Socio-Economic Planning Sciences 68 (2019) 100619

Contents lists available at ScienceDirect

Socio-Economic Planning Sciences

journal homepage: www.elsevier.com/locate/seps

A hybrid multi-criteria decision making approach for strategic retail location investment: Application to Turkish food retailing

Nurdan Yıldız[a], Fatih Tüysüz[b,*]

[a] Department of Industrial Engineering, Istanbul Gelisim University, 34310, Avcılar, Istanbul, Turkey
[b] Department of Industrial Engineering, Istanbul University, 34320, Avcılar, Istanbul, Turkey

ARTICLE INFO

Keywords:
Food retailing
Strategic location investment
Hesitant AHP
GRA
Monte Carlo simulation

ABSTRACT

Retail location selection decision is a critical and complex process which requires the evaluation and aggregation of multiple criteria and also the usage of appropriate data related to them. This study handles the problem at a strategic level and proposes a Monte Carlo simulation based multi-criteria strategic location decision model for food retailing. This model integrates two multi-criteria decision making (MCDM) methods which are Hesitant Analytic Hierarchy Process (H-AHP) and Grey Relational Analysis (GRA) methods. Firstly, H-AHP method is used to obtain the weights of criteria to be used in GRA based on the experts' judgements. Secondly, simulation based GRA is used for ranking the alternative locations. Finally, the effectiveness and the applicability of the proposed model is illustrated with an application of strategic location investment decision of food retail stores in Turkey.

1. Introduction

There are many definitions of retailing which can be simply defined as selling the products or services of producers to customers through different channels of distribution [1]. It is a highly dynamic and fast growing sector which is affected by many factors such as competition, location, changing consumer behavior and demographics, technology, globalization etc. Although the technological developments have led to multiple ways of retailing, the traditional bricks and mortar stores are still popular and valid forms of retailing, especially for food retailing which is selling food like products through emporiums and supermarkets.

As Mazza and Rydin [2] state that retail sector creates employment, provides income by generating taxes and reflects the community's viability and vitality, which make it a city's one of the most important economic activities. Retail activities have effect on city's economic condition in terms of creating employment and supplying people's needs, social condition in terms of diversity, product quality and availability of the same prices for all, and environment in terms of transportation. All these make the retailing an important and integral part of urban policy making [3]. It can also be concluded that although retailing is a private sector economic activity, public authorities' planning, regulations and policies may have effect on this activity [4]. For these reasons, retail planning or retail investment decisions can also be considered as a socio-economic problem which is also valid in this study. Although, this study handles the problem from a private sector point of view, retail planning or retail investment decisions can also be considered as a socio-economic problem, which is also valid in this study, due to the reasons mentioned above.

Socio-economic factors such as rising incomes, rising female participation in workforce, increasing level of urbanization and changing demographics in population increase the demand for supermarket retailing [5]. Turkey's food retail sector has been gaining attention of the international retailers due to its growing economy, favorable population demographics and the quick rate of returns on investment [3,6]. Besides, central government, government agencies and chamber of commerce in Turkey support these organized retailers since they have positive effects on social, economic and environmental effects [3]. This is also the main motivation of the real application of the study.

Food retailers have to satisfy their customer expectations and adapt to the continuously changing market's requirements in global competition environment [7]. They also need to expand their markets and reach more customers in order to maintain their presence in this environment. Location of retail store provides competitive and unique advantage to retailers [8]. Selection of location is an important strategic decision and has a great effect on overall success of the retailer since such decisions involve long-term commitment of resources and generally represent a substantial investment which may affect the long-term profitability and sustainability of the company [9,10]. Another important characteristics of location selection problem for the retailers is that it is usually irreversible which means that it cannot be overcome easily. It can be said that location is the most important among all

* Corresponding author.
E-mail address: fatih.tuysuz@istanbul.edu.tr (F. Tüysüz).

https://doi.org/10.1016/j.seps.2018.02.006
Received 20 February 2017; Received in revised form 31 January 2018; Accepted 23 February 2018
Available online 01 March 2018

affecting the success of the retailers [11].

There are four developed theories related to retail location selection which are central place theory [12], spatial interaction theory [13], bid rent theory [14] and the principle of minimum differentiation [15]. According to the central place theory, customers patronize the nearest retailer selling the demanded good or service whereas spatial interaction theory assumes that customers may choose a less attractive retailer closer to them or a distant one which provides more goods and services. Principle of minimum differentiation is mainly used for micro-scale retail location [16], and assumes that demand is identical and customers patronize stores by only considering the prices. According to bid rent theory, retailers seek higher rents to gain more and higher profile customers. High rent is considered to be a good indicator of performance and competitiveness and as the distance from the central market increases, the amount of rent should also decrease. The studies related to the applications of these theories can be found in Turhan et al. [17] and Reigadinha et al. [18].

In addition to the above mentioned theories, there are some different approaches and techniques used in location selection literature which usually depend on the type of the business. Other location analysis techniques that are available in the literature include checklist analysis [19], analogue approach [20,21], gravity modeling [22,23], regression modeling [24–26], Geographic Information Systems (GIS) [27–31], and financial analysis [10,32]. The formulation and solution of these approaches vary in terms of fundamental assumptions, mathematical complexity and computational performance. These approaches only analyze the problem from certain aspects and do not consider the relationships between the decision factors globally [33]. For example, analogue approach focuses on sales forecasting by assessing present stores performance, GIS optimizes the problem using visual mapping for criteria, and gravity models take into account population and travel distance.

Retail location selection decision is a critical and complex process which requires the evaluation and aggregation of multiple qualitative and quantitative criteria. The main problem for evaluating criteria is that decision makers usually assess their perceptions and judgements by using linguistic terms in a more natural way. The crisp multi-criteria decision making (MCDM) methods tend to be less effective in dealing with the imprecision or vagueness nature of the linguistic assessment [34]. Due to this reason, the use of the fuzzy set theory and MCDM approach for evaluating location selection seems more convenient by allowing decision makers to express their ideas more adequately [10]. The applications of MCDM methods for location selection are usually in the form of fuzzyfying the crisp ones. Fuzzy MCDM methods have been widely used in location selection such as fuzzy AHP [35–43], fuzzy ANP [10,44–46], fuzzy TOPSIS [47–55], fuzzy AHP and TOPSIS [56–63], fuzzy AHP and ELECTRE [64], fuzzy AHP and PROMETHEE [65], fuzzy DEMATEL and ANP [66], fuzzy DEMATEL, ANP and TOPSIS [45,67], hesitant fuzzy AHP [68–70], hesitant fuzzy TOPSIS [71], fuzzy VIKOR [72] and intuitionistic fuzzy VIKOR [73].

Due to the reasons mentioned above and based on the literature review, it can be concluded that location selection decisions should take into consideration more than one criterion, and also appropriate data related to these criteria should be used. In this study, we propose a hybrid multi-criteria strategic location decision model for food retailing. This model integrates two MCDM methods which are Hesitant Analytic Hierarchy Process (H-AHP) and simulation based Grey Relational Analysis (GRA) methods. H-AHP method is used to obtain the weights of criteria to be used in GRA based on the experts' judgements whereas simulation based GRA is used for ranking the alternative locations based on the collected data set. The proposed model is applied for the strategic location decision of food retail stores in Turkey. This study is fairly important in two ways. First, to the best of our knowledge, there has not been a previous study that was applied to select location at strategic level for food retail stores. The previously mentioned methods and techniques used in the literature are mostly applied for small regions whereas this study handles the problem at a strategic level by considering all the cities in the country. Second, the simulation based GRA method is introduced in this study which can be helpful in many real life problems and applications.

The organization of the paper is as follows. In section 2, the methodology used in the study is explained in detail. In section 3, the proposed approach for strategic food retail investment is presented. Section 4 presents an application of the proposed approach for Turkey. Finally, the results and the conclusions are presented.

2. Methodology

This section presents the detailed information about the methodology proposed in the study. Since the proposed hybrid MCDM approach integrates H-AHP and simulation based GRA methods, they will be explained in detail before giving the algorithm of the model to maintain the integrity of the section.

2.1. Hesitant sets and hesitant AHP

Hesitant fuzzy sets (HFSs) [74] which are the extensions of regular fuzzy sets [75] handle the situations where a set of values are possible for the membership of a single element. HFS allows the membership degrees to have a set of possible values between 0 and 1 [76]. Determining the membership value of an element on a set is one of the important difficulties and Torra and Narukawa [76] state that HFSs can be used in cases where uncertainty on the possible membership values are limited such as; a group of experts may not agree on the membership of an element. In such cases, HFS can represent the situation and instead of using an aggregation operator to get a single value, it is useful to deal with all the possible values [76].

Since people may have hesitancy in providing their preferences, HFS can be effectively used to represent these in different levels of decision making process. Some basic concepts related to HFS which are taken from Torra and Narukawa [76] and Torra [74] are as follows.

Definition 1. Let X be a fixed set, a HFS on X is in terms of a function that when applied to X returns a subset of [0, 1]. Mathematical expression for HFS is as follows;

$$E = \{<x, h_E(x)> \mid x\varepsilon X\} \tag{1}$$

where $h_E(x)$ is a set of some values in [0, 1], denoting the possible membership degrees of the element $x\varepsilon X$ to the set E. Xu and Xia [77] call $h = h_E(x)$ a hesitant fuzzy element (HFE).

Definition 2. Let h, h_1 and h_2 be three HFEs, then basic operations on these elements can be defined as follows;

$$h^-(x) = \min h(x) \tag{2}$$

$$h^+(x) = \max h(x) \tag{3}$$

where $h^-(x)$ and $h^+(x)$ are the lower and upper bounds of h respectively.

$$h^c = \cup_{\gamma\in h}\{1-\gamma\} \tag{4}$$

where h^c is the complement of h.

$$h^\lambda = \cup_{\gamma\in h}\{\gamma^\lambda\} \tag{5}$$

$$\lambda h = \cup_{\gamma\in h}\{1-(1-\gamma)^\lambda\} \tag{6}$$

$$h_1 \cup h_2 = \cup_{\gamma_1\in h_1,\gamma_2\in h_2,} max\{\gamma_1, \gamma_2\} \tag{7}$$

$$h_1 \cap h_2 = \cup_{\gamma_1\in h_1,\gamma_2\in h_2,} min\{\gamma_1, \gamma_2\} \tag{8}$$

$$h_1 \oplus h_2 = \cup_{\gamma_1\in h_1,\gamma_2\in h_2,}\{\gamma_1 + \gamma_2 - \gamma_1\gamma_2\} \tag{9}$$

$$h_1 \otimes h_2 = \cup_{\gamma_1\in h_1,\gamma_2\in h_2,}\{\gamma_1\gamma_2\} \tag{10}$$

There are some studies related to the HFS extensions of AHP method in literature which can be summarized as follows; Rodriguez et al. [78] presented a different approach named as hesitant fuzzy linguistic term set (HFLTS) to deal with the situations when ordinary fuzzy linguistic approaches which aim to use a single linguistic term are incapable of handling the hesitation of decision makers. This approach provides a linguistic and computational basis to increase the richness of linguistic elicitation based on the fuzzy linguistic approach and the use of context-free grammars by using comparative terms.

Rodriguez et al. [79] proposed a new group decision model based on HFLTS in order to enhance the elicitation of flexible and rich linguistic expressions. Their model is based on m experts evaluating n alternatives on a single criterion. Since this model considers only single criterion, it cannot be used for complex MCDM problems.

Zhu and Xu [80] proposed a methodology called AHP-hesitant group decision making (AHP-HGDM) in which each hesitant judgment that includes several possible values is used to indicate the original judgments provided by the decision makers. They also proposed hesitant multiplicative preference relations (HMPRs) to collect the hesitant judgments, and then they developed a hesitant multiplicative programming method (HMPM) as a new prioritization method to derive ratio-scale priorities from HMPRs.

Mousavi et al. [81] proposed a method called hesitant fuzzy AHP (HF-AHP) in which decision makers' evaluations for comparison matrices are expressed by linguistic variables and then the DMs' judgments are aggregated by utilizing the hesitant fuzzy geometric operator.

Yavuz et al. [82] extended HFLTS to multi-criteria evaluation which considers hesitancy of the experts in defining membership degrees or functions. In this model, linguistic term sets are used together with context free grammar such as "at most medium importance", "between low and high importance" etc. This model can handle a complex multicriteria problem with a hierarchical structure and use a fuzzy representation for comparative linguistic expressions based on a fuzzy envelope for HFLTS.

Öztayşi et al. [83] developed a hesitant fuzzy AHP method involving multi-experts' linguistic evaluations aggregated by ordered weighted averaging (OWA) operator. The developed method was successfully applied to a multicriteria supplier selection problem.

Zhu et al. [84] proposed hesitant AHP method with new concepts by using a new stochastic prioritization method. They defined two indices which are an expected geometric consistency index to check the consistency degrees of individual hesitant comparison matrices and an expected geometric consensus index to check the consensus degrees of multiple hesitant comparison matrices.

Onar et al. [85] proposed a new hesitant fuzzy Quality Function Deployment (QFD) approach for selection of computer workstation. QFD was used to define design requirements of computer workstation. They used hesitant fuzzy AHP based on HFLTS to determine the weights of criteria and used hesitant fuzzy Technique for Order Performance by Similarity to Ideal Solution (TOPSIS) to select the most suitable alternative.

Zhou and Xu [86] introduced the hesitant fuzzy preference format and defined the hesitant fuzzy continuous preference term. They presented a model framework of the asymmetric hesitant fuzzy sigmoid preference relation (AHSPR) in the AHP. As the authors indicated that their model requires complex calculations and a more simplified calculation process needs to be developed.

Tüysüz and Şimşek [70] applied HFLTS based AHP method as an HFS extension of AHP for assessing and prioritizing the factors used in the performance evaluation of the branches of a cargo company operating in Turkey, and Tüysüz and Çelikbilek [69] used HFLTS based AHP approach for determining the importance of the factors used in the evaluation of renewable energy resources. Due to the flexibility of the model in defining linguistic terms, HFLTS based AHP method is used in this study.

HFLTS enable to mathematically represent and solve decision making problems with multiple linguistic assessments and enhance the elicitation of flexible and rich linguistic expressions. Before we explain and give the algorithmic steps of the HFLTS based AHP method, some basic concepts related to HFLTS which are taken from Rodriguez et al. [78] will be given.

Definition 3. An HFLTS, H_s, is an ordered finite subset of consecutive linguistic terms of a linguistic term set S which can be shown as $S = \{s_0, s_1, \ldots, s_g\}$.

Definition 4. Assume that E_{G_H} is a function that converts linguistic expressions into HFLTS, H_S. Let G_H be a context-free grammar that uses the linguistic term set S. Let S_{ll} be the expression domain generated by G_H. This relation can be shown as $E_{G_H}: S_{ll} \rightarrow H_S$.

Using the following transformations comparative linguistic expressions are converted into HFLTSs;

$$E_{G_H}(s_i) = \{s_i | s_i \in S\} \tag{11}$$

$$E_{G_H}(at\ most\ s_i) = \{s_j | s_j \in S\ and\ s_j \leq s_i\} \tag{12}$$

$$E_{G_H}(lower\ than\ s_i) = \{s_j | s_j \in S\ and\ s_j < s_i\} \tag{13}$$

$$E_{G_H}(at\ least\ s_i) = \{s_j | s_j \in S\ and\ s_j \geq s_i\} \tag{14}$$

$$E_{G_H}(greater\ than\ s_i) = \{s_j | s_j \in S\ and\ s_j > s_i\} \tag{15}$$

$$E_{G_H}(between\ s_i\ and\ s_j) = \{s_k | s_k \in S\ and\ s_i \leq s_k \leq s_j\} \tag{16}$$

Definition 5. The envelope of an HFLTS is represented by $env(H_S)$, and it is a linguistic interval whose limits are obtained by its maximum value and minimum value,

$$env(H_S) = \left[H_{S^-}, H_{S^+}\right], \quad H_{S^-} \leq H_{S^+} \tag{17}$$

where

$$H_{S^-} = \min(s_i) = s_j, \quad s_i \in H_S\ and\ s_i \geq s_j\ \forall\ i \tag{18}$$

$$H_{S^+} = \max(s_i) = s_j, \quad s_i \in H_S\ and\ s_i \leq s_j\ \forall\ i \tag{19}$$

The algorithmic steps of the HFLTS based AHP method are as follows;

$$V_N = \{primary\ term, composite\ term, unary\ relation, binary\ relation, conjunction\}$$

$$V_T = \{lower\ than, greater\ than, at\ least, at\ most, between, and, s_0, s_1, \ldots, s_g\}$$

$I \varepsilon V_N$.

Step 1 Define the semantics and syntax of the linguistic term set S and the context-free grammar G_H, where $G_H = \{V_N, V_T, I, P\}$

The production rules can be obtained by Eq. (20).

$$P = \left\{ \begin{array}{l} I ::= \langle primary\ term\rangle | \langle composite\ term\rangle, \langle composite\ term\rangle ::= \\ \langle unary\ relation\rangle\langle primary\ term\rangle | \langle binary\ relation\rangle\langle primary\ term\rangle \\ \langle conjunction\rangle\langle primary\ term\rangle, \\ primary\ term ::= s_0 | s_1 | \ldots | s_g, \langle unary\ relation\rangle :: \\ \quad = lower\ than | greater\ than | at\ least | at\ most, \\ \langle binary\ relation\rangle ::= between, \langle conjunction\rangle ::= and \end{array} \right\} \tag{20}$$

$$p^k = \begin{pmatrix} p_{11}^k & \cdots & p_{1m}^k \\ \vdots & \ddots & \vdots \\ p_{n1}^k & \cdots & p_{nm}^k \end{pmatrix} \tag{21}$$

where p_{ij}^k shows the degree of preference of the alternative x_i over x_j according to expert e_k. In this step the preference matrix is constructed for the criteria.

$$\Delta(\beta) = (s_i, \alpha) with \begin{cases} i = round(\beta) \\ \alpha = \beta - i \end{cases} \tag{22}$$

where round assigns to β the integer number $i \in \{0,1,...,g\}$ closest to β and Δ^{-1}: $S \to [0, g]$ is defined as shown in Eq. (23).

$$\Delta^{-1}(s_i, \alpha) = i + \alpha \tag{23}$$

Step 2 Gather the pairwise comparisons from the experts. In the domain of group decision making, m decision makers ($\boldsymbol{E} = \{e_1, e_2,...,e_m\}$) try to select the best alternative among n alternatives ($X = \{x_1, x_2,...,x_n\}$) where $m > 1$ and $n > 1$. In this case, a matrix composed of preference relations (p^ks) are formed as given in Eq. (21).

Step 3 Transform the preference relations into HFLTS by using the transformation function E_{G_H}. For each HFLTS obtain an envelope $\left[p_{ij}^{k-}, p_{ij}^{k+}\right]$.

Step 4 Obtain the pessimistic and optimistic collective preference relations (P_C^- and P_C^+). Compute the pessimistic and optimistic collective preference for each alternative using 2-tuple sets. The 2-tuple set associated with S is defined as $S = S \times [0.5, 0.5)$. The function Δ: $[0, g] \to S$ is given in Eq. (22).

Step 5 Build a vector of intervals $V^R = (p_1^R, p_2^R,...,p_n^R)$ of collective preferences for the alternatives $p_i^R = [p_i^-, p_i^+]$

Step 6 Calculate the midpoints of the intervals and normalize the results in order to find the weights.

2.2. Grey relational analysis

Grey systems theory which was developed by Deng [87] presents an effective methodology for the analysis of systems with imprecise information and can handle uncertainty successfully. The grey theory consists of five parts which are grey prediction, grey relational analysis (GRA), grey decision making, grey programming and grey control [87]. GRA is one of the most important techniques that can be used to solve MCDM problems. The main advantages of the GRA are that it is computationally simple, based on the original discrete data, robust and practical [88,89]. GRA distinguishes from classical statistical methods by its ability to assess quantitative and qualitative relationships between the factors by using relatively small amount of data [90].

Recent studies in the literature indicate that GRA is commonly used together with other methods such as GRA and AHP [91–94], GRA and ANP [95], GRA and DEMATEL [1], GRA and TOPSIS [96], GRA and ANOVA [97–101], GRA and Delphi method [102], GRA and Dempster-Shafer theory [103,104], GRA and entropy measurement method [105], GRA and failure mode and effect analysis [106], GRA and design of experiment [107], GRA and data envelopment analysis [108] GRA and Taguchi method [109,110], and GRA, Taguchi method and ANOVA [111–115].

The algorithmic steps of the GRA are as follows;

Step 1 Establish the comparability sequences. For each alternative, comparability sequence $X_i = \{x_i(1), x_i(2),..., x_i(n)\}$ is established. This sequence includes performance values of alternative i regarding each criterion. Decision matrix is generated using comparability sequences as follows:

$$X = \begin{bmatrix} x_1(1) & x_1(2) & \cdots & x_1(n) \\ x_2(1) & x_2(2) & \cdots & x_2(n) \\ \vdots & \vdots & \cdots & \vdots \\ x_m(1) & x_m(2) & \cdots & x_m(n) \end{bmatrix} \tag{24}$$

where m is the number of alternatives ($i = 1,2,...,m$), n is the number of criteria ($j = 1,2,...,n$) and $x_i(j)$ is the value of the jth criterion of the ith alternative.

Step 2 Establish the reference sequence. According to comparability sequences, a reference sequence $X_0 = \{x_0(1), x_0(2),..., x_0(n)\}$ is generated. This sequence consists of the best or target values of criteria.

Step 3 Normalize the data series. Normalized values of the comparability sequences are calculated by using Eqs. (25)–(27).

If the expectancy is larger-the-better,

$$x_i(j) = \frac{x_i(j) - \min_i x_i(j)}{\max_i x_i(j) - \min_i x_i(j)} \tag{25}$$

If the expectancy is smaller-the-better,

$$x_i(j) = \frac{\max_i x_i(j) - x_i(j)}{\max_i x_i(j) - \min_i x_i(j)} \tag{26}$$

If the expectancy is nominal-the-better,

$$x_i(j) = 1 - \frac{|x_i(j) - u_j|}{\max\{\max x_i(j) - u_j, u_j - \min x_i(j)\}} \tag{27}$$

where u_j is the nominal performance value for criterion j.

Step 4 Calculate the grey relational coefficient. Grey relational coefficient shows the relationship between the reference sequence and comparability sequence. This coefficient is calculated using the normalized values as follows:

$$\gamma_i(j) = \frac{\Delta \min + \xi \Delta \max}{\Delta_i(j) + +\xi \Delta \max} \tag{28}$$

where

$$\Delta_i(j) = |x_i(j) - x_0(j)| \tag{29}$$

$$\Delta_{\max} = \max_i \max_j |x_i(j) - x_0(j)| \tag{30}$$

$$\Delta_{\min} = \min_i \min_j |x_i(j) - x_0(j)| \tag{31}$$

ξ is the distinguishing coefficient and $\xi \varepsilon$ [0,1]. ξ which is used to decrease the effect of Δmax is taken as 0.5 in most problems.

Step 5 Calculate the grey relational grade. Grey relational grade between the reference sequence and every comparability sequence is calculated using grey relational coefficients and criteria weights.

$$r_i = \sum_{j=1}^{n} \gamma_i(j) * w_j \tag{32}$$

The alternative with the highest grey relational grade (r_i) is evaluated as the best one.

As mentioned before, one of the significant contributions of this study is the introduction of simulation based GRA which integrates Monte Carlo simulation technique with GRA method to be able to represent the variability and the uncertainty inherent in the data. GRA method works well with objective and discrete data, and its results are

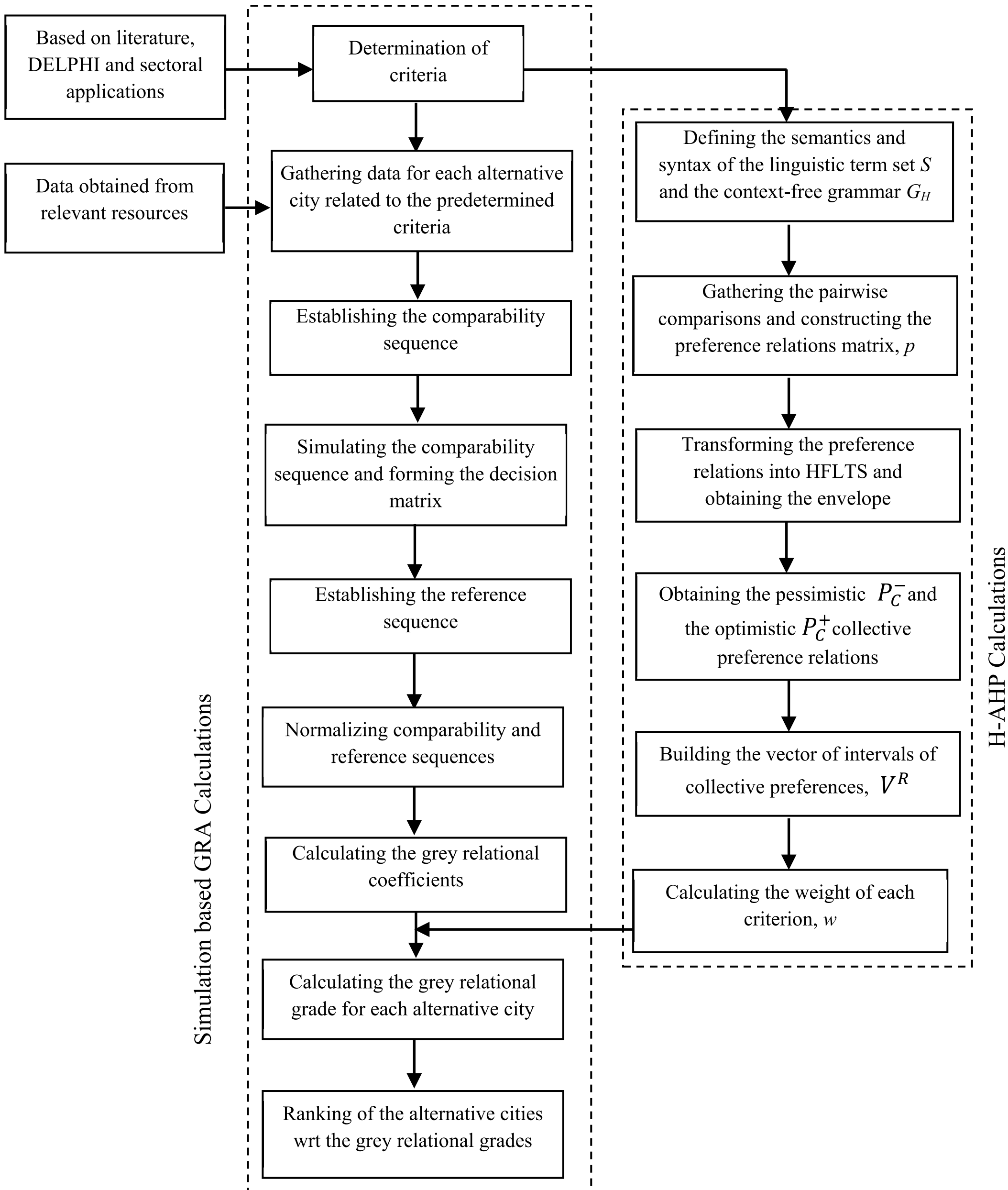

Fig. 1. Proposed strategic food retail location investment framework.

affected by the accuracy and the precision of the data used as the inputs of the model. These data are usually obtained by using statistical techniques and measurement which cause uncertainty. In simulation integrated GRA method, the elements of the comparability matrix are expressed as random variables and Monte Carlo simulation analysis is applied to represent the variability and the uncertainty. This is the main advantage of the simulation integrated GRA method over classical GRA and the previously mentioned methods and techniques.

Table 1
Criteria set for the location (city) selection.

Criterion	Code	Criterion Type	Explanation
Number of competitors in the city	C1	Min	The total sales area of the province (m^2)
Rent levels in the city	C2	Min	Amount of rent per square meter (TL/m^2)
Per capita GDP (gross domestic product) of the city	C3	Max	Amount of income per capita ($/person)
Food retailing consumption amount in the city	C4	Max	Total food expenditure (TL)
Number of enterprises in the city	C5	Max	Number of enterprises (#)
Age distribution of the population in the city	C6	Max	Population rate between the age 18–50 (%)
Urbanization level of the population in the city	C7	Max	Ratio of people living in the midtown (%)
Population density of the city	C8	Max	Number of people per square kilometer (number of people/km^2)
Average saving account amount per person	C9	Max	Amount of saving account per person (TL/person)
Unemployment rate of the city	C10	Min	Ratio of the unemployed people to the population of the city (%)

Table 2
The defined context-free grammar or the binding expression.

Binding expression
Lower than
Greater than
At least
At most
Between
Is (Exactly)

3. Proposed approach

In this study, we propose a simulation based multi-criteria strategic location decision model for food retailing which integrates two MCDM methods which are Hesitant Analytic Hierarchy Process (H-AHP) and Grey Relational Analysis (GRA) methods. The main contribution of this model is that it enables to rank the cities (simulation based GRA) and also to determine the level of importance of each criterion used for assessing the cities for food retailing investment which are two of the most important issues in strategic investment planning applications. In the proposed model, H-AHP method is used to obtain the weights of criteria to be used in GRA based on the experts' judgements whereas simulation based GRA is used for ranking the alternative locations/cities based on the collected data set with respect to the weighted criteria.

The algorithmic procedure for the proposed approach is as follows:

Step 1 Define the criteria and the semantics and syntax of the linguistic term set S and the context-free grammar: Criteria are established based on literature, DELPHI and sectoral applications, and semantics and syntax of the linguistic term set S and the context-free grammar G_H are defined. The production rules are obtained as in Eq. (20).

Step 2 Gather the pairwise comparisons from the experts by using questionnaires and construct the preference relations matrix: To determine the weights of the criteria, a group experts are asked to make pairwise comparisons by using linguistic term sets and the preference relations matrix is formed as in Eq. (21).

Step 3 Transform the preference relations into HFLTS by using the transformation function E_{G_H}: For each HFLTS, an envelope $\left[p_{ij}^{k-}, p_{ij}^{k+}\right]$ is obtained.

Step 4 Obtain the pessimistic and optimistic collective preference relations: The pessimistic and optimistic collective preferences (P_C^- and P_C^+) for each criterion using 2-tuple sets are computed by using Eqs. (22) and (23).

Step 5 Build a vector of intervals of collective preferences for the criteria.

Step 6 Obtain the weight of importance for each criterion: The midpoints of the intervals are calculated and the results are normalized in order to find the weights of the criteria.

Step 7 Establish the comparability sequences: For each alternative, comparability sequence whose elements are defined as triangular random variable with parameters (a, b, c) is established. The probability density function for triangular distribution is defined as in Eq. (33).

$$f(x) = \begin{cases} \frac{2(x-a)}{(c-a)(b-a)}, & a < x < b \\ \frac{2(c-x)}{(c-a)(c-b)}, & b \le x < c \end{cases} \tag{33}$$

where a is the minimum value, c is the maximum value and b is the most likely value.

Step 8 Simulate the comparability sequence: Each element of the comparability matrix which is defined as triangular random

Table 3
Pairwise evaluations of the criteria with respect to goal for Expert 1.

Expert 1's linguistic evaluations										
	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
C1	–	At least (h)	Between (l and h)	Between (vl and m)	At least (h)	At least (m)	Between (l and h)	At most (m)	Between (l and h)	At least (l)
C2	At most (l)	–	At most (l)	Between (l and h)	Between (m and vh)	Between (m and vh)	Between (l and h)	At most (h)	At most (m)	At most (m)
C3	Between (l and h)	At least (h)	-	At least (m)	Between (m and vh)	At least (h)	Between (l and h)	At most (m)	Between (l and h)	At most (h)
C4	Between (m and vh)	Between (l and h)	At most (m)	-	Between (l and vh)	Between (m and vh)	Between (vl and l)	Between (l and h)	Between (l and h)	At most (m)
C5	At most (l)	Between (vl and m)	Between (vl and m)	Between (vl and h)	–	Between (l and h)	At least (vl)	Between (m and vh)	Between (vl and l)	Between (l and m)
C6	At most (m)	Between (vl and m)	At most (l)	Between (vl and m)	Between (l and h)	–	Between (l and h)	At most (m)	Between (l and h)	At most (h)
C7	Between (l and h)	Between (l and h)	Between (l and h)	Between (h and vh)	At most (vh)	Between (l and h)	-	At most (h)	Between (vl and m)	At most (m)
C8	At least (m)	At least (l)	At least (m)	Between (l and h)	Between (vl and m)	At least (m)	At least (l)	-	Between (m and vh)	At least (l)
C9	Between (l and h)	At least (m)	Between (l and h)	Between (l and h)	Between (h and vh)	Between (l and h)	Between (m and vh)	Between (vl and m)	-	Between (l and h)
C10	At most (h)	At least (m)	At least (l)	At least (m)	Between (m and h)	At least (l)	At least (m)	At most (h)	Between (l and h)	-

Table 4
Obtained envelops for the HFLTS given in Table 3.

Expert 1's Obtained Envelops										
Goal	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
C1	–	[h,ah]	[l, h]	[vl,m]	[h,ah]	[m,ah]	[l,h]	[n,m]	[l,h]	[l,ah]
C2	[n,l]	–	[n,l]	[l,h]	[m,vh]	[m,vh]	[l,h]	[n,h]	[n,m]	[n,m]
C3	[l,h]	[h,ah]	–	[m,ah]	[m,vh]	[h,ah]	[l,h]	[n,m]	[l,h]	[n,h]
C4	[m,vh]	[l,h]	[n,m]	–	[l,vh]	[m,vh]	[vl,l]	[l, h]	[l, h]	[n,m]
C5	[n,l]	[vl,m]	[vl,m]	[vl, h]	–	[l,h]	[vl,ah]	[m,vh]	[vl,l]	[l,m]
C6	[n,m]	[vl,m]	[n,l]	[vl,m]	[l,h]	–	[l,h]	[n,m]	[l,h]	[n,h]
C7	[l,h]	[l,h]	[l,h]	[h,vh]	[n,vh]	[l, h]	–	[n,h]	[vl,m]	[n,m]
C8	[m,ah]	[l,ah]	[m,ah]	[l,h]	[vl,m]	[m,ah]	[l,ah]	–	[m,vh]	[l,ah]
C9	[l,h]	[m,ah]	[l,h]	[l,h]	[h,vh]	[l,h]	[m,vh]	[vl,m]	–	[l,h]
C10	[n,h]	[m,ah]	[l,ah]	[m,ah]	[m,h]	[l,ah]	[m,ah]	[n,h]	[l,h]	–

Table 5
The scale for linguistic terms.

A. Low (n)	V. Low (vl)	Low (l)	Medium (m)	High (h)	V. High (vh)	A. High (ah)
0	1	2	3	4	5	6

variable is simulated. The average of the simulated elements are calculated and the decision matrix with the average values is formed as given in Eq. (24).

Step 9 Establish the reference sequence: According to comparability sequences, a reference sequence is generated which consists of the best of criteria.

Step 10 Normalize the data series: The values of the comparability sequences and reference sequence are normalized by using Eqs. (25)–(27).

Step 11 Calculate the grey relational coefficient: Grey relational coefficient which shows the relationship between the reference sequence and comparability sequence is calculated using the normalized values by using Eqs. (28)–(31).

Step 12 Calculate the grey relational grade and rank the alternatives: Grey relational grade between the reference sequence and every comparability sequence is calculated using grey relational coefficients and criteria weights as given in Eq. (32). The alternatives are ranked according to the grey relational grade in descending order to show the preferability. More the grey relational grade, more the alternative's preferability is.

Table 7
Weights of the criteria.

Criteria	Linguistic intervals	Interval utilities	Midpoints	Weights
C1	[(m,.03), (h,-.15)]	[3.03, 3.85]	3.4402	0.1147
C2	[(l,.07), (m,.03)]	[2.07, 3.03]	2.5513	0.085
C3	[(m,.12), (h,.01)]	[3.12, 4.01]	3.5641	0.1188
C4	[(m,-.09), (h,-.20)]	[2.91, 3.80]	3.3547	0.1118
C5	[(l,.44), (m,.33)]	[2.44, 3.33]	2.8889	0.0963
C6	[(l,-.08), (m,-.40)]	[1.92, 2.60]	2.2607	0.0754
C7	[(m,-.46), (m,.34)]	[2.54, 3.34]	2.9402	0.098
C8	[(m,-.14), (h,-.32)]	[2.86, 3.68]	3.2692	0.109
C9	[(l,.49), (m,.25)]	[2.49, 3.25]	2.8675	0.0956
C10	[(l,.46), (m,.26)]	[2.46, 3.26]	2.8632	0.0954

4. An application of the proposed approach

The proposed simulation based multi-criteria strategic location decision model for food or supermarket retailing which integrates H-AHP and simulation based GRA methods aims at finding the level of importance of the criteria to be used in location or city selection (H-AHP) and also ranking the alternative locations or cities (GRA) according to these criteria. Fig. 1 displays framework for the proposed food retail

Table 6
Pessimistic and optimistic collective preferences for the criteria.

Goal	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
Pessimistic Collective Preferences (P_C^-)										
C1	–	(h,-.38)	(l,.23)	(m,-.31)	(h,-.38)	(h,.15)	(m,-.23)	(l,.46)	(l,.46)	(m,.31)
C2	(l, −.38)	–	(vl,.31)	(vl,.46)	(m,-.08)	(m,-.15)	(l,.46)	(l,-.46)	(l,.31)	(l,.15)
C3	(m,-.08)	(m,.08)	–	(l,.31)	(m,-.38)	(h,-.08)	(h,-.15)	(m,.38)	(m,-.46)	(m,.46)
C4	(m,-.46)	(m,-.0)	(m,-.31)	–	(m,.31)	(h,-.23)	(m,-46)	(m,-.38)	(m,.08)	(m,-.38)
C5	(l,-.31)	(l,.31)	(l,.31)	(l,-.15)	–	(m,.31)	(l,.38)	(m,-.46)	(m,-.38)	(m,-.0)
C6	(vl,.15)	(l,.38)	(vl,.38)	(l,-.38)	(l,-.23)	–	(l,.31)	(l,-.23)	(l,.46)	(l,.46)
C7	(l,.46)	(m,-.15)	(vl,.38)	(m,-.46)	(m,-.38)	(m,.23)	–	(l,.08)	(m,.23)	(l,.46)
C8	(m,-.38)	(h,-.38)	(l,.23)	(l,.46)	(m,-.31)	(h,-.38)	(m,-.46)	–	(h,-.38)	(l,.38)
C9	(l,.38)	(m,.08)	(m,-.23)	(l,.38)	(l,-.15)	(m,-.0)	(l,.23)	(l,-.08)	–	(m,-.23)
C10	(l,-.0)	(m,-.23)	(l,-.38)	(l,.46)	(m,-.38)	(m,-.23)	(m,-.15)	(m,-.38)	(l,.46)	–
Optimistic Collective Preferences (P_C^+)										
C1	–	(h,.38)	(m,.08)	(m,.46)	(h,.31)	(vh,-.15)	(h,-.46)	(m,.38)	(h,-.38)	(h,.0)
C2	(l, .38)	–	(m,-.08)	(m,.0)	(h,-.31)	(h,-.38)	(m,.15)	(l,.38)	(m,-.08)	(m,.23)
C3	(h,-.23)	(vh,-.31)	–	(m,.31)	(h,-.31)	(vh,-.38)	(vh,-.38)	(h,-.23)	(m,.23)	(h,.38)
C4	(m,.31)	(vh,-.46)	(h,-.31)	–	(h,.15)	(h,.38)	(m,.46)	(h,-.46)	(h,-.38)	(h,-.46)
C5	(l, .38)	(m,.08)	(m,.38)	(m,-.31)	–	(h, .23)	(m,.38)	(m,.31)	(h,.15)	(m,.38)
C6	(l,-.15)	(m,.15)	(l,.08)	(l, .23)	(m,-.31)	–	(m,-.23)	(l,.38)	(m,.0)	(m,.23)
C7	(m,.23)	(h,-.46)	(l,.15)	(m,.46)	(h,-.38)	(h,-.31)	–	(m,.46)	(h,-.23)	(m,.15)
C8	(h,-.46)	(h,.46)	(m,-.38)	(m,.38)	(m,.46)	(h, .23)	(h,-.08)	–	(h,.08)	(m,.38)
C9	(h,-.46)	(h,-.31)	(m,.46)	(m,-.08)	(m,.38)	(h,-.46)	(m,-.23)	(l,.38)	–	(h,-.46)
C10	(m,-.31)	(h,-.15)	(m,-.46)	(m,.38)	(m,.0)	(h,-.46)	(h,-.46)	(h,-.38)	(m,.23)	–

Table 8
Simulated comparability sequences for the cities.

City	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
Adana	84,640.548	6.991	5166.258	3,333,773,032.078	84,972.946	0.486	0.983	155.399	9561.190	0.132
Adıyaman	12,763.057	4.024	2027.563	464,279,037.305	18,714.184	0.469	0.653	84.981	548.247	0.091
Afyon	28,346.487	5.981	2792.116	690,229,555.535	28,562.947	0.472	0.579	49.333	1553.438	0.056
Ağrı	13,511.942	2.997	1254.928	312,911,569.900	10,489.726	0.436	0.560	47.911	277.665	0.068
Aksaray	14,848.630	3.000	2131.414	301,937,091.276	15,302.854	0.477	0.649	50.768	720.184	0.058
Amasya	15,760.856	4.996	3179.371	392,782,705.002	13,597.782	0.455	0.703	56.588	659.206	0.066
Ankara	262,916.585	8.999	6076.921	7,967,418,459.199	252,071.121	0.524	0.983	209.950	39,624.081	0.102
Antalya	196,548.278	9.005	4839.950	3,815,700,282.240	141,076.469	0.518	0.984	107.177	13,477.809	0.079
Ardahan	4399.044	3.994	1860.836	84,275,471.581	3193.529	0.460	0.368	20.837	176.330	0.058
Artvin	12,393.139	5.013	4712.195	304,883,166.115	8139.658	0.460	0.590	23.044	490.852	0.071
Aydın	71,789.164	7.003	4453.014	1,206,452,878.025	56,358.394	0.470	0.984	132.795	5318.698	0.069
Balıkesir	90,869.963	5.986	4427.323	1,799,379,096.427	58,797.931	0.463	0.984	83.131	5332.640	0.060
Bartın	7500.380	6.018	2340.037	176,382,864.914	7517.845	0.472	0.407	91.013	733.336	0.062
Batman	9600.817	3.981	2682.033	787,964,087.872	12,664.060	0.454	0.784	119.458	436.183	0.234
Bayburt	2798.525	4.014	2246.033	66,635,588.545	2568.641	0.486	0.589	21.549	79.506	0.062
Bilecik	12,000.691	5.011	5702.396	366,498,076.842	7764.503	0.512	0.790	48.830	498.431	0.065
Bingöl	4999.961	4.008	1756.091	156,491,435.695	6795.080	0.505	0.601	32.236	216.319	0.070
Bitlis	5553.367	4.001	1427.586	227,403,356.271	8540.308	0.456	0.573	48.171	197.688	0.106
Bolu	14,839.464	6.020	9297.097	819,716,571.471	12,251.331	0.489	0.699	34.230	875.589	0.096
Burdur	12,149.977	4.998	4306.425	328,744,301.993	14,031.831	0.463	0.664	37.565	840.280	0.069
Bursa	149,213.306	8.007	5536.618	5,884,450,835.553	130,068.692	0.507	0.983	267.434	12,145.655	0.066
Çanakkale	25,278.172	8.010	5159.579	905,696,573.817	27,157.734	0.486	0.589	51.554	2085.605	0.061
Çankırı	6101.017	4.988	2507.745	172,969,451.242	5569.935	0.442	0.697	24.492	364.983	0.068
Çorum	24,984.215	3.999	3652.870	732,215,581.012	21,366.393	0.447	0.726	41.194	1185.478	0.059
Denizli	49,434.347	5.991	4708.844	1,202,572,679.166	52,140.197	0.497	0.983	83.728	4813.815	0.065
Diyarbakır	36,447.513	5.012	2897.158	2,164,550,537.785	40,270.398	0.471	0.984	108.625	1648.552	0.187
Düzce	17,255.047	4.997	2522.745	275,023,237.993	15,191.112	0.494	0.622	138.376	657.521	0.087
Edirne	24,798.571	6.993	5303.535	644,624,446.461	21,615.009	0.488	0.719	66.003	1972.299	0.078
Elazığ	21,069.471	4.004	3764.986	720,924,118.907	21,105.493	0.495	0.763	67.306	1069.090	0.078
Erzincan	7853.133	3.988	2559.022	215,772,198.556	8302.491	0.499	0.571	19.255	557.591	0.067
Erzurum	32,356.642	5.015	2344.927	675,551,888.901	22,931.105	0.479	0.984	30.131	792.371	0.066
Eskişehir	53,191.319	7.988	5546.325	1,716,419,175.931	33,297.454	0.512	0.983	58.670	3715.949	0.085
Gaziantep	47,205.941	7.984	3516.723	2,577,158,079.259	74,043.269	0.468	0.983	277.184	2709.672	0.069
Giresun	21,158.369	4.014	3186.286	520,799,715.777	18,552.112	0.444	0.646	62.865	1295.707	0.065
Gümüşhane	4200.898	4.978	2374.870	125,124,561.851	4469.719	0.505	0.657	22.725	194.354	0.072
Hakkari	799.746	4.009	1845.408	241,082,773.029	5385.022	0.518	0.548	38.483	157.767	0.117
Hatay	44,897.997	4.989	3878.793	2,090,484,892.994	62,487.456	0.468	0.983	260.628	3904.370	0.122
Iğdır	8954.020	4.004	1886.359	165,641,630.811	6867.436	0.460	0.558	53.522	244.473	0.069
Isparta	25,029.935	7.993	3338.199	483,774,187.453	18,376.236	0.484	0.711	50.523	1510.873	0.087
İstanbul	1,066,285.570	17.013	6764.966	23,308,518,633.269	845,520.682	0.546	0.983	2765.915	148,377.365	0.112
İzmir	302,796.859	10.998	7103.591	7,603,719,215.204	215,410.590	0.508	0.983	342.516	31,301.062	0.154
K.Maraş	24,771.218	3.003	3495.722	1,348,596,919.203	35,745.351	0.462	0.983	75.949	1224.362	0.116
Karabük	11,248.181	6.021	3503.989	332,557,175.615	10,119.733	0.503	0.773	56.290	685.194	0.080
Karaman	9652.751	4.005	4442.670	431,052,846.828	10,136.865	0.480	0.725	27.158	563.089	0.042
Kars	14,037.268	3.995	1954.109	260,906,468.021	7811.543	0.474	0.456	29.296	413.765	0.066
Kastamonu	12,557.257	3.990	3935.692	558,982,308.002	16,424.223	0.442	0.609	28.071	958.692	0.062
Kayseri	63,098.116	5.007	3981.257	1,957,583,682.668	50,987.074	0.489	0.984	77.628	2969.588	0.099
Kırıkkale	13,533.137	5.018	6012.992	596,254,836.167	10,011.231	0.481	0.872	59.874	517.507	0.080
Kırklareli	22,602.332	6.003	7929.681	830,755,213.867	17,749.493	0.497	0.700	54.672	1848.547	0.080
Kırşehir	11,391.971	4.012	3283.844	271,110,239.639	8295.697	0.479	0.767	35.062	566.097	0.073
Kilis	4153.882	3.989	4010.733	220,068,954.174	5509.129	0.464	0.746	90.264	105.496	0.077
Kocaeli	101,811.344	7.005	13,592.664	7,329,115,912.734	72,720.341	0.526	0.984	476.980	6353.349	0.101
Konya	69,964.025	6.013	3434.208	1,820,689,329.070	92,755.581	0.481	0.983	54.295	4289.449	0.047
Kütahya	19,351.341	6.984	3984.328	794,294,603.758	22,508.536	0.488	0.688	47.754	965.349	0.060
Malatya	27,433.324	4.001	3123.965	805,059,478.759	27,552.398	0.481	0.984	65.307	1516.455	0.078
Manisa	48,663.890	4.990	5422.648	2,612,983,100.614	62,540.585	0.483	0.983	104.550	3928.820	0.051
Mardin	16,646.591	3.010	2169.903	895,233,946.429	21,562.393	0.451	0.984	89.605	464.737	0.206
Mersin	79,576.137	7.986	5412.323	3,322,290,710.762	76,934.448	0.483	0.984	111.474	6740.160	0.124
Muğla	104,544.475	11.985	7300.196	2,315,606,805.897	62,659.033	0.495	0.982	69.604	7491.438	0.073
Muş	5048.513	2.989	1276.606	244,495,193.347	8774.073	0.436	0.399	51.029	192.715	0.104
Nevşehir	17,729.994	4.989	4676.839	491,170,054.871	14,900.509	0.472	0.608	53.236	643.699	0.060
Niğde	13,356.280	4.000	3930.250	498,642,092.035	12,977.934	0.474	0.548	46.761	668.802	0.061
Ordu	34,673.268	2.996	2350.076	656,876,321.304	28,714.567	0.451	0.983	121.710	1711.106	0.061
Osmaniye	16,139.816	4.988	2552.893	501,970,457.992	18,156.600	0.464	0.757	162.374	665.311	0.140
Rize	16,738.734	5.015	4188.295	528,461,867.930	15,408.239	0.482	0.655	84.099	781.864	0.067
Sakarya	43,991.890	8.007	4656.263	1,342,837,306.891	43,431.345	0.498	0.983	192.862	2154.602	0.094
Samsun	71,099.285	5.997	3712.022	1,813,433,310.906	52,473.702	0.475	0.984	139.668	3583.155	0.066
Siirt	3002.855	3.999	2451.006	406,820,853.860	6133.259	0.444	0.636	58.179	204.839	0.205
Sinop	10,198.316	4.989	3222.092	250,995,624.702	8552.343	0.417	0.564	35.284	622.816	0.062
Sivas	19,406.789	6.004	3088.971	700,420,957.426	21,281.418	0.466	0.731	21.834	1452.262	0.100
Şanlıurfa	29,408.101	4.018	2223.982	1,898,773,474.280	56,228.469	0.424	0.983	98.402	931.485	0.163
Şırnak	2801.013	4.009	1410.201	357,509,505.579	10,634.281	0.449	0.620	68.383	199.364	0.201
Tekirdağ	71,832.486	6.023	5513.764	1,561,608,076.909	44,817.125	0.523	0.983	143.724	3888.232	0.072
Tokat	22,293.525	4.002	3022.920	686,268,686.780	21,035.160	0.453	0.639	60.065	866.782	0.066

(continued on next page)

Table 8 *(continued)*

City	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
Trabzon	41,273.906	4.014	3326.260	979,942,278.848	34,350.887	0.478	0.984	164.515	2698.463	0.074
Tunceli	1200.851	4.030	3497.775	100,356,190.488	2982.397	0.566	0.655	11.645	372.278	0.081
Uşak	16,146.184	5.986	3170.188	418,300,123.959	16,980.411	0.487	0.704	65.422	1472.128	0.054
Van	14,844.454	3.028	1897.338	974,957,022.315	28,710.497	0.456	0.983	56.186	728.880	0.103
Yalova	18,957.114	6.994	7635.740	567,376,987.724	12,548.348	0.484	0.719	267.357	1020.648	0.110
Yozgat	14,662.647	2.990	1881.303	315,891,275.704	16,523.874	0.448	0.627	30.731	671.715	0.086
Zonguldak	29,339.010	4.991	6556.175	1,563,736,345.569	23,674.326	0.481	0.610	181.273	2746.466	0.076

In step 9, the reference sequence is defined using the simulated comparability sequences of 81 cities (Table 8). The reference sequence in the case study is; X_0 = {799.746, 2.989, 13,592.664, 23,308,518,633.269, 845,520.682, 0.566, 0.984, 2765.915, 148,377.365, 0.042}.

location strategic investment model.

The proposed model is applied for the strategic location decision of food retail stores in Turkey since food retailing is a growing sector and where to open new stores is strategically very important for organized supermarket retailers. As a real life application, we investigated the feasibility of investment in food retailing of Turkey's 81 provinces. For this purpose, in step 1, the criteria to be used are obtained by considering literature [9,33,40,116–118], interview with the experts from both academy and sector, and sectoral applications. According to the results of this, 10 criteria are determined which are given in Table 1.

The semantics and syntax of the linguistic term set S is defined as following.

$$S = \left\{ \begin{array}{c} absolutely\ low(n),\ very\ low(vl),\ low(l),\ medium(m), \\ high(h),\ very\ high(vh),\ absolutely\ high(ah) \end{array} \right\}$$

The context-free grammar G_H is defined as given in Table 2.

In step 2, the pairwise comparisons of experts which represent the preference relations (p^ks) as given in Eq. (21) are collected. Table 3 presents the linguistic pairwise evaluations of Expert 1 as sample (see Appendix Table A1 for the linguistic pairwise evaluations of all 13 experts).

In step 3, the preference relations are transformed into HFLTS by using the transformation function E_{G_H}. Then, the envelope of each HFLTS or the HFLTS intervals are obtained. For the sake of keeping the study short and making the methodology be understood more clearly, the rest of the calculations will be given for only the evaluations of Expert 1 (Table 3). For the rest of the evaluations, the same calculations can be easily performed. Table 4 presents the obtained envelops for the values given in Table 3 (see Appendix Table A2 for all the obtained envelops for the HFLTS).

The pairwise evaluations in Table 3 are first expressed as discrete sets, later they are transformed into intervals. For example, Expert 1's preference of *C1* with respect to *C2* is "at least high" in linguistic terms and it can be expressed as discrete set {h,vh,ah} and then as the interval [h, ah]. Similarly, Expert 1's preference of *C1* with respect to *C10* is "at least low" in linguistic terms and it can be expressed as discrete set {l,m,h,vh,ah} and then as the interval [l,ah] as it can be seen in Table 4.

In step 4, the pessimistic and optimistic collective preferences ($P_C^-$and P_C^+) are calculated using 2-tuple operations. Before these calculations, the scale given in Table 5 is assigned to the linguistic terms.

For example, the pessimistic collective preference value for *C1* with respect to *C2* is calculated as follows based on the values given in Table 4;

$$\begin{aligned} P_{12}^- &= \Delta\Big(\tfrac{1}{13}(\Delta^{-1}(h,4) + \Delta^{-1}(vh,5) + \Delta^{-1}(h,4) + \Delta^{-1}(vh,5) + \Delta^{-1}(h,4) \\ &\quad + \Delta^{-1}(h,4) + \Delta^{-1}(n,0) + \Delta^{-1}(m,3) + \Delta^{-1}(h,4) + \Delta^{-1}(h,4) \\ &\quad + \Delta^{-1}(vh,5) + \Delta^{-1}(l,2) + \Delta^{-1}(m,3))\Big) \\ &= \Delta\Big(\tfrac{1}{13}(4+5+4+5+4+4+0+3+4+4+5+2+3)\Big) \\ &= \Delta(3{,}62) = (h, -.38) \end{aligned}$$

Similarly, the optimistic collective preference value for *C1* with respect to *C2* is calculated as follows based on the values given in Table 4;

$$\begin{aligned} P_{12}^+ &= \Delta\Big(\tfrac{1}{13}(\Delta^{-1}(ah,6) + \Delta^{-1}(ah,6) + \Delta^{-1}(vh,5) + \Delta^{-1}(vh,5) \\ &\quad + \Delta^{-1}(vh,5) + \Delta^{-1}(h,4) + \Delta^{-1}(l,2) + \Delta^{-1}(vh,5) + \Delta^{-1}(h,4) \\ &\quad + \Delta^{-1}(h,4) + \Delta^{-1}(vh,5) + \Delta^{-1}(l,2) + \Delta^{-1}(h,4))\Big) \\ &= \Delta\Big(\tfrac{1}{13}(6+6+5+5+5+4+2+5+4+4+5+2+4)\Big) \\ &= \Delta(4{,}38) = (h, .38) \end{aligned}$$

Table 6 gives the pessimistic and optimistic collective preferences for the values given in Appendix Table A2.

In step 5, the linguistic intervals are converted to interval utilities. In Step 6, midpoints of interval utilities are obtained and then weights are obtained by normalizing those midpoints. Table 7 gives linguistic intervals of the criteria, interval utilities associated with them, midpoints and obtained weights of all 10 criteria.

According to the results given in Table 7, the most important criterion is "Per capita GDP (gross domestic product) of the city" (*C3*) with the weight of 11.88% and the least important criterion "Age distribution of the population in the city" (*C6*) with the weight of 7.54%.

In step 7, comparability sequence is established for each of 81 cities in Turkey. The comparability sequence includes values for cities according to the predetermined criteria whose elements are defined as triangular random variables as given in Eq. (33) (see Appendix Table A3 for the comparability sequence of 81 cities). The data related to the predetermined criteria are obtained from the web sites of the 20 organized food retailers operating in Turkey and also from Turkish Statistical Institute as of November 2016.

In step 8, each element of the comparability matrix whose elements are defined as triangular random variables with the parameters given in Appendix Table A3 is simulated. Random numbers are used to conduct a Monte Carlo simulation analysis to better represent the variability and the uncertainty of the comparability matrix. The performance values given in the comparability sequence that come from a triangular probability distribution with the respective parameters are simulated. 1000 simulation runs are conducted to prevent the impact of random variations. The averages of the simulated elements are calculated and the decision matrix with the average values is formed as given in Table 8.

In step 10, the normalized values for each city are calculated by using the GRA. In the application, Eq. (25) for the *C3*, *C4*, *C5*, *C6*, *C7*, *C8* and *C9* criteria, and Eq. (26) for the *C1*, *C2* and *C10* criteria are used. The obtained normalized values for the 81 cities are presented in Table 9.

In step 11, the grey relational coefficient for each data point is calculated using Eqs. (28)–(31) based on the normalized values. The obtained grey relational coefficients for 81 cities are shown in Table 10.

Finally, in step 12, the grey relational grade for each city is calculated using grey relational coefficients and the weights of the criteria which are determined by H-AHP method in Step 6. Then, the cities are ranked according to the obtained grey relational grades. The city with

Table 9
Normalized values of the 81 cities.

City	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
Adana	0.921	0.715	0.317	0.141	0.098	0.464	0.999	0.052	0.064	0.531
Adıyaman	0.989	0.926	0.063	0.017	0.019	0.350	0.463	0.027	0.003	0.744
Afyon	0.974	0.787	0.125	0.027	0.031	0.368	0.342	0.014	0.010	0.927
Ağrı	0.988	0.999	0.000	0.011	0.009	0.130	0.311	0.013	0.001	0.864
Aksaray	0.987	0.999	0.071	0.010	0.015	0.403	0.455	0.014	0.004	0.916
Amasya	0.986	0.857	0.156	0.014	0.013	0.252	0.544	0.016	0.004	0.875
Ankara	0.754	0.571	0.391	0.340	0.296	0.722	0.998	0.072	0.267	0.688
Antalya	0.816	0.571	0.291	0.161	0.164	0.678	0.999	0.035	0.090	0.807
Ardahan	0.997	0.928	0.049	0.001	0.001	0.289	0.000	0.003	0.001	0.916
Artvin	0.989	0.856	0.280	0.010	0.007	0.286	0.361	0.004	0.003	0.849
Aydın	0.933	0.714	0.259	0.049	0.064	0.359	1.000	0.044	0.035	0.859
Balıkesir	0.915	0.786	0.257	0.075	0.067	0.310	1.000	0.026	0.035	0.906
Bartın	0.994	0.784	0.088	0.005	0.006	0.367	0.064	0.029	0.004	0.895
Batman	0.992	0.929	0.116	0.031	0.012	0.250	0.674	0.039	0.002	0.000
Bayburt	0.998	0.927	0.080	0.000	0.000	0.466	0.358	0.004	0.000	0.895
Bilecik	0.989	0.856	0.360	0.013	0.006	0.636	0.684	0.014	0.003	0.880
Bingöl	0.996	0.927	0.041	0.004	0.005	0.593	0.379	0.007	0.001	0.854
Bitlis	0.996	0.928	0.014	0.007	0.007	0.262	0.332	0.013	0.001	0.666
Bolu	0.987	0.784	0.652	0.032	0.011	0.484	0.537	0.008	0.005	0.718
Burdur	0.989	0.857	0.247	0.011	0.014	0.307	0.479	0.009	0.005	0.859
Bursa	0.861	0.642	0.347	0.250	0.151	0.603	0.998	0.093	0.081	0.874
Çanakkale	0.977	0.642	0.316	0.036	0.029	0.461	0.358	0.014	0.014	0.901
Çankırı	0.995	0.857	0.102	0.005	0.004	0.168	0.534	0.005	0.002	0.864
Çorum	0.977	0.928	0.194	0.029	0.022	0.200	0.581	0.011	0.007	0.911
Denizli	0.954	0.786	0.280	0.049	0.059	0.535	0.998	0.026	0.032	0.880
Diyarbakır	0.967	0.856	0.133	0.090	0.045	0.361	0.999	0.035	0.011	0.243
Düzce	0.985	0.857	0.103	0.009	0.015	0.521	0.412	0.046	0.004	0.765
Edirne	0.977	0.714	0.328	0.025	0.023	0.477	0.570	0.020	0.013	0.812
Elazığ	0.981	0.928	0.203	0.028	0.022	0.527	0.642	0.020	0.007	0.813
Erzincan	0.993	0.929	0.106	0.006	0.007	0.554	0.328	0.003	0.003	0.870
Erzurum	0.970	0.856	0.088	0.026	0.024	0.414	0.999	0.007	0.005	0.875
Eskişehir	0.951	0.644	0.348	0.071	0.036	0.640	0.999	0.017	0.025	0.776
Gaziantep	0.956	0.644	0.183	0.108	0.085	0.341	0.999	0.096	0.018	0.859
Giresun	0.981	0.927	0.157	0.020	0.019	0.183	0.450	0.019	0.008	0.880
Gümüşhane	0.997	0.858	0.091	0.003	0.002	0.589	0.469	0.004	0.001	0.844
Hakkari	1.000	0.927	0.048	0.008	0.003	0.679	0.292	0.010	0.001	0.608
Hatay	0.959	0.857	0.213	0.087	0.071	0.344	0.999	0.090	0.026	0.583
Iğdır	0.992	0.928	0.051	0.004	0.005	0.292	0.308	0.015	0.001	0.859
Isparta	0.977	0.643	0.169	0.018	0.019	0.449	0.557	0.014	0.010	0.765
İstanbul	0.000	0.000	0.447	1.000	1.000	0.866	0.998	1.000	1.000	0.634
İzmir	0.717	0.429	0.474	0.324	0.252	0.612	0.998	0.120	0.211	0.416
K.Maraş	0.978	0.999	0.182	0.055	0.039	0.305	0.998	0.023	0.008	0.614
Karabük	0.990	0.784	0.182	0.011	0.009	0.576	0.657	0.016	0.004	0.801
Karaman	0.992	0.928	0.258	0.016	0.009	0.421	0.580	0.006	0.003	1.000
Kars	0.988	0.928	0.057	0.008	0.006	0.383	0.142	0.006	0.002	0.875
Kastamonu	0.989	0.929	0.217	0.021	0.016	0.168	0.391	0.006	0.006	0.895
Kayseri	0.942	0.856	0.221	0.081	0.057	0.485	0.999	0.024	0.019	0.703
Kırıkkale	0.988	0.855	0.386	0.023	0.009	0.430	0.817	0.018	0.003	0.802
Kırklareli	0.980	0.785	0.541	0.033	0.018	0.536	0.539	0.016	0.012	0.801
Kırşehir	0.990	0.927	0.164	0.009	0.007	0.415	0.648	0.009	0.003	0.838
Kilis	0.997	0.929	0.223	0.007	0.003	0.313	0.613	0.029	0.000	0.817
Kocaeli	0.905	0.714	1.000	0.312	0.083	0.730	0.999	0.169	0.042	0.692
Konya	0.935	0.784	0.177	0.075	0.107	0.429	0.998	0.015	0.028	0.973
Kütahya	0.983	0.715	0.221	0.031	0.024	0.478	0.519	0.013	0.006	0.906
Malatya	0.975	0.928	0.151	0.032	0.030	0.428	0.999	0.019	0.010	0.812
Manisa	0.955	0.857	0.338	0.110	0.071	0.441	0.998	0.034	0.026	0.953
Mardin	0.985	0.998	0.074	0.036	0.023	0.231	0.999	0.028	0.003	0.145
Mersin	0.926	0.644	0.337	0.140	0.088	0.446	0.999	0.036	0.045	0.573
Muğla	0.903	0.359	0.490	0.097	0.071	0.525	0.997	0.021	0.050	0.838
Muş	0.996	1.000	0.002	0.008	0.007	0.130	0.049	0.014	0.001	0.676
Nevşehir	0.984	0.857	0.277	0.018	0.015	0.371	0.389	0.015	0.004	0.906
Niğde	0.988	0.928	0.217	0.019	0.012	0.381	0.292	0.013	0.004	0.901
Ordu	0.968	1.000	0.089	0.025	0.031	0.229	0.998	0.040	0.011	0.900
Osmaniye	0.986	0.857	0.105	0.019	0.018	0.315	0.630	0.055	0.004	0.489
Rize	0.985	0.856	0.238	0.020	0.015	0.438	0.466	0.026	0.005	0.869
Sakarya	0.959	0.642	0.276	0.055	0.048	0.544	0.998	0.066	0.014	0.729
Samsun	0.934	0.786	0.199	0.075	0.059	0.388	0.999	0.046	0.024	0.875
Siirt	0.998	0.928	0.097	0.015	0.004	0.182	0.435	0.017	0.001	0.150
Sinop	0.991	0.857	0.159	0.008	0.007	0.000	0.318	0.009	0.004	0.895
Sivas	0.983	0.785	0.149	0.027	0.022	0.330	0.588	0.004	0.009	0.697
Şanlıurfa	0.973	0.927	0.079	0.079	0.064	0.046	0.999	0.031	0.006	0.369
Şırnak	0.998	0.927	0.013	0.013	0.010	0.213	0.409	0.021	0.001	0.171
Tekirdağ	0.933	0.784	0.345	0.064	0.050	0.714	0.998	0.048	0.026	0.843
Tokat	0.980	0.928	0.143	0.027	0.022	0.241	0.440	0.018	0.005	0.875

(continued on next page)

Table 9 *(continued)*

City	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
Trabzon	0.962	0.927	0.168	0.039	0.038	0.408	0.999	0.056	0.018	0.832
Tunceli	1.000	0.926	0.182	0.001	0.000	1.000	0.466	0.000	0.002	0.796
Uşak	0.986	0.786	0.155	0.015	0.017	0.470	0.545	0.020	0.009	0.937
Van	0.987	0.997	0.052	0.039	0.031	0.265	0.999	0.016	0.004	0.681
Yalova	0.983	0.714	0.517	0.022	0.012	0.448	0.569	0.093	0.006	0.645
Yozgat	0.987	1.000	0.051	0.011	0.017	0.210	0.419	0.007	0.004	0.770
Zonguldak	0.973	0.857	0.430	0.064	0.025	0.433	0.393	0.062	0.018	0.823

Table 10
Grey relational coefficients of the 81 cities.

City	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
Adana	0.864	0.637	0.423	0.368	0.357	0.483	0.997	0.345	0.348	0.516
Adıyaman	0.978	0.871	0.348	0.337	0.338	0.435	0.482	0.339	0.334	0.662
Afyon	0.951	0.701	0.364	0.339	0.340	0.442	0.432	0.336	0.336	0.873
Ağrı	0.977	0.999	0.333	0.336	0.335	0.365	0.421	0.336	0.334	0.787
Aksaray	0.974	0.998	0.350	0.336	0.337	0.456	0.478	0.337	0.334	0.857
Amasya	0.973	0.777	0.372	0.336	0.336	0.401	0.523	0.337	0.334	0.800
Ankara	0.670	0.538	0.451	0.431	0.415	0.643	0.995	0.350	0.405	0.616
Antalya	0.731	0.538	0.413	0.373	0.374	0.608	0.999	0.341	0.355	0.722
Ardahan	0.993	0.875	0.345	0.334	0.333	0.413	0.333	0.334	0.333	0.856
Artvin	0.979	0.776	0.410	0.336	0.335	0.412	0.439	0.334	0.334	0.768
Aydın	0.882	0.636	0.403	0.345	0.348	0.438	1.000	0.343	0.341	0.780
Balıkesir	0.855	0.701	0.402	0.351	0.349	0.420	1.000	0.339	0.341	0.842
Bartın	0.988	0.698	0.354	0.334	0.335	0.441	0.348	0.340	0.334	0.827
Batman	0.984	0.876	0.361	0.340	0.336	0.400	0.606	0.342	0.334	0.333
Bayburt	0.996	0.872	0.352	0.333	0.333	0.484	0.438	0.334	0.333	0.827
Bilecik	0.979	0.776	0.439	0.336	0.335	0.579	0.613	0.336	0.334	0.806
Bingöl	0.992	0.873	0.343	0.334	0.334	0.551	0.446	0.335	0.334	0.774
Bitlis	0.991	0.874	0.336	0.335	0.335	0.404	0.428	0.336	0.334	0.599
Bolu	0.974	0.698	0.590	0.341	0.336	0.492	0.519	0.335	0.335	0.639
Burdur	0.979	0.777	0.399	0.336	0.336	0.419	0.490	0.335	0.334	0.780
Bursa	0.782	0.583	0.434	0.400	0.371	0.557	0.995	0.355	0.352	0.799
Çanakkale	0.956	0.583	0.422	0.342	0.340	0.481	0.438	0.337	0.336	0.834
Çankırı	0.990	0.778	0.358	0.334	0.334	0.376	0.517	0.334	0.334	0.786
Çorum	0.957	0.874	0.383	0.340	0.338	0.385	0.544	0.336	0.335	0.849
Denizli	0.916	0.700	0.410	0.345	0.347	0.518	0.995	0.339	0.341	0.806
Diyarbakır	0.937	0.776	0.366	0.355	0.344	0.439	0.998	0.341	0.336	0.398
Düzce	0.970	0.777	0.358	0.335	0.337	0.511	0.460	0.344	0.334	0.680
Edirne	0.957	0.637	0.427	0.339	0.338	0.489	0.537	0.338	0.336	0.727
Elazığ	0.963	0.874	0.386	0.340	0.338	0.514	0.582	0.338	0.335	0.727
Erzincan	0.987	0.875	0.359	0.335	0.335	0.529	0.427	0.334	0.334	0.793
Erzurum	0.944	0.776	0.354	0.339	0.339	0.460	0.999	0.335	0.334	0.800
Eskişehir	0.910	0.584	0.434	0.350	0.342	0.582	0.997	0.337	0.339	0.691
Gaziantep	0.920	0.584	0.380	0.359	0.353	0.432	0.997	0.356	0.337	0.780
Giresun	0.963	0.872	0.372	0.338	0.338	0.380	0.476	0.338	0.335	0.806
Gümüşhane	0.994	0.779	0.355	0.334	0.334	0.549	0.485	0.334	0.334	0.762
Hakkari	1.000	0.873	0.344	0.335	0.334	0.609	0.414	0.336	0.333	0.561
Hatay	0.924	0.778	0.388	0.354	0.350	0.432	0.997	0.355	0.339	0.545
Iğdır	0.985	0.874	0.345	0.334	0.334	0.414	0.419	0.337	0.334	0.780
Isparta	0.956	0.584	0.376	0.337	0.338	0.476	0.530	0.336	0.335	0.680
İstanbul	0.333	0.333	0.475	1.000	1.000	0.789	0.996	1.000	1.000	0.578
İzmir	0.638	0.467	0.487	0.425	0.401	0.563	0.996	0.362	0.388	0.461
K.Maraş	0.957	0.998	0.379	0.346	0.342	0.418	0.996	0.339	0.335	0.564
Karabük	0.981	0.698	0.379	0.336	0.335	0.541	0.593	0.337	0.334	0.716
Karaman	0.984	0.873	0.403	0.337	0.335	0.463	0.543	0.335	0.334	1.000
Kars	0.976	0.875	0.346	0.335	0.335	0.447	0.368	0.335	0.334	0.799
Kastamonu	0.978	0.875	0.390	0.338	0.337	0.375	0.451	0.335	0.335	0.827
Kayseri	0.895	0.777	0.391	0.352	0.347	0.492	0.998	0.339	0.338	0.627
Kırıkkale	0.977	0.776	0.449	0.338	0.335	0.467	0.732	0.337	0.334	0.716
Kırklareli	0.961	0.699	0.521	0.341	0.337	0.518	0.520	0.337	0.336	0.716
Kırşehir	0.981	0.873	0.374	0.335	0.335	0.461	0.587	0.335	0.334	0.755
Kilis	0.994	0.875	0.392	0.335	0.334	0.421	0.564	0.340	0.333	0.732
Kocaeli	0.841	0.636	1.000	0.421	0.353	0.650	0.998	0.376	0.343	0.619
Konya	0.885	0.699	0.378	0.351	0.359	0.467	0.997	0.337	0.340	0.949
Kütahya	0.966	0.637	0.391	0.340	0.339	0.489	0.510	0.336	0.335	0.842
Malatya	0.952	0.874	0.371	0.341	0.340	0.467	0.998	0.338	0.336	0.727
Manisa	0.918	0.778	0.430	0.360	0.350	0.472	0.997	0.341	0.339	0.914
Mardin	0.971	0.997	0.351	0.341	0.338	0.394	0.998	0.340	0.334	0.369
Mersin	0.871	0.584	0.430	0.368	0.354	0.474	0.998	0.342	0.344	0.540
Muğla	0.837	0.438	0.495	0.356	0.350	0.513	0.994	0.338	0.345	0.755

(continued on next page)

Table 10 *(continued)*

City	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
Muş	0.992	1.000	0.334	0.335	0.335	0.365	0.345	0.337	0.334	0.607
Nevşehir	0.969	0.778	0.409	0.337	0.337	0.443	0.450	0.337	0.334	0.841
Niğde	0.977	0.874	0.390	0.338	0.336	0.447	0.414	0.336	0.334	0.834
Ordu	0.940	0.999	0.354	0.339	0.340	0.393	0.997	0.342	0.336	0.834
Osmaniye	0.972	0.778	0.358	0.338	0.337	0.422	0.575	0.346	0.334	0.495
Rize	0.971	0.776	0.396	0.338	0.337	0.471	0.483	0.339	0.334	0.792
Sakarya	0.925	0.583	0.408	0.346	0.344	0.523	0.997	0.349	0.336	0.649
Samsun	0.883	0.700	0.384	0.351	0.347	0.450	0.998	0.344	0.339	0.799
Siirt	0.996	0.874	0.356	0.337	0.334	0.379	0.470	0.337	0.334	0.370
Sinop	0.983	0.778	0.373	0.335	0.335	0.333	0.423	0.335	0.334	0.827
Sivas	0.966	0.699	0.370	0.340	0.338	0.427	0.548	0.334	0.335	0.623
Şanlıurfa	0.949	0.872	0.352	0.352	0.348	0.344	0.997	0.340	0.335	0.442
Şırnak	0.996	0.873	0.336	0.336	0.335	0.388	0.458	0.338	0.334	0.376
Tekirdağ	0.882	0.698	0.433	0.348	0.345	0.636	0.997	0.344	0.339	0.762
Tokat	0.961	0.874	0.369	0.339	0.338	0.397	0.472	0.337	0.335	0.800
Trabzon	0.929	0.872	0.375	0.342	0.342	0.458	0.998	0.346	0.337	0.749
Tunceli	0.999	0.871	0.379	0.334	0.333	1.000	0.483	0.333	0.334	0.711
Uşak	0.972	0.701	0.372	0.337	0.337	0.486	0.524	0.338	0.335	0.888
Van	0.974	0.994	0.345	0.342	0.340	0.405	0.998	0.337	0.334	0.611
Yalova	0.967	0.636	0.509	0.338	0.336	0.475	0.537	0.355	0.335	0.585
Yozgat	0.975	1.000	0.345	0.336	0.337	0.388	0.463	0.335	0.334	0.685
Zonguldak	0.949	0.778	0.467	0.348	0.339	0.469	0.452	0.348	0.337	0.738

Table 11
Grey relational grades and ranks of the 81 cities.

City	Grey Relational Grade	Rank	City	Grey Relational Grade	Rank
Adana	0.533	33	K.Maraş	0.563	12
Adıyaman	0.510	68	Karabük	0.523	47
Afyon	0.510	67	Karaman	0.557	17
Ağrı	0.519	54	Kars	0.512	65
Aksaray	0.540	30	Kastamonu	0.523	46
Amasya	0.518	55	Kayseri	0.552	19
Ankara	0.546	23	Kırıkkale	0.545	24
Antalya	0.540	28	Kırklareli	0.529	38
Ardahan	0.512	63	Kırşehir	0.534	32
Artvin	0.512	64	Kilis	0.530	37
Aydın	0.551	20	Kocaeli	0.630	2
Balıkesir	0.558	15	Konya	0.572	6
Bartın	0.500	73	Kütahya	0.518	57
Batman	0.491	79	Malatya	0.570	8
Bayburt	0.526	42	Manisa	0.587	3
Bilecik	0.549	22	Mardin	0.540	29
Bingöl	0.526	43	Mersin	0.531	36
Bitlis	0.496	76	Muğla	0.544	27
Bolu	0.529	39	Muş	0.496	75
Burdur	0.518	56	Nevşehir	0.522	48
Bursa	0.559	14	Niğde	0.525	45
Çanakkale	0.508	69	Ordu	0.582	4
Çankırı	0.514	60	Osmaniye	0.495	78
Çorum	0.532	35	Rize	0.522	50
Denizli	0.568	9	Sakarya	0.545	25
Diyarbakır	0.528	40	Samsun	0.557	16
Düzce	0.508	71	Siirt	0.479	80
Edirne	0.513	62	Sinop	0.507	72
Elazığ	0.535	31	Sivas	0.499	74
Erzincan	0.526	44	Şanlıurfa	0.533	34
Erzurum	0.564	10	Şırnak	0.477	81
Eskişehir	0.554	18	Tekirdağ	0.572	5
Gaziantep	0.550	21	Tokat	0.520	53
Giresun	0.520	52	Trabzon	0.570	7
Gümüşhane	0.522	51	Tunceli	0.562	13
Hakkari	0.508	70	Uşak	0.527	41
Hatay	0.545	26	Van	0.564	11
Iğdır	0.513	61	Yalova	0.511	66
Isparta	0.496	77	Yozgat	0.516	59
İstanbul	0.748	1	Zonguldak	0.522	49
İzmir	0.518	58			

the highest grey relational grade is evaluated as the best alternative. The grey relational grade and rank values for cities are given in Table 11.

According to the results given in Table 11, the best 5 cities for food retail investment are İstanbul, Kocaeli, Manisa, Ordu and Tekirdağ with the relational grades of 0.748, 0.630, 0.587, 0.582 and 0.572 respectively. The worst 5 cities are Isparta, Osmaniye, Batman, Siirt and Şırnak with the relational grades of 0.496, 0.495, 0.491, 0.479 and 0.477 respectively. The average of relational grades of 81 cities is 0.534. Among 81 cities, only 32 cities have relational grades which are equal to or more than the average. The other 49 cities' relational grades are below the average.

5. Results and discussion

The main problem in the retail location selection problem is to estimate the market potential or attractiveness of the location and it is difficult to calculate the actual values of them. The proposed model is successfully applied for evaluating Turkey's 81 cities according to their attractiveness of food retail investment based on the original and actual data. When looked at the application results, it is seen that Istanbul is the first in the ranking. This is no surprise since Istanbul is the most populated and the most industrialized city of Turkey. Another reason can be that Istanbul city has the best values in terms of the four evaluation criteria which distinguishes it from the other cities. Besides, when looked carefully, it can be seen that there are quite surprising cities in the first 10. For example, Manisa, Ordu, Malatya, Denizli and Erzurum are in the first 10 in the ranking, which means that there is an important potential for organized food retail investments in these cities, which is not possible to estimate without a mathematical and comprehensive analysis. Besides, Ankara, which is the capital city and the second most populated city of Turkey, is the 23rd in the ranking and İzmir, which is the third most populated city of Turkey, is the 58th in the ranking which indicates the market saturation in these cities. The similar results can be derived as the final ranking is analyzed deeply which is left to the interested readers. It should also be stated that organized food retailers usually want to know other attractive cities other than the clearly known ones for their investments. For this reason, the main objective of this study in the application should be seen as the ranking of cities, not as choice of city/alternative.

When the organized food retailers decide to invest for enlarging their market or penetrating new markets depending on their current strategy (aggressive, balanced etc.), the first thing they need is to decide where to begin and how to allocate their resources effectively. The methodology presented in this study can help the decision and policy makers for such decisions. In terms of the application results, if an organized food retailer wants to enlarge its market by penetrating new cities, it can easily decide which new cities and in what order it can invest. If it chooses a balanced growth strategy, it may only consider the first 32 cities which have relational grades which are equal to or more than the average. If it chooses an aggressive growth strategy, it may consider all 81 cities and select the ones in which it has no presence. This may also cause other important decisions to be considered related to supply chain and logistics.

Another way of using the results can be for evaluating the position of the organized food retailer. It may question its nonpresence in the cities which are above in the ranking while it has presence in the cities which are below in the ranking. It may even consider to close some stores and open new ones in different cities by analyzing the results.

The possible limitation of the study is that the future food demands of cities are not included. As stated before, a total of 10 criteria were used to reveal the attractiveness or the potential for organized food retailing to reflect the different dimensions. The related data were obtained from the 20 organized retailers' (which constitutes to about 70% of the sector) web sites and also from Turkish Statistical Institute. Unfortunately, there are no other relevant data or study including the market city by city. There is also another problem about forecasting the market potential. Unfortunately, the organized food retailers do not share their revenues for each city, and also there are unregistered transactions in local food bazaars and local non-organized supermarkets. This makes almost impossible to forecast the food demand city by city for our case. We think it may quite increase the utility of the presented methodology if the forecast of future food demand is included.

6. Conclusion

Food retailing is a growing sector and where to open new stores is strategically very important for organized food retailers since the location of retail store provides competitive and unique advantage, and has great effect on overall success of the retailer. Food retailers also need to expand their markets and reach more customers in order to maintain their presence in this competitive environment. Most of the studies related to the subject are mostly applied for small regions whereas this study handles the problem at a strategic level by considering all the cities in the country, which is one of the significant contributions of the study. This study presents a hybrid multi-criteria strategic location decision model for food retailing. This model integrates two MCDM methods that are H-AHP and simulation based GRA. Since the proposed model enables to rank alternative locations (simulation based GRA) and also to determine the level of importance of each criterion (H-AHP), the results can give guidance to many strategic decisions and actions.

Importance of this study is the hybrid usage of MCDM methods for the strategic retail location investment decision in such an integrated manner. Another contribution is the Monte Carlo simulation based GRA method proposed which can be helpful in many real life problems and applications. The authors also think that this study may lead the researchers to more focus on studying retail location selection problems at a macro and strategic level.

The criteria used in the application are based on literature, interview with the experts from both academy and sector, and sectoral applications. The methodology presented provides the flexibility of removing or adding some new criteria which increases the applicability of the approach. In terms of practical implications, the presented methodology can be used for other strategic location selection problems other than food retailing by modifying the criteria.

For further research, in addition to the application of the presented methodology for other MCDM problems and evaluation problems related to retailing, the application of the presented simulation based GRA method and its integration with other fuzzy MCDM methods can be a promising area for interested researchers.

Appendix A

Table A1
Pairwise evaluations of the criteria with respect to goal.

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
Expert 1's linguistic evaluations										
C1	–	At least (h)	Between (l and h)	Between (vl and m)	At least (h)	At least (m)	Between (l and h)	At most (m)	Between (l and h)	At least (l)
C2	At most (l)	–	At most (l)	Between (l and h)	Between (m and vh)	Between (m and vh)	Between (l and h)	At most (h)	At most (m)	At most (m)
C3	Between (l and h)	At least (h)	–	At least (m)	Between (m and vh)	At least (h)	Between (l and h)	At most (m)	Between (l and h)	At most (h)
C4	Between (m and vh)	Between (l and h)	At most (m)	–	Between (l and vh)	Between (m and vh)	Between (vl and l)	Between (l and h)	Between (l and h)	At most (m)
C5	At most (l)	Between (vl and m)	Between (vl and m)	Between (vl and h)	–	Between (l and h)	At least (vl)	Between (m and vh)	Between (vl and l)	Between (l and m)
C6	At most (m)	Between (vl and m)	At most (l)	Between (vl and m)	Between (l and h)	–	Between (l and h)	At most (m)	Between (l and h)	At most (h)
C7	Between (l and h)	Between (l and h)	Between (l and h)	Between (h and vh)	At most (vh)	Between (l and h)	–	At most (h)	Between (vl and m)	At most (m)
C8	At least (m)	At least (l)	At least (m)	Between (l and h)	Between (vl and m)	At least (m)	At least (l)	–	Between (m and vh)	At least (l)
C9	Between (l and h)	At least (m)	Between (l and h)	Between (l and h)	Between (h and vh)	Between (l and h)	Between (m and vh)	Between (vl and m)	–	Between (l and h)
C10	At most (h)	At least (m)	At least (l)	At least (m)	Between (m and h)	At least (l)	At least (m)	At most (h)	Between (l and h)	–
Expert 2's linguistic evaluations										

C1	–	Between(vh and ah)	Is (m)	Between (h and vh)	Is (ah)	Between (l and h)	At most (l)	At most (n)	At least (l)	Between (m and h)
C2	Between (n and vl)	–	At most (m)	Between (vl and m)	Between (m and h)	Is (vl)	At least (vh)	Is (n)	Between (m and h)	At least (m)
C3	Is (m)	At least (m)	–	Is (n)	At most (h)	Is (m)	Between (l and m)	Is (vl)	At most (l)	Is (ah)
C4	Between (vl and l)	Between (m and vh)	Is (ah)	–	Is (m)	Between (m and h)	Is (n)	Is (l)	Is (m)	Between (l and m)
C5	Is (n)	Between (l and m)	At least (l)	Is (m)	–	At least (h)	Is (h)	Between (m and h)	At most (m)	Between (l and m)
C6	Between (l and h)	Is (vh)	Is (m)	Between (l and m)	At most (l)	–	At most (l)	Is (m)	At most (m)	At most (l)
C7	At least (h)	At most (vl)	Between (m and h)	Is (ah)	Is (l)	At least (h)	–	Between (h and vh)	Between (h and vh)	At least (l)
C8	At least (ah)	Is (ah)	Is (vh)	Is (h)	Between (l and m)	Is (m)	Between (vl and l)	–	Is (vh)	At least (l)
C9	At most (h)	Between (l and m)	At least (h)	Is (m)	At least (m)	At least (m)	Between (vl and l)	Is (vl)	–	Is (m)
C10	Between (l and m)	At most (m)	Is (n)	Between (m and h)	Between (m and h)	At least (h)	At most (h)	At most (h)	Is (m)	–
Expert 3's linguistic evaluations										
C1	–	Between (h and vh)	Between (l and m)	Is (m)	At most (l)	At least (vh)	Between (m and h)	Between (m and h)	At least (h)	Is (m)
C2	Between (vl and l)	–	At most (l)	Between (vl and l)	At most (l)	Between (m and h)	Between (l and m)	At most (m)	At least (m)	At most (l)
C3	Between (m and h)	At least (h)	–	At least (h)	Between (h and vh)	Between(vh and ah)	At least (h)	At least (vh)	At least (vh)	Between (h and vh)
C4	Is (m)	Between (h and vh)	At most (l)	–	At least (m)	Between (h and vh)	At least (h)	Between (m and h)	At least (vh)	Is (m)
C5	At least (h)	At least (h)	Between (vl and l)	At most (m)	–	Between(vh and ah)	Between (h and vh)	At least (vh)	At least (h)	Between (m and h)
C6	At most (vl)	Between (l and m)	Between (n and vl)	Between (vl and l)	Between (n and vl)	–	Is (vl)	Is (m)	Between (vl and l)	Is (l)
C7	Between (l and m)	Between (m and h)	At most (l)	At most (l)	Between (vl and l)	Is (vh)	–	Between (m and h)	Between (vl and l)	Between (l and m)
C8	Between (l and m)	At least (m)	At most (vl)	Between (l and m)	At most (vl)	Is (m)	Between (l and m)	–	At least (vh)	Between (m and h)
C9	At most (l)	At most (m)	At most (vl)	At most (vl)	At most (l)	Between (h and vh)	Between (h and vh)	At most (vl)	–	Between (vl and l)
C10	Is (m)	At least (h)	Between (vl and l)	Is (m)	Between (l and m)	Is (h)	Between (m and h)	Between (l and m)	Between (h and vh)	–
Expert 4's linguistic evaluations										
C1	–	Is (vh)	Is (n)	Between (vl and l)	At most (l)	Is (h)	Is (m)	Is (m)	Is (l)	Is (vl)
C2	Is (vl)	–	Is (l)	At least (l)	Is (l)	At least (m)	Is (m)	Between (vl and l)	Is (l)	Is (l)
C3	Is (ah)	Is (h)	–	At most (l)	Is (m)	At least (h)	Is (h)	Is (h)	Is (m)	Is (m)
C4	Between (h and vh)	At most (h)	At least (h)	–	Is (vh)	Is (ah)	At least (h)	Between (h and vh)	Is (h)	At least (h)
C5	At least (h)	Is (h)	Is (m)	Is (vl)	–	Is (h)	Between (m and h)	Is (m)	At least (l)	Is (m)
C6	Is (l)	At most (m)	At most (l)	Is (n)	Is (l)	–	Is (l)	Between (l and m)	Is (vl)	Is (l)
C7	Is (m)	Is (m)	Is (l)	At most (l)	Between (l and m)	Is (h)	–	Is (m)	Is (l)	Is (m)
C8	Is (m)	Between (h and vh)	Is (l)	Between (vl and l)	Is (m)	Between (m and h)	Is (m)	–	At most (l)	Is (l)
C9	Is (h)	Is (h)	Is (m)	Is (l)	At most (h)	Is (vh)	Is (h)	At least (h)	–	At most (h)
C10	Is (vh)	Is (h)	Is (m)	At most (l)	Is (m)	Is (h)	Is (m)	Is (h)	At least (l)	–
Expert 5's linguistic evaluations										
C1	–	Between (h and vh)	Is (h)	Is (m)	Is (ah)	Is (ah)	Is (ah)	Is (h)	Between (l and m)	Is (vh)
C2	Between (vl and l)	–	Is (l)	Is (n)	Is (m)	Is (l)	Is (l)	Is (l)	Is (m)	Between (h and vh)
C3	Is (l)	Is (h)	–	At least (m)	At least (m)	Is (h)	Is (ah)	Is (l)	Is (h)	Is (ah)
C4	Is (m)	Is (ah)	At most (m)	–	Is (m)	At least (m)	Is (h)	At least (m)	Is (h)	Is (ah)
C5	Is (n)	Is (m)	At most (m)	Is (m)	–	Between (h and vh)	Is (l)	Is (vl)	Is (h)	Is (ah)
C6	Is (n)	Is (h)	Is (l)	At most (m)		–	Is (m)	At most (vl)	Is (m)	At most (l)

					Between (vl and l)					
C7	Is (n)	Is (h)	Is (n)	Is (l)	Is (h)	Is (m)	–	At most (l)	Is (m)	Is (m)
C8	Is (l)	Is (h)	Is (h)	At most (m)	Is (vh)	At least (vh)	At least (h)	–	Is (h)	Is (h)
C9	Between (m and h)	Is (m)	Is (l)	Is (l)	Is (l)	Is (m)	Is (m)	Is (l)	–	Is (m)
C10	Is (vl)	Between (vl and l)	Is (n)	Is (n)	Is (n)	At least (h)	Is (m)	Is (l)	Is (m)	–
Expert 6's linguistic evaluations										
C1	–	Is (h)	At least (m)	Between (m and h)	Greater than (l)	Between (m and h)	Is (m)	At least (m)	Is (m)	Is (m)
C2	Is (l)	–	At least (m)	Between (l and m)	Greater than (l)	Between (m and vh)	Is (l)	Between (l and h)	Is (h)	Is (l)
C3	At most (m)	At most (m)	–	At least (m)	Is (m)	Between (m and vh)	Between (m and h)	Is (ah)	Is (m)	Between (l and m)
C4	Between (l and m)	Between (m and h)	At most (m)	–	Between (l and h)	Is (h)	Between (m and h)	Between (l and m)	Is (l)	Is (n)
C5	Lower than (h)	Lower than (h)	Is (m)	Between (l and h)	–	Is (h)	At least (m)	Is (vh)	Is (vh)	Is (m)
C6	Between (l and m)	Between (vl and m)	Between (vl and m)	Is (l)	Is (l)	–	Between (m and h)	Is (l)	Is (m)	Greater than (h)
C7	Is (m)	Is (h)	Between (l and m)	Between (l and m)	At most (m)	Between (l and m)	–	Between (l and m)	Between (m and vh)	Is (m)
C8	At most (m)	Between (l and h)	Is (n)	Between (m and h)	Is (vl)	Is (h)	Between (m and h)	–	Is (vh)	Is (vl)
C9	Is (m)	Is (l)	Is (m)	Is (h)	Is (vl)	Is (m)	Between (vl and m)	Is (vl)	–	Greater than (m)
C10	Is (m)	Is (h)	Between (m and h)	Is (ah)	Is (m)	Lower than (l)	Is (m)	Is (vh)	Lower than (m)	–
Expert 7's linguistic evaluations										
C1	–	At most (l)	Lower than (vl)	Is (h)	Is (n)	Greater than (m)	Lower than (l)	Is (vl)	Lower than (l)	Lower than (h)
C2	At least (h)	–	Lower than (n)	Is (m)	Is (ah)	Is (h)	Lower than (vl)	Lower than (vl)	Is (vl)	Between (l and m)
C3	Greater than (vh)	Greater than (ah)	–	Is (h)	Is (vl)	Is (h)	Between(vh and ah)	Is (m)	Is (vl)	Is (m)
C4	Is (l)	Is (m)	Is (l)	–	Greater than (vh)	Is (l)	Greater than (l)	Is (l)	Is (m)	Lower than (h)
C5	Is (ah)	Is (n)	Is (vh)	Lower than (vl)	–	Is (vh)	Is (l)	Is (vl)	Is (vl)	Is (vh)
C6	Lower than (m)	Is (l)	Is (l)	Is (h)	Is (vl)	–	Is (m)	Is (l)	Is (l)	Is (h)
C7	Greater than (h)	Greater than (vh)	Between (n and vl)	Lower than (h)	Is (h)	Is (m)	–	Lower than (n)	Greater than (ah)	Is (l)
C8	Is (vh)	Greater than (vh)	Is (m)	Is (h)	Is (vh)	Is (h)	Greater than (ah)	–	Is (m)	Is (h)
C9	Greater than (h)	Is (vh)	Is (vh)	Is (m)	Is (vh)	Is (h)	Lower than (n)	Is (m)	–	Is (h)
C10	Greater than (l)	Between (m and h)	Is (m)	Greater than (l)	Is (vl)	Is (l)	Is (h)	Is (l)	Is (l)	–
Expert 8's linguistic evaluations										
C1	–	Between (m and vh)	At most (h)	At least (m)	Is (h)	Greater than (vh)	At most (h)	At most (h)	At most (h)	Greater than (h)
C2	Between (vl and m)	–	At least (n)	At least (vl)	At least (vh)	At least (vh)	At most (h)	Is (l)	Is (m)	At least (m)
C3	At least (l)	At most (ah)	–	Is (vl)	At least (h)	At least (vh)	At least (h)	Is (m)	At most (l)	At least (vl)
C4	At most (m)	At most (vh)	Is (vh)	–	At least (h)	Is (ah)	Between (l and h)	At most (m)	At most (l)	At least (h)
C5	Is (l)	At most (vl)	At most (l)	At most (l)	–	At most (vl)	Is (n)	At least (l)	At least (vl)	At least (vh)
C6	Lower than (vl)	At most (vl)	At most (vl)	Is (n)	At least (vh)	–	Is (vh)	At most (l)	Between (h and vh)	Is (h)
C7	At least (l)	At least (l)	At most (l)	Between (l and h)	Is (ah)	Is (vl)	–	At least (l)	Is (vh)	At least (vh)
C8	At least (l)	Is (h)	Is (m)	At least (m)	At most (h)	At least (h)	At most (h)	–	Is (m)	At most (h)
C9	At least (l)	Is (m)	At least (h)	At least (h)	At most (vh)	Between (vl and l)	Is (vl)	Is (m)	–	Is (vh)
C10	Lower than (l)	At most (m)	At most (vh)	At most (l)	At most (vl)	Is (l)	At most (vl)	At least (l)	Is (vl)	–
Expert 9's linguistic evaluations										
C1	–	Is (h)	Is (l)	Is (n)	Is (ah)	Is (vh)	Is (h)			Is (vh)

								Between(vh and ah)	Between (h and vh)	
C2	Is (l)	–	Is (vl)	Is (vl)	Is (h)	Is (m)	Is (vh)	Is (m)	Is (l)	Is (h)
C3	Is (h)	Is (vh)	–	Is (vl)	Between(vh and ah)	Is (h)	Is (m)	Is (h)	Between (vl and l)	Is (ah)
C4	Is (ah)	Is (vh)	Is (vh)	–	Is (h)	Is (h)	Is (vl)	Is (l)	Between (l and m)	Is (h)
C5	Is (n)	Is (l)	Between (n and vl)	Is (l)	–	Is (l)	Between (m and vh)	Between (n and vl)	Is (m)	Is (n)
C6	Is (vl)	Is (m)	Is (l)	Is (l)	Is (h)	–	Is (m)	Is (vl)	Is (vh)	Is (h)
C7	Is (l)	Is (vl)	Is (m)	Is (vh)	Between (vl and m)	Is (m)	–	Is (h)	Is (l)	Is (m)
C8	Between (n and vl)	Is (m)	Is (l)	Is (h)	Between(vh and ah)	Is (vh)	Is (l)	–	Is (vh)	Is (l)
C9	Between (vl and l)	Is (h)	Between (h and vh)	Between (m and h)	Is (m)	Is (vl)	Is (h)	Is (vl)	–	Is (h)
C10	Is (vl)	Is (l)	Is (n)	Is (l)	Is (ah)	Is(l)	Is (m)	Is (h)	Is (l)	–
Expert 10's linguistic evaluations										
C1	–	Is (h)	Is (h)	Is (ah)	Is (ah)	Is (m)	Is (m)	Is (m)	Is (m)	Is (vh)
C2	Is (l)	–	Is (vh)	Is (l)	Is (h)	Is (m)	Is (h)	Is (h)	Is (h)	Is (l)
C3	Is (l)	Is (vl)	–	Is (ah)	Is (l)	Is (ah)	Is (ah)	Is (m)	Is (m)	Is (vh)
C4	Is (n)	Is (h)	Is (n)	–	Is (m)	Is (vh)	Is (n)	Is (m)	Is (h)	Is (l)
C5	Is (n)	Is (l)	Is (h)	Is (m)	–	Is (vh)	Is (m)	Is (m)	Is (h)	Is (h)
C6	Is (m)	Is (m)	Is (n)	Is (vl)	Is (vl)	–	Is (n)	Is (l)	Is (h)	Is (h)
C7	Is (m)	Is (l)	Is (n)	Is (ah)	Is (m)	Is (ah)	–	Is (l)	Is (h)	Is (h)
C8	Is (m)	Is (l)	Is (m)	Is (m)	Is (m)	Is (h)	Is (h)	–	Is (vh)	Is (vh)
C9	Is (m)	Is (l)	Is (m)	Is (l)	Is (l)	Is (l)	Is (l)	Is (vl)	–	Is (vh)
C10	Is (vl)	Is (h)	Is (vl)	Is (h)	Is (l)	Is (l)	Is (l)	Is (vl)	Is (vl)	–
Expert 11's linguistic evaluations										
C1	–	Is (vh)	Is (h)	Is (m)	Is (h)	Is (vh)	Is (h)	Is (h)	Is (vh)	Is (h)
C2	Is (vl)	–	Is (l)	Is (vl)	Is (n)	Is (m)	Is (l)	Is (l)	Is (m)	Is (vl)
C3	Is (l)	Is (h)	–	Is (l)	Is (vl)	Is (h)	Is (m)	Is (h)	Is (h)	Is (m)
C4	Is (m)	Is (vh)	Is (h)	–	Is (l)	Is (h)	Is (h)	Is (h)	Is (vh)	Is (h)
C5	Is (l)	Is (ah)	Is (vh)	Is (h)	–	Is (h)	Is (h)	Is (vh)	Is (vh)	Is (vh)
C6	Is (vl)	Is (m)	Is (l)	Is (l)	Is (l)	–	Is (h)	Is (vh)	Is (vh)	Is (h)
C7	Is (l)	Is (h)	Is (m)	Is (l)	Is (l)	Is (l)	–	Is (h)	Is (vh)	Is (h)
C8	Is (l)	Is (h)	Is (l)	Is (l)	Is (vl)	Is (vl)	Is (l)	–	Is (h)	Is (l)
C9	Is (vl)	Is (m)	Is (l)	Is (vl)	Is (vl)	Is (vl)	Is (vl)	Is (l)	–	Is (vl)
C10	Is (l)	Is (vh)	Is (m)	Is (l)	Is (vl)	Is (l)	Is (l)	Is (h)	Is (vh)	–
Expert 12's linguistic evaluations										
C1	–	Is (l)	Is (l)	Between (vl and l)	Is (m)	Is (m)	Is (l)	Is (n)	Is (n)	Is (vl)
C2	Is (h)	–	Is (vl)	Is (l)	Is (h)	Is (m)	Is (l)	Is (vl)	Is (vl)	Is (l)
C3	Is (h)	Is (vh)	–	Is (m)	Is (h)	Is (h)	Is (vh)	Is (ah)	Is (ah)	Is (m)
C4	Between (h and vh)	Is (h)	Is (m)	–	Is (vh)	Is (h)	Is (h)	Is (h)	Is (vh)	Is (l)
C5	Is (m)	Is (l)	Is (l)	Is (vl)	–	Is (m)	Is (vl)	Is (vl)	Is (m)	Is (n)
C6	Is (m)	Is (m)	Is (l)	Is (l)	Is (m)	–	Is (m)	Is (l)	Is (l)	Is (l)
C7	Is (h)	Is (h)	Is (vl)	Is (l)	Is (vh)	Is (m)	–	Is (l)	Is (l)	Is (vl)
C8	Is (ah)	Is (vh)	Is (n)	Is (l)	Is (vh)	Is (h)	Is (h)	–	Is (vl)	Is (h)
C9	Is (ah)	Is (vh)	Is (n)	Is (vl)	Is (m)	Is (h)	Is (h)	Is (vh)	–	Is (m)
C10	Is (vh)	Is (h)	Is (m)	Is (h)	Is (ah)	Is (h)	Is (vh)	Is (l)	Is (m)	–
Expert 13's linguistic evaluations										
C1	–	Between (m and h)	Between (m and h)	Between (m and h)	Is (vh)	Is (vh)	Is (ah)	Is (ah)	Is (vh)	Is (ah)
C2	Between (l and m)	–	Greater than (n)	Greater than (n)	Between (vl and l)	Between (vl and l)	Between (m and h)	Between (m and h)	Between (vl and l)	Between (m and h)
C3	Between (l and m)	Lower than (ah)	–	Is (n)	Between (vl and l)	Between (vl and l)	Between (m and h)	Between (m and h)	Between (vl and l)	Between (m and h)
C4	Between (l and m)	Lower than (ah)	Is (ah)	–	Between (vl and l)	Between (vl and l)	Between (m and h)	Between (m and h)	Between (vl and l)	Between (m and h)
C5	Is (vl)	Between (h and vh)	Between (h and vh)	Between (h and vh)	–	Greater than (n)	Between (vl and l)	Between (vl and l)	Greater than (n)	Between (vl and l)
C6	Is (vl)	Between (h and vh)	Between (h and vh)	Between (h and vh)	Lower than (ah)	–	Between (vl and l)	Between (vl and l)	Is (n)	Between (vl and l)
C7	Is (n)	Between (l and m)	Between (l and m)	Between (l and m)	Between (h and vh)	Between (h and vh)	–	Greater than (n)	Between (h and vh)	Is (n)
C8	Is (n)	Between (l and m)	Between (l and m)	Between (l and m)	Between (h and vh)	Between (h and vh)	Lower than (ah)	–	Between (h and vh)	Is (n)

C9	Is (vl)	Between (h and vh)	Between (h and vh)	Between (h and vh)	Lower than (ah)	Is (ah)	Between (vl and l)	Between (vl and l)	–	Between (vl and l)
C10	Is (n)	Between (l and m)	Between (l and m)	Between (l and m)	Between (h and vh)	Between (h and vh)	Is (ah)	Is (ah)	Between (h and vh)	–

Table A2
Obtained envelops for the HFLTS given in Table A1.

Goal	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
Expert 1's Obtained Envelops										
C1	–	[h,ah]	[l, h]	[vl,m]	[h,ah]	[m,ah]	[l,h]	[n,m]	[l,h]	[l,ah]
C2	[n,l]	–	[n,l]	[l,h]	[m,vh]	[m,vh]	[l,h]	[n,h]	[n,m]	[n,m]
C3	[l,h]	[h,ah]	–	[m,ah]	[m,vh]	[h,ah]	[l,h]	[n,m]	[l,h]	[n,h]
C4	[m,vh]	[l,h]	[n,m]	–	[l,vh]	[m,vh]	[vl,l]	[l, h]	[l, h]	[n,m]
C5	[n,l]	[vl,m]	[vl,m]	[vl, h]	–	[l,h]	[vl,ah]	[m,vh]	[vl,l]	[l,m]
C6	[n,m]	[vl,m]	[n,l]	[vl,m]	[l,h]	–	[l,h]	[n,m]	[l,h]	[n,h]
C7	[l,h]	[l,h]	[l,h]	[h,vh]	[n,vh]	[l, h]	–	[n,h]	[vl,m]	[n,m]
C8	[m,ah]	[l,ah]	[m,ah]	[l,h]	[vl,m]	[m,ah]	[l,ah]	–	[m,vh]	[l,ah]
C9	[l,h]	[m,ah]	[l,h]	[l,h]	[h,vh]	[l,h]	[m,vh]	[vl,m]	–	[l,h]
C10	[n,h]	[m,ah]	[l,ah]	[m,ah]	[m,h]	[l,ah]	[m,ah]	[n,h]	[l,h]	–
Expert 2's Obtained Envelops										
C1	–	[vh,ah]	[m,m]	[h,vh]	[ah,ah]	[l,h]	[n,l]	[n,n]	[l,ah]	[m,h]
C2	[n,vl]	–	[n,m]	[vl,m]	[m,h]	[vl,vl]	[vh,ah]	[n,n]	[m,h]	[m,ah]
C3	[m,m]	[m,ah]	–	[n,n]	[n,h]	[m,m]	[l,m]	[vl,vl]	[n,l]	[ah,ah]
C4	[vl,l]	[m,vh]	[ah,ah]	–	[m,m]	[m,h]	[n,n]	[l,l]	[m,m]	[l,m]
C5	[n,n]	[l,m]	[l,ah]	[m,m]	–	[h,ah]	[h,h]	[m,h]	[n,m]	[l,m]
C6	[l,h]	[vh,vh]	[m,m]	[l,m]	[n,l]	–	[n,l]	[m,m]	[n,m]	[n,l]
C7	[h,ah]	[n,vl]	[m,h]	[ah,ah]	[l,l]	[h,ah]	–	[h,vh]	[h,vh]	[l,ah]
C8	[ah,ah]	[ah,ah]	[vh,vh]	[h,h]	[l,m]	[m,m]	[vl,l]	–	[vh,vh]	[l,ah]
C9	[n,h]	[l,m]	[h,ah]	[m,m]	[m,ah]	[m,ah]	[vl,l]	[vl,vl]	–	[m,m]
C10	[l,m]	[n,m]	[n,n]	[m,h]	[m,h]	[h,ah]	[n,h]	[n,h]	[m,m]	–
Expert 3's Obtained Envelops										
C1	–	[h,vh]	[l,m]	[m,m]	[n,l]	[vh,ah]	[m,h]	[m,h]	[h,ah]	[m,m]
C2	[vl,l]	–	[n,l]	[vl,l]	[n,l]	[m,h]	[l,m]	[n,m]	[m,ah]	[n,l]
C3	[m,h]	[h,ah]	–	[h,ah]	[h,vh]	[vh,ah]	[h,ah]	[vh,ah]	[vh,ah]	[h,vh]
C4	[m,m]	[h,vh]	[n,l]	–	[m,ah]	[h,vh]	[h,ah]	[m,h]	[vh,ah]	[m,m]
C5	[h,ah]	[h,ah]	[vl,l]	[n,m]	–	[vh,ah]	[h,vh]	[vh,ah]	[h,ah]	[m,h]
C6	[n,vl]	[l,m]	[n,vl]	[vl,l]	[n,vl]	–	[vl,vl]	[m,m]	[vl,l]	[l,l]
C7	[l,m]	[m,h]	[n,l]	[n,l]	[vl,l]	[vh,vh]	–	[m,h]	[vl,l]	[l,m]
C8	[l,m]	[m,ah]	[n,vl]	[l,m]	[n,vl]	[m,m]	[l,m]	–	[vh,ah]	[m,h]
C9	[n,l]	[n,m]	[n,vl]	[n,vl]	[n,l]	[h,vh]	[h,vh]	[n,vl]	–	[vl,l]
C10	[m,m]	[h,ah]	[vl,l]	[m,m]	[l,m]	[h,h]	[m,h]	[l,m]	[h,vh]	–
Expert 4's Obtained Envelops										
C1	–	[vh,vh]	[n,n]	[vl,l]	[n,l]	[h,h]	[m,m]	[m,m]	[l,l]	[vl,vl]
C2	[vl,vl]	–	[l,l]	[l,ah]	[l,l]	[m,ah]	[m,m]	[vl,l]	[l,l]	[l,l]
C3	[ah,ah]	[h,h]	–	[n,l]	[m,m]	[h,ah]	[h,h]	[h,h]	[m,m]	[m,m]
C4	[h,vh]	[n,h]	[h,ah]	–	[vh,vh]	[ah,ah]	[h,ah]	[h,vh]	[h,h]	[h,ah]
C5	[h,ah]	[h,h]	[m,m]	[vl,vl]	–	[h,h]	[m,h]	[m,m]	[l,ah]	[m,m]
C6	[l,l]	[n,m]	[n,l]	[n,n]	[l,l]	–	[l,l]	[l,m]	[vl,vl]	[l,l]
C7	[m,m]	[m,m]	[l,l]	[n,l]	[l,m]	[h,h]	–	[m,m]	[l,l]	[m,m]
C8	[m,m]	[h,vh]	[l,l]	[vl,l]	[m,m]	[m,h]	[m,m]	–	[n,l]	[l,l]
C9	[h,h]	[h,h]	[m,m]	[l,l]	[n,h]	[vh,vh]	[h,h]	[h,ah]	–	[n,h]
C10	[vh,vh]	[h,h]	[m,m]	[n,l]	[m,m]	[h,h]	[m,m]	[h,h]	[l,ah]	–
Expert 5's Obtained Envelops										
C1	–	[h,vh]	[h,h]	[m,m]	[ah,ah]	[ah,ah]	[ah,ah]	[h,h]	[l,m]	[vh,vh]
C2	[vl,l]	–	[l,l]	[n,n]	[m,m]	[l,l]	[l,l]	[l,l]	[m,m]	[h,vh]
C3	[l,l]	[h,h]	–	[m,ah]	[m,ah]	[h,h]	[ah,ah]	[l,l]	[h,h]	[ah,ah]
C4	[m,m]	[ah,ah]	[n,m]	–	[m,m]	[m,ah]	[h,h]	[m,ah]	[h,h]	[ah,ah]
C5	[n,n]	[m,m]	[n,m]	[m,m]	–	[h,vh]	[l,l]	[vl,vl]	[h,h]	[ah,ah]
C6	[n,n]	[h,h]	[l,l]	[n,m]	[vl,l]	–	[m,m]	[n,vl]	[m,m]	[n,l]
C7	[n,n]	[h,h]	[n,n]	[l,l]	[h,h]	[m,m]	–	[n,l]	[m,m]	[m,m]

C8	[l,l]	[h,h]	[h,h]	[n,m]	[vh,vh]	[vh,ah]	[h,ah]	–	[h,h]	[h,h]
C9	[m,h]	[m,m]	[l,l]	[l,l]	[l,l]	[m,m]	[m,m]	[l,l]	–	[m,m]
C10	[vl,vl]	[vl,l]	[n,n]	[n,n]	[n,n]	[h,ah]	[m,m]	[l,l]	[m,m]	–
Expert 6's Obtained Envelops										
C1	–	[h,h]	[m,ah]	[m,h]	[m,ah]	[m,h]	[m,m]	[m,ah]	[m,m]	[m,m]
C2	[l,l]	–	[m,ah]	[l,m]	[m,ah]	[m,vh]	[l,l]	[l,h]	[h,h]	[l,l]
C3	[n,m]	[n,m]	–	[m,ah]	[m,m]	[m,vh]	[m,h]	[ah,ah]	[m,m]	[l,m]
C4	[l,m]	[m,h]	[n,m]	–	[l,h]	[h,h]	[m,h]	[l,m]	[l,l]	[n,n]
C5	[n,m]	[n,m]	[m,m]	[l,h]	–	[h,h]	[m,ah]	[vh,vh]	[vh,vh]	[m,m]
C6	[l,m]	[vl,m]	[vl,m]	[l,l]	[l,l]	–	[m,h]	[l,l]	[m,m]	[vh,ah]
C7	[m,m]	[h,h]	[l,m]	[l,m]	[n,m]	[l,m]	–	[l,m]	[m,vh]	[m,m]
C8	[n,m]	[l,h]	[n,n]	[m,h]	[vl,vl]	[h,h]	[m,h]	–	[vh,vh]	[vl,vl]
C9	[m,m]	[l,l]	[m,m]	[h,h]	[vl,vl]	[m,m]	[vl,m]	[vl,vl]	–	[h,ah]
C10	[m,m]	[h,h]	[m,h]	[ah,ah]	[m,m]	[n,vl]	[m,m]	[vh,vh]	[n,l]	–
Expert 7's Obtained Envelops										
C1	–	[n,l]	[n,n]	[h,h]	[n,n]	[h,ah]	[n,vl]	[vl,vl]	[n,vl]	[n,m]
C2	[h,ah]	–	[n,n]	[m,m]	[ah,ah]	[h,h]	[n,n]	[n,n]	[vl,vl]	[l,m]
C3	[ah,ah]	[ah,ah]	–	[h,h]	[vl,vl]	[h,h]	[vh,ah]	[m,m]	[vl,vl]	[m,m]
C4	[l,l]	[m,m]	[l,l]	–	[ah,ah]	[l,l]	[m,ah]	[l,l]	[m,m]	[n,m]
C5	[ah,ah]	[n,n]	[vh,vh]	[n,n]	–	[vh,vh]	[l,l]	[vl,vl]	[vl,vl]	[vh,vh]
C6	[n,l]	[l,l]	[l,l]	[h,h]	[vl,vl]	–	[m,m]	[l,l]	[l,l]	[h,h]
C7	[vh,ah]	[ah,ah]	[n,vl]	[n,m]	[h,h]	[m,m]	–	[n,n]	[ah,ah]	[l,l]
C8	[vh,vh]	[ah,ah]	[m,m]	[h,h]	[vh,vh]	[h,h]	[ah,ah]	–	[m,m]	[h,h]
C9	[vh,ah]	[vh,vh]	[vh,vh]	[m,m]	[vh,vh]	[h,h]	[n,n]	[m,m]	–	[h,h]
C10	[m,ah]	[m,h]	[m,m]	[m,ah]	[vl,vl]	[l,l]	[h,h]	[l,l]	[l,l]	–
Expert 8's Obtained Envelops										
C1	–	[m,vh]	[n,h]	[m,ah]	[h,h]	[ah,ah]	[n,h]	[n,h]	[n,h]	[vh,ah]
C2	[vl,m]	–	[n,ah]	[vl,ah]	[vh,ah]	[vh,ah]	[n,h]	[l,l]	[m,m]	[m,ah]
C3	[l,ah]	[n,ah]	–	[vl,vl]	[h,ah]	[vh,ah]	[h,ah]	[m,m]	[n,l]	[vl,ah]
C4	[n,m]	[n,vh]	[vh,vh]	–	[h,ah]	[ah,ah]	[l,h]	[n,m]	[n,l]	[h,ah]
C5	[l,l]	[n,vl]	[n,l]	[n,l]	–	[n,vl]	[n,n]	[l,ah]	[vl,ah]	[vh,ah]
C6	[n,n]	[n,vl]	[n,vl]	[n,n]	[vh,ah]	–	[vh,vh]	[n,l]	[h,vh]	[h,h]
C7	[l,ah]	[l,ah]	[n,l]	[l,h]	[ah,ah]	[vl,vl]	–	[l,ah]	[vh,vh]	[vh,ah]
C8	[l,ah]	[h,h]	[m,m]	[m,ah]	[n,h]	[h,ah]	[n,h]	–	[m,m]	[n,h]
C9	[l,ah]	[m,m]	[h,ah]	[h,ah]	[n,vh]	[vl,l]	[vl,vl]	[m,m]	–	[vh,vh]
C10	[n,vl]	[n,m]	[n,vh]	[n,l]	[n,vl]	[l,l]	[n,vl]	[l,ah]	[vl,vl]	–
Expert 9's Obtained Envelops										
C1	–	[h,h]	[l,l]	[n,n]	[ah,ah]	[vh,vh]	[h,h]	[vh,ah]	[h,vh]	[vh,vh]
C2	[l,l]	–	[vl,vl]	[vl,vl]	[h,h]	[m,m]	[vh,vh]	[m,m]	[l,l]	[h,h]
C3	[h,h]	[vh,vh]	–	[vl,vl]	[vh,ah]	[h,h]	[m,m]	[h,h]	[vl,l]	[ah,ah]
C4	[ah,ah]	[vh,vh]	[vh,vh]	–	[h,h]	[h,h]	[vl,vl]	[l,l]	[l,m]	[h,h]
C5	[n,n]	[l,l]	[n,vl]	[l,l]	–	[l,l]	[m,vh]	[n,vl]	[m,m]	[n,n]
C6	[vl,vl]	[m,m]	[l,l]	[l,l]	[h,h]	–	[m,m]	[vl,vl]	[vh,vh]	[h,h]
C7	[l,l]	[vl,vl]	[m,m]	[vh,vh]	[vl,m]	[m,m]	–	[h,h]	[l,l]	[m,m]
C8	[n,vl]	[m,m]	[l,l]	[h,h]	[vh,ah]	[vh,vh]	[l,l]	–	[vh,vh]	[l,l]
C9	[vl,l]	[h,h]	[h,vh]	[m,h]	[m,m]	[vl,vl]	[h,h]	[vl,vl]	–	[h,h]
C10	[vl,vl]	[l,l]	[n,n]	[l,l]	[ah,ah]	[l,l]	[m,m]	[h,h]	[l,l]	–
Expert 10's Obtained Envelops										
C1	–	[h,h]	[h,h]	[ah,ah]	[ah,ah]	[m,m]	[m,m]	[m,m]	[m,m]	[vh,vh]
C2	[l,l]	–	[vh,vh]	[l,l]	[h,h]	[m,m]	[h,h]	[h,h]	[h,h]	[l,l]
C3	[l,l]	[vl,vl]	–	[ah,ah]	[l,l]	[ah,ah]	[ah,ah]	[m,m]	[m,m]	[vh,vh]
C4	[n,n]	[h,h]	[n,n]	–	[m,m]	[vh,vh]	[n,n]	[m,m]	[h,h]	[l,l]
C5	[n,n]	[l,l]	[h,h]	[m,m]	–	[vh,vh]	[m,m]	[m,m]	[h,h]	[h,h]
C6	[m,m]	[m,m]	[n,n]	[vl,vl]	[vl,vl]	–	[n,n]	[l,l]	[h,h]	[h,h]
C7	[m,m]	[l,l]	[n,n]	[ah,ah]	[m,m]	[ah,ah]	–	[l,l]	[h,h]	[h,h]
C8	[m,m]	[l,l]	[m,m]	[m,m]	[m,m]	[h,h]	[h,h]	–	[vh,vh]	[vh,vh]
C9	[m,m]	[l,l]	[m,m]	[l,l]	[l,l]	[l,l]	[l,l]	[vl,vl]	–	[vh,vh]
C10	[vl,vl]	[h,h]	[vl,vl]	[h,h]	[l,l]	[l,l]	[l,l]	[vl,vl]	[vl,vl]	–
Expert 11's Obtained Envelops										
C1	–	[vh,vh]	[h,h]	[m,m]	[h,h]	[vh,vh]	[h,h]	[h,h]	[vh,vh]	[h,h]
C2	[vl,vl]	–	[l,l]	[vl,vl]	[n,n]	[m,m]	[l,l]	[l,l]	[m,m]	[vl,vl]
C3	[l,l]	[h,h]	–	[l,l]	[vl,vl]	[h,h]	[m,m]	[h,h]	[h,h]	[m,m]
C4	[m,m]	[vh,vh]	[h,h]	–	[l,l]	[h,h]	[h,h]	[h,h]	[vh,vh]	[h,h]
C5	[l,l]	[ah,ah]	[vh,vh]	[h,h]	–	[h,h]	[h,h]	[vh,vh]	[vh,vh]	[vh,vh]

C6	[vl,vl]	[m,m]	[l,l]	[l,l]	[l,l]	–	[h,h]	[vh,vh]	[vh,vh]	[h,h]
C7	[l,l]	[h,h]	[m,m]	[l,l]	[l,l]	[l,l]	–	[h,h]	[vh,vh]	[h,h]
C8	[l,l]	[h,h]	[l,l]	[l,l]	[vl,vl]	[vl,vl]	[l,l]	–	[h,h]	[l,l]
C9	[vl,vl]	[m,m]	[l,l]	[vl,vl]	[vl,vl]	[vl,vl]	[vl,vl]	[l,l]	–	[vl,vl]
C10	[l,l]	[vh,vh]	[m,m]	[l,l]	[vl,vl]	[l,l]	[l,l]	[h,h]	[vh,vh]	–
Expert 12's Obtained Envelops										
C1	–	[l,l]	[l,l]	[vl,l]	[m,m]	[m,m]	[l,l]	[n,n]	[n,n]	[vl,vl]
C2	[h,h]	–	[vl,vl]	[l,l]	[h,h]	[m,m]	[l,l]	[vl,vl]	[vl,vl]	[l,l]
C3	[h,h]	[vh,vh]	–	[m,m]	[h,h]	[h,h]	[vh,vh]	[ah,ah]	[ah,ah]	[m,m]
C4	[h,vh]	[h,h]	[m,m]	–	[vh,vh]	[h,h]	[h,h]	[h,h]	[vh,vh]	[l,l]
C5	[m,m]	[l,l]	[l,l]	[vl,vl]	–	[m,m]	[vl,vl]	[vl,vl]	[m,m]	[n,n]
C6	[m,m]	[m,m]	[l,l]	[l,l]	[m,m]	–	[m,m]	[l,l]	[l,l]	[l,l]
C7	[h,h]	[h,h]	[vl,vl]	[l,l]	[vh,vh]	[m,m]	–	[l,l]	[l,l]	[vl,vl]
C8	[ah,ah]	[vh,vh]	[n,n]	[l,l]	[vh,vh]	[h,h]	[h,h]	–	[vl,vl]	[h,h]
C9	[ah,ah]	[vh,vh]	[n,n]	[vl,vl]	[m,m]	[h,h]	[h,h]	[vh,vh]	–	[m,m]
C10	[vh,vh]	[h,h]	[m,m]	[h,h]	[ah,ah]	[h,h]	[vh,vh]	[l,l]	[m,m]	–
Expert 13's Obtained Envelops										
C1	–	[m,h]	[m,h]	[m,h]	[vh,vh]	[vh,vh]	[ah,ah]	[ah,ah]	[vh,vh]	[ah,ah]
C2	[l,m]	–	[vl,ah]	[vl,ah]	[vl,l]	[vl,l]	[m,h]	[m,h]	[vl,l]	[m,h]
C3	[l,m]	[n,vh]	–	[n,n]	[vl,l]	[vl,l]	[m,h]	[m,h]	[vl,l]	[m,h]
C4	[l,m]	[n,vh]	[ah,ah]	–	[vl,l]	[vl,l]	[m,h]	[m,h]	[vl,l]	[m,h]
C5	[vl,vl]	[h,vh]	[h,vh]	[h,vh]	–	[vl,ah]	[vl,l]	[vl,l]	[vl,ah]	[vl,l]
C6	[vl,vl]	[h,vh]	[h,vh]	[h,vh]	[n,vh]	–	[vl,l]	[vl,l]	[n,n]	[vl,l]
C7	[n,n]	[l,m]	[l,m]	[l,m]	[h,vh]	[h,vh]	–	[vl,ah]	[h,vh]	[n,n]
C8	[n,n]	[l,m]	[l,m]	[l,m]	[h,vh]	[h,vh]	[n,vh]	–	[h,vh]	[n,n]
C9	[vl,vl]	[h,vh]	[h,vh]	[h,vh]	[n,vh]	[ah,ah]	[vl,l]	[vl,l]	–	[vl,l]
C10	[n,n]	[l,m]	[l,m]	[l,m]	[h,vh]	[h,vh]	[ah,ah]	[ah,ah]	[h,vh]	–

Table A3
Comparability sequence of 81 cities.

City	C1			C2			C3			C4			C5		
	a	b	c	a	b	c	a	b	c	a	b	c	a	b	c
Adana	80,417.50	84,650.00	88,882.50	6.00	7.00	8.00	4906.09	5164.31	5422.52	3,164,852,859.23	3,331,424,062.35	3,497,995,265.47	80,643.60	84,888.00	89,132.40
Adıyaman	12,112.50	12,750.00	13,387.50	3.00	4.00	5.00	1925.72	2027.08	2128.43	440,708,622.94	463,903,813.62	487,099,004.30	17,799.20	18,736.00	19,672.80
Afyon	26,932.50	28,350.00	29,767.50	5.00	6.00	7.00	2648.62	2788.02	2927.42	655,396,000.25	689,890,526.58	724,385,052.91	27,122.50	28,550.00	29,977.50
Ağrı	12,825.00	13,500.00	14,175.00	2.00	3.00	4.00	1191.69	1254.41	1317.13	297,464,530.37	313,120,558.28	328,776,586.19	9961.70	10,486.00	11,010.30
Aksaray	14,107.50	14,850.00	15,592.50	2.00	3.00	4.00	2025.42	2132.03	2238.63	286,794,068.61	301,888,493.27	316,982,917.94	14,542.60	15,308.00	16,073.40
Amasya	14,962.50	15,750.00	16,537.50	4.00	5.00	6.00	3016.81	3175.59	3334.37	372,856,722.58	392,480,760.61	412,104,798.64	12,913.35	13,593.00	14,272.65
Ankara	249,897.50	263,050.00	276,202.50	8.00	9.00	10.00	5770.65	6074.37	6378.09	7,572,965,668.67	7,971,542,809.13	8,370,119,949.58	239,213.80	251,804.00	264,394.20
Antalya	186,817.50	196,650.00	206,482.50	8.00	9.00	10.00	4599.45	4841.53	5083.61	3,623,467,500.27	3,814,176,316.07	4,004,885,131.88	133,970.90	141,022.00	148,073.10
Ardahan	4180.00	4400.00	4620.00	3.00	4.00	5.00	1766.64	1859.63	1952.61	79,994,982.86	84,205,245.12	88,415,507.37	3031.45	3191.00	3350.55
Artvin	11,780.00	12,400.00	13,020.00	4.00	5.00	6.00	4481.13	4716.98	4952.83	289,444,669.96	304,678,599.96	319,912,529.96	7731.10	8138.00	8544.90
Aydın	68,210.00	71,800.00	75,390.00	6.00	7.00	8.00	4230.81	4453.48	4676.16	1,144,911,477.69	1,205,169,976.52	1,265,428,475.34	53,579.05	56,399.00	59,218.95
Balıkesir	86,307.50	90,850.00	95,392.50	5.00	6.00	7.00	4205.46	4426.80	4648.14	1,708,611,212.32	1,798,538,118.23	1,888,465,024.14	55,879.00	58,820.00	61,761.00
Bartın	7125.00	7500.00	7875.00	5.00	6.00	7.00	2225.14	2342.26	2459.37	167,613,955.28	176,435,742.40	185,257,529.53	7148.75	7525.00	7901.25
Batman	9120.00	9600.00	10,080.00	3.00	4.00	5.00	2549.60	2683.79	2817.97	747,912,280.38	787,276,084.61	826,639,888.84	12,020.35	12,653.00	13,285.65
Bayburt	2660.00	2800.00	2940.00	3.00	4.00	5.00	2132.32	2244.55	2356.78	63,337,191.27	66,670,727.65	70,004,264.04	2438.65	2567.00	2695.35
Bilecik	11,400.00	12,000.00	12,600.00	4.00	5.00	6.00	5419.96	5705.22	5990.48	348,357,314.78	366,691,910.29	385,026,505.81	7370.10	7758.00	8145.90
Bingöl	4750.00	5000.00	5250.00	3.00	4.00	5.00	1667.32	1755.07	1842.82	148,509,803.87	156,326,109.34	164,142,414.80	6460.00	6800.00	7140.00
Bitlis	5272.50	5550.00	5827.50	3.00	4.00	5.00	1354.32	1425.60	1496.88	216,113,066.29	227,487,438.20	238,861,810.10	8105.40	8532.00	8958.60
Bolu	14,107.50	14,850.00	15,592.50	5.00	6.00	7.00	8840.80	9306.10	9771.41	778,897,356.89	819,891,954.62	860,886,552.35	11,636.55	12,249.00	12,861.45
Burdur	11,542.50	12,150.00	12,757.50	4.00	5.00	6.00	4092.31	4307.70	4523.08	312,384,580.86	328,825,874.59	345,267,168.32	13,328.50	14,030.00	14,731.50
Bursa	141,645.00	149,100.00	156,555.00	7.00	8.00	9.00	5258.03	5534.77	5811.51	5,591,312,650.31	5,885,592,263.48	6,179,871,876.66	123,513.30	130,014.00	136,514.70
Çanakkale	24,035.00	25,300.00	26,565.00	7.00	8.00	9.00	4897.52	5155.28	5413.05	860,745,704.01	906,048,109.49	951,350,514.96	25,774.45	27,131.00	28,487.55
Çankırı	5795.00	6100.00	6405.00	4.00	5.00	6.00	2383.04	2508.47	2633.89	164,413,237.44	173,066,565.73	181,719,894.02	5289.60	5568.00	5846.40
Çorum	23,702.50	24,950.00	26,197.50	3.00	4.00	5.00	3468.03	3650.56	3833.09	696,019,216.44	732,651,806.78	769,284,397.12	20,301.50	21,370.00	22,438.50
Denizli	46,977.50	49,450.00	51,922.50	5.00	6.00	7.00	4472.98	4708.40	4943.82	1,141,433,906.55	1,201,509,375.31	1,261,584,844.08	49,498.80	52,104.00	54,709.20
Diyarbakır	34,627.50	36,450.00	38,272.50	4.00	5.00	6.00	2754.54	2899.51	3044.49	2,055,529,595.83	2,163,715,364.03	2,271,901,132.23	38,244.15	40,257.00	42,269.85
Düzce	16,387.50	17,250.00	18,112.50	4.00	5.00	6.00	2395.89	2521.99	2648.09	261,330,991.33	275,085,254.03	288,839,516.73	14,446.65	15,207.00	15,967.35
Edirne	23,560.00	24,800.00	26,040.00	6.00	7.00	8.00	5039.51	5304.75	5569.99	612,681,574.60	644,927,973.27	677,174,371.93	20,523.80	21,604.00	22,684.20
Elazığ	19,997.50	21,050.00	22,102.50	3.00	4.00	5.00	3574.28	3762.40	3950.52	684,316,805.07	720,333,479.02	756,350,152.97	20,037.40	21,092.00	22,146.60
Erzincan	7457.50	7850.00	8242.50	3.00	4.00	5.00	2429.30	2557.16	2685.02	204,779,643.58	215,557,519.56	226,335,395.54	7880.25	8295.00	8709.75
Erzurum	30,732.50	32,350.00	33,967.50	4.00	5.00	6.00	2225.73	2342.87	2460.02	641,608,445.80	675,377,311.36	709,146,176.93	21,794.90	22,942.00	24,089.10
Eskişehir	50,540.00	53,200.00	55,860.00	7.00	8.00	9.00	5269.35	5546.68	5824.02	1,629,658,038.08	1,715,429,513.77	1,801,200,989.46	31,635.95	33,301.00	34,966.05
Gaziantep	44,840.00	47,200.00	49,560.00	7.00	8.00	9.00	3339.83	3515.61	3691.39	2,449,617,654.44	2,578,544,899.41	2,707,472,144.38	70,280.05	73,979.00	77,677.95
Giresun	20,092.50	21,150.00	22,207.50	3.00	4.00	5.00	3026.59	3185.89	3345.18	495,422,137.81	521,496,987.16	547,571,836.52	17,609.20	18,536.00	19,462.80
Gümüşhane	3990.00	4200.00	4410.00	4.00	5.00	6.00	2255.41	2374.11	2492.82	119,010,146.16	125,273,838.06	131,537,529.97	4247.45	4471.00	4694.55
Hakkari	760.00	800.00	840.00	3.00	4.00	5.00	1752.67	1844.91	1937.16	229,013,980.48	241,067,347.87	253,120,715.26	5117.65	5387.00	5656.35
Hatay	42,655.00	44,900.00	47,145.00	4.00	5.00	6.00	3684.00	3877.89	4071.79	1,986,792,190.52	2,091,360,200.54	2,195,928,210.57	59,299.95	62,421.00	65,542.05
Iğdır	8502.50	8950.00	9397.50	3.00	4.00	5.00	1792.53	1886.87	1981.22	157,350,448.25	165,632,050.79	173,913,653.33	6526.50	6870.00	7213.50
Isparta	23,797.50	25,050.00	26,302.50	7.00	8.00	9.00	3165.83	3332.45	3499.07	459,657,265.38	483,849,753.03	508,042,240.68	17,456.25	18,375.00	19,293.75
İstanbul	1,012,177.50	1,065,450.00	1,118,722.50	16.00	17.00	18.00	6424.46	6762.59	7100.72	22,122,392,639.83	23,286,729,094.55	24,451,065,549.28	804,181.65	846,507.00	888,832.35
İzmir	287,612.50	302,750.00	317,887.50	10.00	11.00	12.00	6742.29	7097.15	7452.01	7,219,218,971.79	7,599,177,865.04	7,979,136,758.29	204,589.15	215,357.00	226,124.85
Kahramanmaraş	23,560.00	24,800.00	26,040.00	2.00	3.00	4.00	3321.89	3496.73	3671.57	1,281,107,141.27	1,348,533,832.91	1,415,960,524.56	33,956.80	35,744.00	37,531.20
Karabük	10,687.50	11,250.00	11,812.50	5.00	6.00	7.00	3328.56	3503.75	3678.93	315,965,448.27	332,595,208.70	349,224,969.14	9614.95	10,121.00	10,627.05

Karaman	9167.50	9650.00	10,132.50	3.00	4.00	5.00	4220.14	4442.25	4664.37	409,420,064.58	430,968,489.03	452,516,913.48	9630.15	10,137.00	10,643.85
Kars	13,347.50	14,050.00	14,752.50	3.00	4.00	5.00	1857.60	1955.37	2053.14	247,989,409.82	261,041,484.02	274,093,558.22	7419.50	7810.00	8200.50
Kastamonu	11,922.50	12,550.00	13,177.50	3.00	4.00	5.00	3736.00	3932.63	4129.26	530,819,059.85	558,756,905.11	586,694,750.36	15,602.80	16,424.00	17,245.20
Kayseri	59,992.50	63,150.00	66,307.50	4.00	5.00	6.00	3788.24	3987.62	4187.00	1,861,115,383.04	1,959,068,824.26	2,057,022,265.47	48,430.05	50,979.00	53,527.95
Kırıkkale	12,872.50	13,550.00	14,227.50	4.00	5.00	6.00	5714.28	6015.03	6315.78	565,782,631.16	595,560,664.38	625,338,697.60	9518.05	10,019.00	10,519.95
Kırklareli	21,470.00	22,600.00	23,730.00	5.00	6.00	7.00	7529.13	7925.39	8321.66	789,006,859.06	830,533,535.85	872,060,212.64	16,876.75	17,765.00	18,653.25
Kırşehir	10,830.00	11,400.00	11,970.00	3.00	4.00	5.00	3120.68	3284.92	3449.17	257,432,371.03	270,981,443.19	284,530,515.35	7881.20	8296.00	8710.80
Kilis	3942.50	4150.00	4357.50	3.00	4.00	5.00	3810.51	4011.06	4211.61	208,795,285.42	219,784,510.97	230,773,736.52	5233.55	5509.00	5784.45
Kocaeli	96,662.50	101,750.00	106,837.50	6.00	7.00	8.00	12,928.70	13,609.16	14,289.62	6,965,340,241.76	7,331,937,096.59	7,698,533,951.42	69,156.20	72,796.00	76,435.80
Konya	66,452.50	69,950.00	73,447.50	5.00	6.00	7.00	3259.48	3431.04	3602.59	1,729,108,833.61	1,820,114,561.69	1,911,120,289.78	88,160.00	92,800.00	97,440.00
Kütahya	18,382.50	19,350.00	20,317.50	6.00	7.00	8.00	3784.93	3984.14	4183.35	754,876,086.87	794,606,407.23	834,336,727.59	21,375.00	22,500.00	23,625.00
Malatya	26,077.50	27,450.00	28,822.50	3.00	4.00	5.00	2970.74	3127.09	3283.45	765,448,874.64	805,735,657.52	846,022,440.39	26,198.15	27,577.00	28,955.85
Manisa	46,265.00	48,700.00	51,135.00	4.00	5.00	6.00	5156.09	5427.47	5698.84	2,483,959,343.23	2,614,694,045.50	2,745,428,747.78	59,444.35	62,573.00	65,701.65
Mardin	15,817.50	16,650.00	17,482.50	2.00	3.00	4.00	2061.91	2170.43	2278.95	850,318,923.87	895,072,551.44	939,826,179.01	20,486.75	21,565.00	22,643.25
Mersin	75,667.50	79,650.00	83,632.50	7.00	8.00	9.00	5142.25	5412.89	5683.54	3,156,101,904.20	3,322,212,530.73	3,488,323,157.27	73,085.40	76,932.00	80,778.60
Muğla	99,370.00	104,600.00	109,830.00	11.00	12.00	13.00	6936.76	7301.85	7666.94	2,200,345,958.28	2,316,153,640.29	2,431,961,322.31	59,500.40	62,632.00	65,763.60
Muş	4797.50	5050.00	5302.50	2.00	3.00	4.00	1212.42	1276.23	1340.04	232,271,132.73	244,495,929.19	256,720,725.65	8337.20	8776.00	9214.80
Nevşehir	16,862.50	17,750.00	18,637.50	4.00	5.00	6.00	4439.57	4673.23	4906.90	466,400,700.68	490,948,105.98	515,495,511.28	14,166.40	14,912.00	15,657.60
Niğde	12,682.50	13,350.00	14,017.50	3.00	4.00	5.00	3735.66	3932.27	4128.89	473,669,488.06	498,599,461.12	523,529,434.17	12,327.20	12,976.00	13,624.80
Ordu	32,917.50	34,650.00	36,382.50	2.00	3.00	4.00	2231.32	2348.76	2466.20	623,983,134.26	656,824,351.86	689,665,569.45	27,315.35	28,753.00	30,190.65
Osmaniye	15,342.50	16,150.00	16,957.50	4.00	5.00	6.00	2425.49	2553.15	2680.81	477,224,576.94	502,341,659.94	527,458,742.94	17,247.25	18,155.00	19,062.75
Rize	15,912.50	16,750.00	17,587.50	4.00	5.00	6.00	3978.94	4188.36	4397.78	502,167,676.44	528,597,554.15	555,027,431.86	14,624.30	15,394.00	16,163.70
Sakarya	41,800.00	44,000.00	46,200.00	7.00	8.00	9.00	4421.43	4654.14	4886.84	1,275,534,175.82	1,342,667,553.49	1,409,800,931.17	41,256.60	43,428.00	45,599.40
Samsun	67,545.00	71,100.00	74,655.00	5.00	6.00	7.00	3522.70	3708.10	3893.51	1,722,960,847.47	1,813,642,997.34	1,904,325,147.20	49,866.45	52,491.00	55,115.55
Siirt	2850.00	3000.00	3150.00	3.00	4.00	5.00	2330.21	2452.85	2575.49	386,454,196.96	406,793,891.53	427,133,586.11	5827.30	6134.00	6440.70
Sinop	9690.00	10,200.00	10,710.00	4.00	5.00	6.00	3060.05	3221.10	3382.16	238,710,381.53	251,274,085.82	263,837,790.11	8126.30	8554.00	8981.70
Sivas	18,430.00	19,400.00	20,370.00	5.00	6.00	7.00	2933.06	3087.43	3241.80	664,708,102.38	699,692,739.35	734,677,376.31	20,225.50	21,290.00	22,354.50
Şanlıurfa	27,930.00	29,400.00	30,870.00	3.00	4.00	5.00	2113.30	2224.53	2335.75	1,804,031,272.27	1,898,980,286.60	1,993,929,300.93	53,434.65	56,247.00	59,059.35
Şırnak	2660.00	2800.00	2940.00	3.00	4.00	5.00	1338.90	1409.37	1479.84	339,770,869.76	357,653,547.12	375,536,224.47	10,097.55	10,629.00	11,160.45
Tekirdağ	68,210.00	71,800.00	75,390.00	5.00	6.00	7.00	5239.19	5514.94	5790.68	1,484,109,381.16	1,562,220,401.22	1,640,331,421.28	42,600.85	44,843.00	47,085.15
Tokat	21,185.00	22,300.00	23,415.00	3.00	4.00	5.00	2873.82	3025.08	3176.33	652,332,278.34	686,665,556.15	720,998,833.95	19,983.25	21,035.00	22,086.75
Trabzon	39,187.50	41,250.00	43,312.50	3.00	4.00	5.00	3158.00	3324.22	3490.43	930,942,391.33	979,939,359.30	1,028,936,327.26	32,639.15	34,357.00	36,074.85
Tunceli	1140.00	1200.00	1260.00	3.00	4.00	5.00	3322.83	3497.71	3672.60	95,348,987.52	100,367,355.28	105,385,723.05	2835.75	2985.00	3134.25
Uşak	15,342.50	16,150.00	16,957.50	5.00	6.00	7.00	3011.04	3169.51	3327.99	397,679,390.39	418,609,884.62	439,540,378.85	16,113.90	16,962.00	17,810.10
Van	14,107.50	14,850.00	15,592.50	2.00	3.00	4.00	1802.09	1896.94	1991.79	926,090,172.86	974,831,760.90	1,023,573,348.95	27,293.50	28,730.00	30,166.50
Yalova	18,002.50	18,950.00	19,897.50	6.00	7.00	8.00	7261.97	7644.18	8026.39	538,919,384.31	567,283,562.43	595,647,740.55	11,927.25	12,555.00	13,182.75
Yozgat	13,917.50	14,650.00	15,382.50	2.00	3.00	4.00	1787.06	1881.11	1975.17	300,250,477.02	316,053,133.71	331,855,790.39	15,694.00	16,520.00	17,346.00
Zonguldak	27,835.00	29,300.00	30,765.00	4.00	5.00	6.00	6227.55	6555.32	6883.08	1,486,521,237.14	1,564,759,196.99	1,642,997,156.84	22,503.60	23,688.00	24,872.40

City	C6			C7			C8			C9			C10		
	a	b	c	a	b	c	a	b	c	a	b	c	a	b	c
Adana	0.46	0.49	0.51	0.95	1.00	1.00	147.85	155.63	163.41	9096.05	9574.79	10,053.53	12.54	13.20	13.86
Adıyaman	0.45	0.47	0.49	0.62	0.65	0.69	80.75	85.00	89.25	520.59	547.99	575.39	8.65	9.10	9.56
Afyon	0.45	0.47	0.50	0.55	0.58	0.61	46.88	49.35	51.82	1474.99	1552.62	1630.25	5.32	5.60	5.88
Ağrı	0.41	0.44	0.46	0.53	0.56	0.59	45.51	47.90	50.30	263.62	277.50	291.37	6.46	6.80	7.14
Aksaray	0.45	0.48	0.50	0.62	0.65	0.68	48.22	50.76	53.30	684.45	720.47	756.49	5.51	5.80	6.09
Amasya	0.43	0.45	0.48	0.67	0.70	0.74	53.75	56.58	59.40	626.10	659.05	692.01	6.27	6.60	6.93
Ankara	0.50	0.52	0.55	0.95	1.00	1.00	199.53	210.03	220.53	37,675.46	39,658.38	41,641.30	9.69	10.20	10.71
Antalya	0.49	0.52	0.54	0.95	1.00	1.00	101.89	107.25	112.61	12,806.74	13,480.78	14,154.82	7.51	7.90	8.30
Ardahan	0.44	0.46	0.48	0.35	0.37	0.39	19.78	20.82	21.86	167.46	176.27	185.08	5.51	5.80	6.09

Artvin	0.44	0.46	0.48	0.56	0.59	0.62	21.88	23.03	24.18	466.07	490.60	515.13	6.75	7.10	7.46
Aydın	0.45	0.47	0.49	0.95	1.00	1.00	126.08	132.72	139.36	5054.19	5320.20	5586.21	6.56	6.90	7.25
Balıkesir	0.44	0.46	0.49	0.95	1.00	1.00	79.00	83.16	87.31	5067.72	5334.44	5601.16	5.70	6.00	6.30
Bartın	0.45	0.47	0.49	0.39	0.41	0.43	86.51	91.06	95.61	696.68	733.35	770.01	5.89	6.20	6.51
Batman	0.43	0.45	0.48	0.74	0.78	0.82	113.70	119.68	125.66	414.63	436.46	458.28	22.23	23.40	24.57
Bayburt	0.46	0.49	0.51	0.56	0.59	0.62	20.48	21.56	22.64	75.49	79.46	83.44	5.89	6.20	6.51
Bilecik	0.49	0.51	0.54	0.75	0.79	0.83	46.36	48.80	51.24	473.78	498.71	523.65	6.18	6.50	6.83
Bingöl	0.48	0.51	0.53	0.57	0.60	0.63	30.62	32.23	33.84	205.51	216.32	227.14	6.65	7.00	7.35
Bitlis	0.43	0.46	0.48	0.54	0.57	0.60	45.74	48.14	50.55	187.90	197.79	207.68	10.07	10.60	11.13
Bolu	0.47	0.49	0.51	0.66	0.70	0.73	32.52	34.23	35.94	831.85	875.64	919.42	9.12	9.60	10.08
Burdur	0.44	0.46	0.49	0.63	0.66	0.70	35.68	37.56	39.44	798.48	840.51	882.53	6.56	6.90	7.25
Bursa	0.48	0.51	0.53	0.95	1.00	1.00	254.09	267.47	280.84	11,545.58	12,153.24	12,760.90	6.27	6.60	6.93
Çanakkale	0.46	0.49	0.51	0.56	0.59	0.62	48.95	51.52	54.10	1980.62	2084.86	2189.10	5.80	6.10	6.41
Çankırı	0.42	0.44	0.46	0.66	0.70	0.73	23.28	24.51	25.73	347.16	365.43	383.70	6.46	6.80	7.14
Çorum	0.42	0.45	0.47	0.69	0.73	0.76	39.15	41.21	43.28	1126.79	1186.09	1245.39	5.61	5.90	6.20
Denizli	0.47	0.50	0.52	0.95	1.00	1.00	79.52	83.71	87.89	4572.17	4812.81	5053.45	6.18	6.50	6.83
Diyarbakır	0.45	0.47	0.49	0.95	1.00	1.00	103.15	108.58	114.01	1566.58	1649.03	1731.48	17.77	18.70	19.64
Düzce	0.47	0.49	0.52	0.59	0.62	0.65	131.58	138.51	145.43	624.94	657.83	690.72	8.27	8.70	9.14
Edirne	0.46	0.49	0.51	0.68	0.72	0.75	62.61	65.90	69.20	1874.76	1973.43	2072.10	7.41	7.80	8.19
Elazığ	0.47	0.49	0.52	0.73	0.76	0.80	63.90	67.27	70.63	1015.72	1069.18	1122.64	7.41	7.80	8.19
Erzincan	0.47	0.50	0.52	0.54	0.57	0.60	18.28	19.25	20.21	529.78	557.66	585.54	6.37	6.70	7.04
Erzurum	0.45	0.48	0.50	0.95	1.00	1.00	28.64	30.14	31.65	752.31	791.91	831.50	6.27	6.60	6.93
Eskişehir	0.49	0.51	0.54	0.95	1.00	1.00	55.75	58.69	61.62	3530.90	3716.74	3902.57	8.08	8.50	8.93
Gaziantep	0.44	0.47	0.49	0.95	1.00	1.00	263.23	277.09	290.94	2575.49	2711.04	2846.60	6.56	6.90	7.25
Giresun	0.42	0.44	0.47	0.61	0.65	0.68	59.79	62.94	66.08	1231.04	1295.83	1360.62	6.18	6.50	6.83
Gümüşhane	0.48	0.50	0.53	0.62	0.66	0.69	21.60	22.74	23.87	184.65	194.36	204.08	6.84	7.20	7.56
Hakkari	0.49	0.52	0.54	0.52	0.55	0.58	36.56	38.49	40.41	149.84	157.73	165.61	11.12	11.70	12.29
Hatay	0.44	0.47	0.49	0.95	1.00	1.00	247.74	260.78	273.82	3706.68	3901.77	4096.85	11.59	12.20	12.81
Iğdır	0.44	0.46	0.48	0.53	0.56	0.59	50.85	53.53	56.20	232.12	244.33	256.55	6.56	6.90	7.25
Isparta	0.46	0.48	0.51	0.68	0.71	0.75	48.07	50.60	53.13	1436.79	1512.41	1588.03	8.27	8.70	9.14
İstanbul	0.52	0.55	0.57	0.95	1.00	1.00	2628.59	2766.94	2905.29	141,165.13	148,594.87	156,024.61	10.64	11.20	11.76
İzmir	0.48	0.51	0.53	0.95	1.00	1.00	325.29	342.41	359.53	29,740.41	31,305.70	32,870.98	14.63	15.40	16.17
Kahramanmaraş	0.44	0.46	0.49	0.95	1.00	1.00	72.12	75.91	79.71	1163.88	1225.13	1286.39	11.02	11.60	12.18
Karabük	0.48	0.50	0.53	0.73	0.77	0.81	53.48	56.30	59.11	651.11	685.38	719.65	7.60	8.00	8.40
Karaman	0.46	0.48	0.50	0.69	0.73	0.76	25.82	27.17	28.53	534.85	563.00	591.15	3.99	4.20	4.41
Kars	0.45	0.47	0.50	0.43	0.46	0.48	27.81	29.27	30.74	392.94	413.62	434.30	6.27	6.60	6.93
Kastamonu	0.42	0.44	0.46	0.58	0.61	0.64	26.64	28.05	29.45	910.51	958.44	1006.36	5.89	6.20	6.51
Kayseri	0.46	0.49	0.51	0.95	1.00	1.00	73.71	77.59	81.47	2822.02	2970.55	3119.08	9.41	9.90	10.40
Kırıkkale	0.46	0.48	0.51	0.83	0.87	0.92	56.80	59.79	62.78	491.99	517.88	543.78	7.60	8.00	8.40
Kırklareli	0.47	0.50	0.52	0.67	0.70	0.74	52.01	54.75	57.49	1756.21	1848.64	1941.07	7.60	8.00	8.40
Kırşehir	0.46	0.48	0.50	0.73	0.77	0.81	33.31	35.06	36.81	537.69	565.98	594.28	6.94	7.30	7.67
Kilis	0.44	0.46	0.49	0.71	0.75	0.78	85.67	90.18	94.69	100.21	105.48	110.75	7.32	7.70	8.09
Kocaeli	0.50	0.53	0.55	0.95	1.00	1.00	453.12	476.96	500.81	6034.59	6352.20	6669.82	9.60	10.10	10.61
Konya	0.46	0.48	0.50	0.95	1.00	1.00	51.54	54.25	56.96	4080.80	4295.58	4510.36	4.47	4.70	4.94
Kütahya	0.46	0.49	0.51	0.65	0.69	0.72	45.33	47.72	50.11	917.62	965.91	1014.21	5.70	6.00	6.30
Malatya	0.46	0.48	0.50	0.95	1.00	1.00	62.08	65.35	68.62	1439.90	1515.69	1591.47	7.41	7.80	8.19
Manisa	0.46	0.48	0.51	0.95	1.00	1.00	99.23	104.45	109.67	3732.36	3928.80	4125.24	4.85	5.10	5.36
Mardin	0.43	0.45	0.47	0.95	1.00	1.00	85.12	89.60	94.08	441.44	464.67	487.90	19.57	20.60	21.63
Mersin	0.46	0.48	0.51	0.95	1.00	1.00	105.97	111.54	117.12	6400.99	6737.89	7074.78	11.78	12.40	13.02
Muğla	0.47	0.50	0.52	0.95	1.00	1.00	66.13	69.61	73.09	7115.04	7489.51	7863.99	6.94	7.30	7.67
Muş	0.41	0.44	0.46	0.38	0.40	0.42	48.47	51.03	53.58	183.28	192.92	202.57	9.88	10.40	10.92
Nevşehir	0.45	0.47	0.50	0.58	0.61	0.64	50.56	53.22	55.88	611.53	643.72	675.90	5.70	6.00	6.30

Niğde	0.45	0.47	0.50	0.52	0.55	0.58	44.44	46.78	49.11	635.23	668.67	702.10	5.80	6.10	6.41
Ordu	0.43	0.45	0.47	0.95	1.00	1.00	115.60	121.68	127.77	1625.95	1711.53	1797.10	5.80	6.10	6.41
Osmaniye	0.44	0.46	0.49	0.72	0.76	0.79	154.12	162.23	170.34	632.70	666.00	699.30	13.30	14.00	14.70
Rize	0.46	0.48	0.51	0.62	0.66	0.69	79.88	84.08	88.29	742.60	781.69	820.77	6.37	6.70	7.04
Sakarya	0.47	0.50	0.52	0.95	1.00	1.00	183.15	192.79	202.43	2047.21	2154.96	2262.70	8.93	9.40	9.87
Samsun	0.45	0.47	0.50	0.95	1.00	1.00	132.83	139.82	146.81	3403.23	3582.35	3761.47	6.27	6.60	6.93
Siirt	0.42	0.44	0.47	0.61	0.64	0.67	55.26	58.17	61.08	194.69	204.94	215.19	19.48	20.50	21.53
Sinop	0.40	0.42	0.44	0.54	0.56	0.59	33.55	35.31	37.08	591.58	622.72	653.85	5.89	6.20	6.51
Sivas	0.44	0.47	0.49	0.69	0.73	0.77	20.73	21.83	22.92	1378.95	1451.52	1524.10	9.50	10.00	10.50
Şanlıurfa	0.40	0.42	0.44	0.95	1.00	1.00	93.44	98.36	103.27	885.47	932.08	978.68	15.49	16.30	17.12
Şırnak	0.43	0.45	0.47	0.59	0.62	0.65	64.95	68.37	71.79	189.40	199.37	209.34	19.10	20.10	21.11
Tekirdağ	0.50	0.52	0.55	0.95	1.00	1.00	136.45	143.63	150.81	3693.53	3887.92	4082.32	6.84	7.20	7.56
Tokat	0.43	0.45	0.48	0.61	0.64	0.67	57.04	60.04	63.05	823.44	866.78	910.12	6.27	6.60	6.93
Trabzon	0.45	0.48	0.50	0.95	1.00	1.00	156.18	164.40	172.62	2564.52	2699.49	2834.46	7.03	7.40	7.77
Tunceli	0.54	0.57	0.59	0.62	0.66	0.69	11.06	11.64	12.22	353.25	371.84	390.43	7.70	8.10	8.51
Uşak	0.46	0.49	0.51	0.67	0.70	0.74	62.16	65.43	68.70	1399.28	1472.93	1546.58	5.13	5.40	5.67
Van	0.43	0.46	0.48	0.95	1.00	1.00	53.44	56.25	59.06	692.27	728.70	765.14	9.79	10.30	10.82
Yalova	0.46	0.48	0.51	0.68	0.72	0.76	254.06	267.43	280.80	968.78	1019.77	1070.76	10.45	11.00	11.55
Yozgat	0.43	0.45	0.47	0.60	0.63	0.66	29.20	30.74	32.28	639.04	672.67	706.31	8.17	8.60	9.03
Zonguldak	0.46	0.48	0.50	0.58	0.61	0.64	172.17	181.23	190.30	2610.67	2748.07	2885.48	7.22	7.60	7.98

References

[1] Ozcan T, Tuysuz F. Modified grey relational analysis integrated with grey dematel approach for the performance evaluation of retail stores. Int J Inf Technol Decis Making 2016;15(02):353–86.
[2] Mazza L, Rydin Y. Urban sustainability: discourses, networks and policy tools. Prog Plann 1997;1(47):1–74.
[3] Erkip F, Ozuduru BH. Retail development in Turkey: an account after two decades of shopping malls in the urban scene. Prog Plann 2015;102:1–33.
[4] Fernandes JR, Chamusca P. Urban policies, planning and retail resilience. Cities 2014;36:170–7.
[5] Kelly M, Seubsman SA, Banwell C, Dixon J, Sleigh A. Traditional, modern or mixed? Perspectives on social, economic, and health impacts of evolving food retail in Thailand. Agric Hum Val 2015;32(3):445–60.
[6] Kearney AT. Global retailers: cautiously aggressive or aggressively cautious. Global Retail Development Index; 2013.
[7] Shen CY, Yu KT. A generalized fuzzy approach for strategic problems: the empirical study on facility location selection of authors' management consultation client as an example. Expert Syst Appl 2009;36(3):4709–16.
[8] Karande K, Lombard JR. Location strategies of broad-line retailers: an empirical investigation. J Bus Res 2005;58(5):687–95.
[9] Erbıyık H, Özcan S, Karaboğa K. Retail store location selection problem with multiple analytical hierarchy process of decision making an application in Turkey. Procedia Soc Behav Sci 2012;58:1405–14.
[10] Tolga AC, Tuysuz F, Kahraman C. A fuzzy multi-criteria decision analysis approach for retail location selection. Int J Inf Technol Decis Making 2013;12(04):729–55.
[11] Levy M, Weitz BA. Retailing management. New York: The McGraw-Hills/Irwin; 2009.
[12] Christaller W. Central places in southern Germany. Translation into English by carlisle W. Baskin in 1966. Englewood Cliffs, NJ: Prentice-Hall; 1933.
[13] Reilly WJ. The law of retail gravitation. 1931. WJ Reilly.
[14] Haig RM. Regional survey of New York and its environs. Major economic factors in metropolitan growth and its arrangement. 1927. New York.
[15] Hotelling H. Stability in competition. Econ J 1929;39:41–57.
[16] Brown S. Retail location theory: evolution and evaluation. International Review of Retail. Distrib Consum Res 1993;3(2):185–229.
[17] Turhan G, Akalın M, Zehir C. Literature review on selection criteria of store location based on performance measures. Procedia Soc Behav Sci 2013;99:391–402.
[18] Reigadinha T, Godinho P, Dias J. Portuguese food retailers–Exploring three classic theories of retail location. J Retail Consum Serv 2017;34:102–16.
[19] McGoldrick PJ. Retail marketing. New York, NY: McGraw-Hill; 1990.
[20] Applebaum W. Store location strategy cases. Reading, MA: Addison-Wesley; 1968.
[21] Birkin M, Clarke G, Clarke MP. Retail geography and intelligent network planning. John Wiley & Sons; 2002.
[22] Huff DL. A probabilistic analysis of shopping center trade areas. Land Econ 1963;39(1):81–90.
[23] Huff DL. Defining and estimating a trading area. J Market 1964:34–8.
[24] Clarkson RM, Clarke-Hill CM, Robinson T. UK supermarket location assessment. Int J Retail Distrib Manag 1996;24(6):22–33.
[25] Bai X, Chen G, Tian Q, Yin WJ, Dong J. Semi-supervised regression for evaluating convenience store location. IJCAI. 2009, July. p. 1389–94.
[26] Chang HJ, Hsieh CM, Yang FM. Acquiring an optimal retail chain location in China. Information science and control engineering (ICISCE), 2015 2nd international conference on. IEEE; 2015, April. p. 96–9.
[27] Eckert J, Shetty S. Food systems, planning and quantifying access: using GIS to plan for food retail. Appl Geogr 2011;31(4):1216–23.
[28] Joseph L, Kuby M. Regionalism in US retailing. Appl Geogr 2013;37:150–9.
[29] Murray AT, Tong D, Kim K. Enhancing classic coverage location models. Int Reg Sci Rev 2010;33(2):115–33.
[30] Onden I, Tuzla H, Cobb S. Evaluation of retail store location alternatives for investment decisions using the delphi technique and geographic information systems. Int Bus Res Teach Pract 2012;6(2):64–75.
[31] Suárez-Vega R, Santos-Peñate DR, Dorta-González P. Location models and GIS tools for retail site location. Appl Geogr 2012;35(1):12–22.
[32] Reynolds J, Wood S. Location decision making in retail firms: evolution and challenge. Int J Retail Distrib Manag 2010;38(11/12):828–45.
[33] Wang FF, Chen LF, Su CT. Location selection using fuzzy-connective-based aggregation networks: a case study of the food and beverage chain industry in Taiwan. Neural Comput Appl 2015;26(1):161–70.
[34] Kahraman C, Ruan D, Doğan I. Fuzzy group decision-making for facility location selection. Inf Sci 2003;157:135–53.
[35] Budak A, Ustundag A. Fuzzy decision making model for selection of real time location systems. Appl Soft Comput 2015;36:177–84.
[36] Chang XY, Chen ZG. A fuzzy-based location selection method for reverse logistics reprocessing center. 2006 international conference on management science and engineering. IEEE; 2006, October. p. 561–5.
[37] Kayikci Y. A conceptual model for intermodal freight logistics centre location decisions. Procedia Soc Behav Sci 2010;2(3):6297–311.
[38] Keprate A, Ratnayake RC. Enhancing offshore process safety by selecting fatigue critical piping locations for inspection using Fuzzy-AHP based approach. Process Saf Environ Protect 2016;102:71–84.
[39] Kuo RJ, Chi SC, Kao SS. A decision support system for locating convenience store through fuzzy AHP. Comput Ind Eng 1999;37(1):323–6.
[40] Kuo RJ, Chi SC, Kao SS. A decision support system for selecting convenience store location through integration of fuzzy AHP and artificial neural network. Comput

Ind 2002;47(2):199–214.
[41] Tabari M, Kaboli A, Aryanezhad MB, Shahanaghi K, Siadat A. A new method for location selection: a hybrid analysis. Appl Math Comput 2008;206(2):598–606.
[42] Vahidnia MH, Alesheikh AA, Alimohammadi A. Hospital site selection using fuzzy AHP and its derivatives. J Environ Manag 2009;90(10):3048–56.
[43] Wang Y, Jung KA, Yeo GT, Chou CC. Selecting a cruise port of call location using the fuzzy-AHP method: a case study in East Asia. Tourism Manag 2014;42:262–70.
[44] Guneri AF, Cengiz M, Seker S. A fuzzy ANP approach to shipyard location selection. Expert Syst Appl 2009;36(4):7992–9.
[45] Kuo MS, Liang GS. A novel hybrid decision-making model for selecting locations in a fuzzy environment. Math Comput Model 2011;54(1):88–104.
[46] Wu CR, Lin CT, Chen HC. Integrated environmental assessment of the location selection with fuzzy analytical network process. Qual Quantity 2009;43(3):351–80.
[47] Anagnostopoulos K, Doukas H, Psarras J. A linguistic multicriteria analysis system combining fuzzy sets theory, ideal and anti-ideal points for location site selection. Expert Syst Appl 2008;35(4):2041–8.
[48] Awasthi A, Chauhan SS, Goyal SK. A multi-criteria decision making approach for location planning for urban distribution centers under uncertainty. Math Comput Model 2011;53(1):98–109.
[49] Chu TC. Facility location selection using fuzzy TOPSIS under group decisions. Int J Uncertain Fuzziness Knowledge Based Syst 2002;10(06):687–701.
[50] Chung ES, Kim Y. Development of fuzzy multi-criteria approach to prioritize locations of treated wastewater use considering climate change scenarios. J Environ Manag 2014;146:505–16.
[51] Ekmekçioğlu M, Kaya T, Kahraman C. Fuzzy multicriteria disposal method and site selection for municipal solid waste. Waste Manag 2010;30(8):1729–36.
[52] Hu Y, Wu S, Cai L. Fuzzy multi-criteria decision-making TOPSIS for distribution center location selection. Networks security, wireless communications and trusted computing, 2009. NSWCTC'09. International conference on, vol. 2. IEEE; 2009, April. p. 707–10.
[53] Mokhtarian MN, Hadi-Vencheh A. A new fuzzy TOPSIS method based on left and right scores: an application for determining an industrial zone for dairy products factory. Appl Soft Comput 2012;12(8):2496–505.
[54] Rao C, Goh M, Zhao Y, Zheng J. Location selection of city logistics centers under sustainability. Transport Res Part D Transport Environ 2015;36:29–44.
[55] Yong D. Plant location selection based on fuzzy TOPSIS. Int J Adv Manuf Technol 2006;28(7–8):839–44.
[56] Önüt S, Soner S. Transshipment site selection using the AHP and TOPSIS approaches under fuzzy environment. Waste Manag 2008;28(9):1552–9.
[57] Choudhary D, Shankar R. An STEEP-fuzzy AHP-TOPSIS framework for evaluation and selection of thermal power plant location: a case study from India. Energy 2012;42(1):510–21.
[58] Ebrahimi M, Modam MM. Selecting the best zones to add new emergency services based on a hybrid fuzzy MADM method: a case study for Tehran. Saf Sci 2016;85:67–76.
[59] Erdoğan M, Kaya İ. A combined fuzzy approach to determine the best region for a nuclear power plant in Turkey. Appl Soft Comput 2016;39:84–93.
[60] Ertuğrul İ, Karakaşoğlu N. Comparison of fuzzy AHP and fuzzy TOPSIS methods for facility location selection. Int J Adv Manuf Technol 2008;39(7–8):783–95.
[61] Çetinkaya C, Özceylan E, Erbaş M, Kabak M. GIS-based fuzzy MCDA approach for siting refugee camp: a case study for southeastern Turkey. Int J Disaster Risk Reduct 2016;18:218–31.
[62] Chauhan A, Singh A. A hybrid multi-criteria decision making method approach for selecting a sustainable location of healthcare waste disposal facility. J Clean Prod 2016;139:1001–10.
[63] Sánchez-Lozano JM, García-Cascales MS, Lamata MT. GIS-based onshore wind farm site selection using Fuzzy Multi-Criteria Decision Making methods. Evaluating the case of Southeastern Spain. Appl Energy 2016;171:86–102.
[64] Ka B. Application of fuzzy AHP and ELECTRE to China dry port location selection. Asian J Shipp Logist 2011;27(2):331–53.
[65] Kabir G, Sumi RS. Power substation location selection using fuzzy analytic hierarchy process and PROMETHEE: a case study from Bangladesh. Energy 2014;72:717–30.
[66] Yeh TM, Huang YL. Factors in determining wind farm location: integrating GQM, fuzzy DEMATEL, and ANP. Renew Energy 2014;66:159–69.
[67] Kuo MS. Optimal location selection for an international distribution center by using a new hybrid method. Expert Syst Appl 2011;38(6):7208–21.
[68] Topraklı AY, Adem A, Dağdeviren M. A courthouse site selection method using hesitant fuzzy linguistic term set: a case study for Turkey. Procedia Comput Sci 2016;102:603–10.
[69] Tüysüz F, Çelikbilek Y. Analysis of the factors for the evaluation of renewable energy resources using hesitant fuzzy linguistic term sets. 8th international Ege energy syposium May 11-13, 2016 Afyonkarahisar, Turkey. 2016. p. 934–8.
[70] Tüysüz F, Şimşek B. Analysis of the factors affecting performance evaluation of Branches in A Cargo company by using hesitant fuzzy AHP. Uncertainty modelling in knowledge engineering and decision making: proceedings of the 12th international FLINS conference, August 24-26, 2016 Roubaix, France. 2016. p. 866–71.
[71] Senvar O, Otay I, Bolturk E. Hospital site selection via hesitant fuzzy TOPSIS. IFAC-PapersOnLine 2016;49(12):1140–5.
[72] Çelikbilek Y, Tüysüz F. A fuzzy multi criteria decision making approach for evaluating renewable energy sources. The 4th international fuzzy systems symposium, İstanbul, Turkey, 5–6 November 2015. 2015. p. 322–7.
[73] Gupta P, Mehlawat MK, Grover N. Intuitionistic fuzzy multi-attribute group decision-making with an application to plant location selection based on a new extended VIKOR method. Inf Sci 2016;370:184–203.
[74] Torra V. Hesitant fuzzy sets. Int J Intell Syst 2010;25(6):529–39.
[75] Zadeh LA. Fuzzy sets. Inf Control 1965;8(3):338–53.
[76] Torra V, Narukawa Y. On hesitant fuzzy sets and decision. Fuzzy systems, 2009. FUZZ-IEEE 2009. IEEE international conference on. IEEE; 2009, August. p. 1378–82.
[77] Xu Z, Xia M. Distance and similarity measures for hesitant fuzzy sets. Inf Sci 2011;181(11):2128–38.
[78] Rodríguez RM, Martinez L, Herrera F. Hesitant fuzzy linguistic term sets for decision making. Fuzzy Syst IEEE Trans 2012;20(1):109–19.
[79] Rodríguez RM, Martinez L, Herrera F. A group decision making model dealing with comparative linguistic expressions based on hesitant fuzzy linguistic term sets. Inf Sci 2013;241:28–42.
[80] Zhu B, Xu Z. Analytic hierarchy process-hesitant group decision making. Eur J Oper Res 2014;239(3):794–801.
[81] Mousavi SM, Gitinavard H, Siadat A. A new hesitant fuzzy analytical hierarchy process method for decision-making problems under uncertainty. Industrial engineering and engineering management (IEEM), 2014 IEEE international conference on. IEEE; 2014, December. p. 622–6.
[82] Yavuz M, Oztaysi B, Onar SC, Kahraman C. Multicriteria evaluation of alternative-fuel vehicles via a hierarchical hesitant fuzzy linguistic model. Expert Syst Appl 2015;42(5):2835–48.
[83] Öztaysi B, Onar SÇ, Boltürk E, Kahraman C. Hesitant fuzzy analytic hierarchy process. Fuzzy systems (FUZZ-IEEE), 2015 IEEE international conference on. IEEE; 2015, August. p. 1–7.
[84] Zhu B, Xu Z, Zhang R, Hong M. Hesitant analytic hierarchy process. Eur J Oper Res 2016;250(2):602–14.
[85] Onar SÇ, Büyüközkan G, Öztayşi B, Kahraman C. A new hesitant fuzzy QFD approach: an application to computer workstation selection. Appl Soft Comput 2016;46:1–16.
[86] Zhou W, Xu Z. Asymmetric hesitant fuzzy sigmoid preference relations in the analytic hierarchy process. Inf Sci 2016;358:191–207.
[87] Deng JL. Control problems of grey systems. Syst Contr Lett 1982;1(5):288–94.
[88] Wei GW. Grey relational analysis method for 2-tuple linguistic multiple attribute group decision making with incomplete weight information. Expert Syst Appl 2011;38(5):4824–8.
[89] Wu HH. A comparative study of using grey relational analysis in multiple attribute decision making problems. Qual Eng 2002;15(2):209–17.
[90] Ju-Long D. Control problems of grey systems. Syst Contr Lett 1982;1(5):288–94.
[91] Samvedi A, Jain V, Chan FT. An integrated approach for machine tool selection using fuzzy analytical hierarchy process and grey relational analysis. Int J Prod Res 2012;50(12):3211–21.
[92] Wang Z, Lei T, Chang X, Shi X, Xiao J, Li Z, ... Yang S. Optimization of a biomass briquette fuel system based on grey relational analysis and analytic hierarchy process: a study using cornstalks in China. Appl Energy 2015;157:523–32.
[93] Xu G, Yang YP, Lu SY, Li L, Song X. Comprehensive evaluation of coal-fired power plants based on grey relational analysis and analytic hierarchy process. Energy Pol 2011;39(5):2343–51.
[94] Yang CC, Chen BS. Supplier selection using combined analytical hierarchy process and grey relational analysis. J Manuf Technol Manag 2006;17(7):926–41.
[95] Hashemi SH, Karimi A, Tavana M. An integrated green supplier selection approach with analytic network process and improved Grey relational analysis. Int J Prod Econ 2015;159:178–91.
[96] Sakthivel G, Ilangkumaran M, Nagarajan G, Priyadharshini GV, Dinesh Kumar S, Satish Kumar S, ... Thilakavel T. Multi-criteria decision modelling approach for biodiesel blend selection based on GRA–TOPSIS analysis. Int J Ambient Energy 2014;35(3):139–54.
[97] Dixit NK, Srivastava R, Narain R. Comparison of two different rapid prototyping system based on dimensional performance using grey relational grade method. Procedia Technol 2016;25:908–15.
[98] Kumar SS, Uthayakumar M, Kumaran ST, Parameswaran P, Mohandas E, Kempulraj G, ... Natarajan SA. Parametric optimization of wire electrical discharge machining on aluminium based composites through grey relational analysis. J Manuf Process 2015;20:33–9.
[99] Nagesh S, Murthy HN, Pal R, Krishna M, Satyanarayana BS. Influence of nanofillers on the quality of CO2 laser drilling in vinylester/glass using orthogonal array experiments and grey relational analysis. Optic Laser Technol 2015;69:23–33.
[100] Pandey RK, Panda SS. Optimization of multiple quality characteristics in bone drilling using grey relational analysis. J Orthop 2015;12(1):39–45.
[101] Prakash S, Mercy JL, Salugu MK, Vineeth KSM. Optimization of drilling characteristics using grey relational analysis (GRA) in medium density fiber board (MDF). Mater Today Proc 2015;2(4–5):1541–51.
[102] Sun B, Jiang J, Zheng F, Zhao W, Liaw BY, Ruan H, ... Zhang W. Practical state of health estimation of power batteries based on Delphi method and grey relational grade analysis. J Power Sources 2015;282:146–57.
[103] Li X, Hipel KW, Dang Y. An improved grey relational analysis approach for panel data clustering. Expert Syst Appl 2015;42(23):9105–16.
[104] Tang H. A novel fuzzy soft set approach in decision making based on grey relational analysis and Dempster–Shafer theory of evidence. Appl Soft Comput 2015;31:317–25.
[105] Wang Q, Wu C, Sun Y. Evaluating corporate social responsibility of airlines using entropy weight and grey relation analysis. J Air Transport Manag 2015;42:55–62.
[106] Geum Y, Cho Y, Park Y. A systematic approach for diagnosing service failure: service-specific FMEA and grey relational analysis approach. Math Comput Model 2011;54(11):3126–42.
[107] Wang P, Meng P, Zhai JY, Zhu ZQ. A hybrid method using experiment design and grey relational analysis for multiple criteria decision making problems. Knowl

Based Syst 2013;53:100–7.
[108] Huang C, Dai C, Guo M. A hybrid approach using two-level DEA for financial failure prediction and integrated SE-DEA and GCA for indicators selection. Appl Math Comput 2015;251:431–41.
[109] Raykar SJ, D'Addona DM, Mane AM. Multi-objective optimization of high speed turning of Al 7075 using grey relational analysis. Procedia CIRP 2015;33:293–8.
[110] Pahange H, Abolbashari MH. Mass and performance optimization of an airplane wing leading edge structure against bird strike using Taguchi-based grey relational analysis. Chin J Aeronaut 2016;29(4):934–44.
[111] Ahmad N, Kamal S, Raza ZA, Hussain T, Anwar F. Multi-response optimization in the development of oleo-hydrophobic cotton fabric using Taguchi based grey relational analysis. Appl Surf Sci 2016;367:370–81.
[112] Nelabhotla DM, Jayaraman TV, Asghar K, Das D. The optimization of chemical mechanical planarization process-parameters of c-plane gallium-nitride using Taguchi method and grey relational analysis. Mater Des 2016;104:392–403.
[113] Sahu PK, Pal S. Multi-response optimization of process parameters in friction stir welded AM20 magnesium alloy by Taguchi grey relational analysis. J Magnes Alloys 2015;3(1):36–46.
[114] Sarıkaya M, Güllü A. Multi-response optimization of minimum quantity lubrication parameters using Taguchi-based grey relational analysis in turning of difficult-to-cut alloy Haynes 25. J Clean Prod 2015;91:347–57.
[115] Shanmugarajan B, Shrivastava R, Sathiya P, Buvanashekaran G. Optimisation of laser welding parameters for welding of P92 material using Taguchi based grey relational analysis. Def Technol 2016;12(4):343–50.
[116] Ho HP, Chang CT, Ku CY. On the location selection problem using analytic hierarchy process and multi-choice goal programming. Int J Syst Sci 2013;44(1):94–108.
[117] Cheng EW, Li H, Yu L. The analytic network process (ANP) approach to location selection: a shopping mall illustration. Construct Innovat 2005;5(2):83–97.
[118] Zolfani SH, Aghdaie MH, Derakhti A, Zavadskas EK, Varzandeh MHM. Decision making on business issues with foresight perspective; an application of new hybrid MCDM model in shopping mall locating. Expert Syst Appl 2013;40(17):7111–21.

Nurdan Yıldız received her B.Sc. in industrial engineering in 2013 from Konya Selçuk University and her M.Sc. in industrial engineering from İstanbul University in 2017. She is currently working as a researcher at İstanbul Gelişim University. Her research interests include fuzzy logic, decision theory and system simulation.

Fatih Tüysüz received his B.Sc. in industrial engineering in 2002, M.Sc. in engineering management in 2004, and Ph.D. in industrial engineering from İstanbul Technical University in 2010 respectively. He has been a full time faculty member at the department of Industrial Engineering in İstanbul University since 2012. He has been giving lectures relating decision theory, system simulation, engineering economics, manufacturing systems modeling, and lean production at both undergraduate and graduate levels. His research interests include fuzzy logic and applications, grey system theory, system modeling, and modern manufacturing systems.