0349
TR81	0.0448	0.0142	0.0386	0.0455	0.0376	0.0290	0.0359	0.0262	0.0197
TR82	0.0116	0.0155	0.0435	0.0294	0.0377	0.0458	0.0284	0.0301	0.0400
TR83	0.0033	0.0075	0.0515	0.0282	0.0367	0.0489	0.0359	0.0287	0.0400
TR90	0.0000	0.0000	0.0580	0.0212	0.0329	0.0489	0.0153	0.0392	0.0268
TRA1	0.0874	0.0000	0	0.0663	0.0358	0.0238	0.0478	0.0281	0.0191
TRA2	0.0526	0.0036	0	0.0460	0.0362	0.0245	0.0359	0.0502	0.0197
TRB1	0.0545	0.0004	0.0079	0.0463	0.0361	0.0357	0.0359	0.0281	0.0268
TRB2	0.0826	0.0000	0	0.0620	0.0285	0.0329	0.0534	0.0262	0.0268
TRC1	0.0065	0.0098	0	0.0279	0.0376	0.0312	0.0215	0.0394	0.0191
TRC2	0.0022	0.0088	0	0.0282	0.0331	0.0256	0.0273	0.0331	0.0191
TRC3	0.0333	0.0000	0	0.0357	0.0122	0.0251	0.0277	0.0167	0.0266

According to the Earthquake Risk (ER) in Table 4, TR42 is the most dangerous sub-region computed by FAHP-EA and FAHP-GM whereas TR41 is the most dangerous region with respect to FAHP-FPP. TR31 has the highest priority according to the FAHP-EA, FAHP-GM and FAHP-FPP with respect to Security (S). Also, TR21 seems to be the most dangerous region for Security (S) criteria. TR61 and TR10 are the most attractive sub-regions computed by FAHP-EA and FAHP-GM on the other hand TR32 and TR62 are also the most attractive sub-regions with respect to FAHP-FPP with respect to the Tourism (T).

3.3. FAHP/DEA application

In this section, we combined priorities of qualitative data calculated by FAHP with the quantitative data for the years 2009 and 2010. The CCR and BCC efficiencies were used for ranking the NUTS-2 sub-regions with respect to two models in order to understand the effects of earthquake risk, tourism and security.

Model 1:
Inputs: Crude suicide rate (%000), Security, Earthquake risk
Outputs: College or university graduate rate (%), Exports per capita, Value of crop production per capita (TL), Tourism.

Model 2:
Inputs: Per capita electricity consumption (2009), Number of enterprises (2010), Security, Earthquake risk
Outputs; Literacy rate, College or university graduate rate (%) Imports per capita, Number of benefit from the libraries thousands per capita.

The efficiency scores of DMUs, i.e. NUTS-2 sub-regions of Turkey, according to the Model 1 and Model 2, are computed by integrated FAHP/DEA method with CCR and BCC models as shown in Tables 5–6, respectively.

In Table 5, an efficiency score of **"1"** shows that a sub-region has been determined to belong to the efficient frontier group. TR10 (İstanbul) is the most efficient sub-region according to the Model 1. As shown in Table 6, the FAHP-EA/CCR model determines the following ten sub-regions TR10, TR41, TR51, TR61, TR62, TR63, TR71, TR83, TR90 and TRC3 as efficient frontiers while the FAHP-EA/BCC finds the following fifteen sub-regions TR10, TR21, TR41, TR42, TR51, TR52, TR61, TR62, TR63, TR71, TR83, TR90, TRC1, TRC2 and TRC3 for the year 2009. According to the results, we see that the FAHP-EA/CCR model reduces the number of efficient DMUs for the Model 1.

As shown in Table 5, FAHP-GM/CCR model determines nine efficient sub-regions while the FAHP-GM/BCC model finds ten efficient sub-regions. On the other hand, FAHP-GM/CCR model determines fourteen efficient sub-regions while the FAHP-FPP/BCC model finds sixteen sub-regions. According to the results, we see that the FAHP-GM/CCR and FAHP-GM/BCC models decrease the number of efficient DMUs. Hence, the FAHP-GM/CCR and FAHP-GM/BCC models have better results than the other models for the year 2009.

Table 5. Efficiency scores of the NUTS-2 sub-regions for the years 2009 and 2010 using CCR and BCC models for Model 1

	FAHP-EA/DEA				FAHP-GM/DEA				FAHP-FPP/DEA			
Alternatives	2009		2010		2009		2010		2009		2010	
	CCR	BCC	CCR	BCC	CCR	BCC	CCR	BCC	CCR	BCC	CCR	BCC
TR10	1	1	1	1	1	1	1	1	1	1	1	1
TR21	1.2908	1	1.3326	1	1.1557	1.1256	1.1205	1.0979	1.5920	1.2299	1.4891	1.2734
TR22	1.5025	1.2458	1.3785	1.2852	1.3810	1.2458	1.3982	1.2852	1.5154	1.0775	1.2932	1.0977
TR31	1.4188	1.1156	1.0938	1.1128	1.4574	1.1323	1.1561	1.1212	1.3435	1	1.0766	1
TR32	1.9376	1.2052	1.5696	1.2221	1.4683	1.2052	1.4884	1.2221	1.1466	1	1.0576	1
TR33	1.4505	1.3147	1.2756	1.2680	1.2826	1.2711	1.2015	1.1886	1	1	1	1
TR41	1	1	1	1	1	1	1	1	1	1	1	1
TR42	1.0285	1	1	1	1.1460	1.1110	1	1	1	1	1	1
TR51	1	1	1	1	1	1	1	1	1	1	1	1
TR52	1	1	1.0027	1	1	1	1	1	1	1	1.1052	1.0886
TR61	1	1	1	1	1	1	1	1	1	1	1	1
TR62	1	1	1.2125	1	1	1	1.0072	1	1	1	1	1
TR63	1	1	1.0564	1.0476	1	1	1.0843	1.0113	1	1	1	1
TR71	1.1753	1	1	1	0.9904	1	1	1	1	1	1	1
TR72	1.3453	1.2416	1.2126	1.1965	1.3524	1.2950	1.2248	1.1824	1.1393	1.0547	1.0277	1.0052
TR81	2.5115	1.5612	2.3829	1.5810	1.9146	1.7612	1.8880	1.7558	1.3302	1.3212	1.3058	1.3138
TR82	1.5802	1.3047	1.1456	1.0807	1.2844	1.2696	1.1582	1.0807	1.1346	1.0703	1.0289	0.9457
TR83	1	1	0.9851	1	1.0810	1.0105	1.1365	1.0804	1	1	1	1
TR90	1	1	1	1	1	1	1	1	1	1	1	1
TRA1	1.1846	0.9364	1.4722	1.4531	1.4039	1.0777	1.5064	1.4741	1.3696	1.0866	1.3523	1.0643
TRA2	3.1203	2.6809	4.3767	2.8548	2.3754	2.2735	2.3902	2.2778	2.8501	2.6031	3.1259	2.6011
TRB1	1.7789	1.2998	1.7884	1.3105	1.5682	1.3678	1.4963	1.4587	1.1696	1.1806	1.2155	1.2016
TRB2	3.0024	2.7814	3.4131	2.7541	1.5304	1.5071	1.4936	1.5071	1.5614	1.5578	1.5614	1.5578
TRC1	1.0525	1	1	1	1.2775	1.2719	1.0633	1.0623	1	1	1	1
TRC2	1.2528	1	1.3478	1.2652	1.3051	1.1833	1.5034	1.4444	1.3121	1.1840	1.5904	1.4719
TRC3	1	1	1.3832	1.3056	1	1	1	1	1	1	1	1

Table 6. Efficiency scores of the NUTS-2 regions for the years 2009 and 2010 using CCR and BCC models for Model 2

Alternatives	FAHP-GM/DEA				FAHP-FPP/DEA			
	2009		2010		2009		2010	
	CCR	BCC	CCR	BCC	CCR	BCC	CCR	BCC
TR10	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**
TR21	1.6761	**1**	1.6702	**1**	1.7785	0.9838	1.7951	**1**
TR22	2.3816	1.0036	2.3241	**1**	2.3373	1.0036	2.3314	**1**
TR31	2.3273	**1**	2.2859	**1**	2.0792	**1**	2.0526	**1**
TR32	1.9865	**1**	2.0472	**1**	1.5180	**1**	1.5442	**1**
TR33	1.6872	1.0044	1.4991	1.0064	1.0917	1.0002	1.0171	**1**
TR41	1.1776	**1**	1.1364	**1**	1.1261	**1**	0.9795	**1**
TR42	1.3706	**1**	1.1658	**1**	1.2866	**1**	1.1018	**1**
TR51	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**
TR52	**1**	**1**	**1**	**1**	1.1496	**1**	1.1453	**1**
TR61	1.8863	0.9864	1.8856	**1**	1.2001	**1**	1.1799	**1**
TR62	1.4797	1.0336	1.4701	1.0230	1.3535	1.0268	1.3542	**1**
TR63	1.4551	1.0066	1.4601	1.0084	1.1388	1.0196	1.1385	**1**
TR71	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**
TR72	1.1700	1.0304	1.1688	1.0252	1.0271	1.0007	1.0234	**1**
TR81	1.3537	1.0101	1.3869	1.0165	**1**	**1**	1.0167	**1**
TR82	1.0959	1.0143	1.0179	**1**	**1**	**1**	**1**	**1**
TR83	1.2940	1.0196	1.2986	1.0187	1.1087	**1**	1.1149	**1**
TR90	1.0884	1.0205	1.0693	1.0199	**1**	**1**	**1**	**1**
TRA1	1.4729	1.0228	1.6634	1.0203	**1**	**1**	1.1253	**1**
TRA2	1.7276	1.0687	1.7440	1.0495	1.7410	1.1065	1.7302	1.0541
TRB1	1.3639	1.0470	1.4149	1.0322	**1**	**1**	1.0505	1.0062
TRB2	1.9142	1.0695	1.8937	1.0425	1.5410	1.0521	1.5018	1.0301
TRC1	1.2838	1.0522	1.1631	1.0341	**1**	**1**	**1**	**1**
TRC2	1.3827	1.1080	1.3328	1.0828	1.2724	1.1119	1.2594	1.0609
TRC3	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**

Because FAHP-EA assigns “0” value to the DMUs, we couldn't compute efficiency scores of FAHP/DEA and did not give in Table 6. In Table 6, TR10, TR51, TR52, TR71 and TRC3 are the most efficient sub-regions according to the FAHP-GM/CCR model for the year 2010. As shown in Table 6, the FAHP-GM/CCR model determines five efficient sub-regions while the FAHP-GM/BCC finds thirteen efficient sub-regions. According to the results, we see that the FAHP-GM/CCR model reduces the number of efficient DMUs for the Model 2.

As shown in Table 6, FAHP-FPP/CCR model determines seven efficient sub-regions while the FAHP-FPP/BCC model finds twenty two efficient sub-regions. According to the results, we see that the FAHP-GM/CCR and FAHP-GM/BCC models reduce the number of efficient DMUs for the data. Hence it can be concluded that the FAHP-GM/CCR and FAHP-GM/BCC models have better results than the others.

The results of our analyses have some policy implications for understanding the differences among sub-regions. The current research found 38%, 34%, 53% of the 26 efficient sub-regions in the output-oriented CCR model with FAHP-EA/DEA, FAHP-GM/DEA and FAHP-FPP/DEA for the year 2009, respectively. The smallest relative efficiency scores are found for the East sub-regions (TRA1, TRA2, TRB1 etc.). This is an important outcome highlighting the disparity in socio-economic status among sub-regions in Turkey. The decision makers can improve the sub-regions' performance with higher industrial development, strong economy policies, new investment and trade policy, etc. The result of this analysis shows that the big sub-regions, 30% of the 26 sub-regions output-oriented CCR model with FAHP-EA/DEA for the year 2010, are on the efficiency frontiers. The result indicates a lower efficient performance amongst the sub-regions and it is reflected in the specific aspects in Turkey. The sub-regions of the Turkey, such as TR10, TR41, TR51, etc., have more natural resources, industries and national/international investments. Therefore, these sub-regions show efficient performances by integrated FAHP/DEA methods.

Conclusions

In this study, the ranking of the NUTS-2 sub-regions in Turkey has been obtained by integrated FAHP/DEA models for the related data for the years 2009 and 2010. For converting qualitative data to quantitative data, FAHP methods have been used. According to the decision makers' judgments, fuzzy comparison matrices have been constituted by using triangular fuzzy scale of preferences. Priorities of qualitative data have been combined with other quantitative ones. DEA method has been applied to the combined data with Model 1 and Model 2. Finally, the efficiency scores have been computed for ranking the NUTS-2 sub-regions. The results are useful for understanding the differences of sub-regions in Turkey. The results of this study show that the ranking of 26 sub-regions exhibits a divergence between different models. Thus, we pointed out that different FAHP methods affect the efficiency scores of CCR and BCC models.

The practical implication of the proposed integrated FAHP/DEA method is the usage of linguistic variables for evaluation of the qualitative criteria and construction of the fuzzy pairwise comparison matrices. The capability of FAHP is to tackle with qualitative criteria for converting them to quantitative ones. The DEA based mathematical programming techniques can successfully help researchers to measure the performance of DMUs in the presence of qualitative and quantitative criteria. For the DEA method, the East sub-regions are the lowest ranked sub-regions while the West and Central sub-regions are ranked higher. The results of efficiency scores clearly indicate that the West and Central sub-regions perform better than the others.

Turkey was divided into 12 regions, 26 sub-regions and 81 provinces according to the (NUTS) classification, called as NUTS-1, NUTS-2 and NUTS-3, respectively. As a limitation of our study, we only focused on performance evaluation of the NUTS-2 sub-regions in Turkey. It is difficult to realize the pairwise comparison of qualitative criteria (security, earthquake risk and tourism) due to their large dimension. The process of obtaining weights of criteria and alternatives from this matrix often results in inconsistency. Based on this limitation, the calculations of the FAHP methods are very complicated and consume much time.

These research results can be used by many disciplines in Turkey for comparing the regions and sub-regions. However, the integrated approach can be also extended for the future researches by making improvements in different aspects. For instance, other types of MCDM methods such as TOPSIS, MOORA, etc. can be used and the obtained results can be compared with ours.

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