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A MULTI-CRITERIA CALL CENTER SITE SELECTION BY HIERARCHY GREY RELATIONAL ANALYSIS

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ABSTRACT

Facility location selection is a decision problem that takes into consideration both qualitative and quantitative factors and also is one of the most important strategic decisions affecting organizations in terms of business success. Fundamentally, it comprises evaluating a group of alternative sites on the basis of multiple criteria. In this context when alternatives and factors are multitudinous, multi-criteria decision making methods are being used for successful decisions. In this paper the decision problem is exemplified by applying on a part of a project for a call center site selection by using one of the multi-criteria decision-making methods, namely hierarchy grey relational analysis, based on application of analytic hierarchy process (AHP) and grey relational analysis (GRA) methods. The goal of the selection is to determine the most appropriate location among the alternatives. Nine cities given as alternatives are evaluated and compared against human resources, economic and regional conditions including fourteen sub-criteria.

***Keywords:** Analytic Hierarchy Process, Grey Relational Analysis, Call Center Site Selection.*

HİYERARŞİK GRİ İLİŞKİSEL ANALİZ YÖNTEMİYLE ÇOK KRİTERLİ ÇAĞRI MERKEZİ YERİ SEÇİMİ

ÖZET

Tesis kuruluş yeri seçimi nitel ve nicel faktörleri dikkate alan bir karar problemi olmakla beraber aynı zamanda organizasyonun başarısını etkilemesi açısından da en önemli stratejik kararlardan birisidir. Esasında bir grup alternatifi birçok kriter temelinde değerlendirmeyi içermektedir. Bu kapsamda alternatif ve etkenler fazla olduğu zaman başarılı kararlar için çok kriterli karar verme yöntemleri kullanılmaktadır. Bu makalede karar problemi, Analitik Hiyerarşi Prosesi (AHP) ve Gri İlişkisel Analiz (GİA) yöntemlerini temel alan çok kriterli karar verme yöntemlerinden Hiyerarşik Gri İlişkisel Analiz yönteminin çağrı merkezi yer seçimi için bir projenin parçası olarak uygulanmasıyla örneklendirilmiştir. Seçimin amacı alternatifler arasından en uygun yeri belirlemektir. Alternatif olarak verilen dokuz şehir ondört alt kriter içeren insan kaynağı, ekonomik ve bölgesel şartlar kapsamında karşılaştırılmış ve değerlendirilmiştir.

***Anahtar Kelimeler:** Analitik Hiyerarşi Prosesi, Gri İlişkisel Analiz, Çağrı Merkezi Kuruluş Yeri Seçimi.*

1. INTRODUCTION

Decision making is one of the most important problem in any field and it is the process of finding the best option from all of the feasible alternatives. Most decision making problems often have multiple and contradictory evaluation standards. Various opinions among decision makers are the main cause contributing to the conflicts in the process of decision making. In real world situations, because of deficient or non – obtainable information, the attributes are often not so deterministic. But the majority of these attributes can be assessed by human perception and human judgment.

Facility location selection is a decision problem that takes into consideration both qualitative and quantitative factors in this respect and is one of the most important strategic decision affecting organizations substantially, competitiveness and

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performance. It would be not only a challenging decison for the companies but also too costly and too difficult to change the site after the installation of a plant.

Nowadays numerous companies are benefiting from numerical decision making methods in the decision making process of site selection because this strategic decision allow them to perform operations with minimum cost and maximum profit and also to maintain their presence effectively. Including diverse factors, facility location selection desicion is a process that requires selection of the rational processes among alternatives. In this context when alternatives and factors are multitudinous, multi-criteria decision making methods are being used for successful decisions.

In this study facility location selection problem is handled and solved for the call centers, considered to open in the near future in southeastern Anatolia, using a combination of the Analytic Hierarchy Process (AHP) and the Grey Relational Analysis (GRA).
The selection of call center location is a complex multi-criteria task which includes both quantitative and qualitative factors are in conflict and uncertain. For the purpose of solving the problem all criteria which affect the decision making process are determined by a group of experts occupied on call center sector as executives. The most appropriate location among the alternatives is set in the decision making process and created by examining call center facility location selection criteria.

2. LITERATURE REVIEW

Selection problem has been interested by many researchers, thus numerous optimization models have been developed in the various studies for the site selection problems during the past years. This paper deals with an approach based on AHP and GRA for choosing the best call centre site.

Analytic Hierarchical Process (AHP) which is a special case of the ANP, has been widely used for location problems, including in Aras et al. [1], in which a pretty number of criteria were taken into account for a wind observation station location problem. Another example of AHP location problems is Tzeng et al. [2] in which 4 alternatives, 5 aspects and 11 criteria were used for a location evaluation of a restaurant. In this paper, the compromise ranking method, named VIKOR, has been introduced as one applicable technique. The VIKOR algorithm determines the weight stability intervals, for the obtained compromise solution with the ‘‘input” weights, indicating the preference stability of obtained compromise solution. Fernandez and Ruiz [3] considered the selection of a location for an industrial park. In their paper, they have proposed a three-level hierarchical decision process in which each level has its own geographical decision criteria. They then used AHP to find the location. Goal programming has been utilized to improve the problems solved by AHP. For example, Badri [4] offered a combined AHP and goal program modeling approach for international facility location/allocation problem; the role of AHP was to prioritize the set of location alternatives at first.

Under many situations, the values of the quantitative and qualitative criteria are often imprecise or vague, therefore GRA, one of the sub-branches of Deng’s Grey Theory [5] which has been applied in prediction, control, social and economic system management, decision making about environmental systems in recent years [6-9], is becoming a handy approach, like Zhen-qiang et al. [10] which presented an analysis for the facility’s location of logistics distribution network. Huang and Huang [11] integrated fuzzy and grey modeling methods for predicting the monthly average temperatures in Taipei. The basic grey model GM(1,1) is accompanied with the adaptive fuzzy method to improve its prediction capability. They found that the predictive capability of the integrated model was satisfactory for those systems demanding complicated control variables and rules. In another study Chang and Lin [12] used GRA to analyze how energy-induced CO_2 emissions from 34 industries in Taiwan are affected by the factors: production, total energy consumption, coal, oil, gas and electricity uses. Results of the study indicated that industrial production has the closest relationship with aggregate CO_2 emission changes; electricity consumption the second in importance. They pointed out the economy in Taiwan relied heavily on CO_2 intensive industries, and that electricity consumption had become more important for economic growth. Another example is Kahraman et al. [13] in which to select technology for renewable electricity generation, implemented AHP and GRA for their multi-criteria decision making. They obtained best alternative by evaluating the problem under 3 criteria, 10 sub criteria. The result showed that photovoltaic power is the optimal alternative for investing in the different renewable electricity generation technologies. Yang and Chen [14] used a combined AHP and GRA for supplier selection problem. They used AHP to calculate relative importance weightings of qualitative criteria. Then, the qualitative and quantitative data were utilized together and obtained the grey relational grade values. The best supplier had the highest grey relational value among others. Zeng et al. [15] employed an approach for the waste water treatment alternative selection problem. This was based on AHP and GRA. They used 3 main attributes including 8 indices that represented the alternatives and evaluated four water treatment methods. Feng et al. [16] presented a study based on establishing an evaluation index system of logistics center location. For this purpose they constructed an integrated decision model by using the entropy method and grey relational analysis. The weights of the evaluation indexes were defined by the entropy method. The quantitative process and comparison of the qualitative information were made by GRA.

3. METHODOLOGY: INTEGRATED AHP AND GRA

A. AHP Procedure

Analytic hierarchy process (AHP) was introduced by Saaty [17] and afterwards it gained widely acceptance [1-4], [13-15]. AHP has been used to solve multiple criteria decision making problems in different areas of human needs and interests. The hierarchy is constructed in such a way that the overall decision goal is at the top level, decision criteria are in the middle level(s), and decision alternatives at the bottom [18]. Three steps in AHP, decomposition, judgment and synthesizing are the same way as people think. So it could be said that the AHP is a subjective weighting method. The relative importance between two comparative factors is reflected by the element values of judgment matrix. Table 1 shows general form of the measurement scale. It has relative importance in scale of 1-9 [17], [19].

Table 1. Scale for pairwise comparison in AHP.

Importance degree	Descriptions	Explanation
1	Equally important	Criteria *i* and *j* are of equal importance
3	Weakly important	Criteria *i* is weakly more important than objective *j*
5	Strongly important	Criteria *i* is strongly more important than objective *j*
7	Very strongly important	Criteria *i* is very strongly more important than objective *j*
9	Extremely important	Criteria *i* is extremely more important than objective *j*
2, 4, 6, 8	Intermediate values	For example, a value of 8 means that Criteria *i* is midway between strongly and more important than objective *j*

After defining and decomposing the problem into a hierarchical structure with decision elements, the procedures of AHP to solve the problem generally involve three essential steps in order [20]:

1) The pairwise comparison matrix (A) is formed

$$A=(a_{ij})_{nxn}=\begin{vmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ a_{n1} & a_{n2} & \cdots & a_{nn} \end{vmatrix} \quad (1)$$

where a_{ij} represents the judgment degree of i^{th} factor compared to j^{th} factor.

2) The inconsistency of comparison matrix is computed as follows:

$$CI=\left(\frac{\lambda_{maks}-n}{n-1}\right) \quad (2)$$

where eigenvalue close to n is the largest eigenvalue (λ_{max}) and can be found by "eig()" instruction via Matlab and CI is the consistency index. Consistency check is applied by computing the consistency ratio (CR):

$$CR=\frac{CI}{RI} \quad (3)$$

where RI is the random index. The values of RI are shown in Table 2.

Table 2. RI values.

m	2	3	4	5	6	7	8
R.I.	0	0,58	0,9	1,12	1,24	1,32	1,41

When CR ≤ 0.10, it means that the inconsistency of the pairwise comparison matrix is in the desired interval and matrix is acceptable.

3) The weights vector (W_A) is then estimated by using the eigenvalue method through the following formula:

$$W_A=\begin{vmatrix} \left(\prod_{j=1}^{n} a_{1j}\right)^{1/n} \\ \left(\prod_{j=1}^{n} a_{2j}\right)^{1/n} \\ \vdots \\ \left(\prod_{j=1}^{n} a_{nj}\right)^{1/n} \end{vmatrix}=\begin{vmatrix} \sqrt[n]{(a_{11}.a_{12}.\cdots.a_{1n})} \\ \sqrt[n]{(a_{21}.a_{22}.\cdots.a_{2n})} \\ \cdots \\ \sqrt[n]{(a_{n1}.a_{n2}.\cdots.a_{nn})} \end{vmatrix} \quad (3)$$

The normalized weights vector (W'_A) is then obtained as follows:

$$W'_A=\begin{vmatrix} \left(\prod_{j=1}^{n} a_{1j}\right)^{1/n} / \sum_{i=1}^{n}\left(\left(\prod_{j=1}^{n} a_{ij}\right)^{1/n}\right) \\ \left(\prod_{j=1}^{n} a_{2j}\right)^{1/n} / \sum_{i=1}^{n}\left(\left(\prod_{j=1}^{n} a_{ij}\right)^{1/n}\right) \\ \cdots \\ \left(\prod_{j=1}^{n} a_{nj}\right)^{1/n} / \sum_{i=1}^{n}\left(\left(\prod_{j=1}^{n} a_{ij}\right)^{1/n}\right) \end{vmatrix}=\begin{vmatrix} W_1 \\ W_2 \\ \cdots \\ W_n \end{vmatrix} \quad (4)$$

B. Grey Relational Analysis

The grey relational analysis (GRA) is used to determine the relationship (similarity) between two series of data in a grey system. Its structure has uncertainty, therefore it handles the problems consisted of discrete data and partial information [5]. It operates the grey relational grade to determine the relational degree of factors. The algorithm of GRA is illustrated as follows [13-16], [20]:

1) Let x_0 denote the referential series with n entities and let x_i represent the compared series.

$$X_0 = (X_0(1), X_0(2), \ldots\ldots, X_0(n)) \tag{5}$$

$$X_i = (X_i(1), X_i(j), \ldots\ldots, X_i(n)), \quad i = 1,2,\ldots,m \quad j = 1,2,\ldots,n \tag{6}$$

2) Before calculating the grey relational grade, we must perform data pre-processing. Normalization of series must be done to ensure that all of them are in the same order. Normalized sequences can be denoted as:

$$X_i^*(j) = (X_i^*(1), X_i^*(j), \ldots\ldots, X_i^*(n)) \tag{7}$$

For cost x_i indices, the normalized data can be acquired by

$$X_i^*(j) = \frac{X_{i\min}}{X_i(j)} \quad i = 1,2,\ldots,m \quad j = 1,2,\ldots,n \tag{8}$$

While for benefit x_i indices, the normalized data can be acquired by

$$X_i^*(j) = \frac{X_i(j)}{X_{i\max}} \quad i = 1,2,\ldots,m \quad j = 1,2,\ldots,n \tag{9}$$

3) For j^{th} factor, the grey relational coefficient between series x_0 and x_i is then given as:

$$\xi_{0i}(j) = \frac{\Delta\min + \rho\Delta\max}{\Delta_{0i}(j) + \rho\Delta\max} \tag{10}$$

where,

$\Delta_{0i}(j) = \left|X_0(j) - X_i^*(j)\right|$, $\Delta\max = \max_i \max_j \Delta_{0i}(j)$, $\Delta\min = \min_i \min_j \Delta_{0i}(j)$ and ρ is the distinguishing coefficient, ρ € [0,1], and typically ρ = 0,5.

4) Finally, by using the weights the aggregated evaluation model can be written as follows:

$$\varepsilon_i = \sum_{j=1}^{n} w_j \xi_{0i}(j) \tag{11}$$

4. PRACTICAL CASE

In this section, the hierarchy GRA is applied to the site selection of a call center which is going to be established in the southeastern Anatolia region in accordance with the opinion of the project executives of a corporation, located in Istanbul, interested in investing in the region. In this context, nine cities are taken into account and coded for the simplicity from A1 to A9 in alphabetic order.

The decision model for the call center site selection problem is given in Fig. 1. It contains four levels: at the top of the hierarchy, the overall objective is to select the most appropriate site for the call center. The criteria level is the second level of the hierarchy and consisted of human resources, economic and regional conditions criterion (C1, C2, C3). The third level considered as index level contains indices: population, non-farm payrolls, educated population, population growth rate, youthful population, unemployment rate, presence of higher education institutions, number of employees in the sector, income per capita, investment incentives, land cost, labor cost, transportation, climate (I_1 to I_{14}). Finally, alternative level of the model points out the cities to be compared and evaluated.

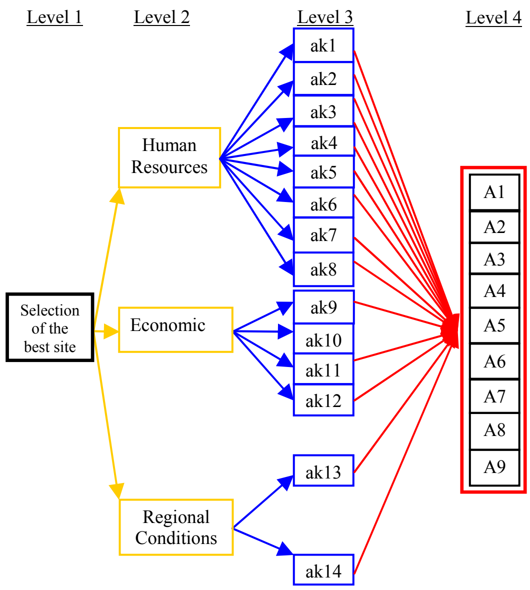

Figure 1. A hierarchy decision model for call center site selection.

Since the hierarchy has been established for the problem, we need to compute the weights describing the decision makers' relative importance of their judgments on alternatives. Table 3 and Table 4 displays obtained weights and consistency ratios and the values of criteria handled by decision makers respectively. The results in Table 3 illustrate that the weight of the economic criterion is 0.550 as compared to 0.368 for the human resources criterion, indicating that the importance of economic criterion is nearly more one and a half times than human resources criterion. And also as compared to 0.082 for the regional conditions criterion, economic criterion has nearly seven times more importance than regional conditions criterion.

In Table 4 some indices are provided by the numerical values and some are by the quantification of the linguistic values. In some cases uncertain indices, such as climate, transportation etc., can be quantified. Decision makers can classify indices into five grades with descriptive language including excellent, good, moderate, poor and very poor.

Table 3. Criteria and indice weights noted by decision makers.

Criteria	Weight	CR	Indices	Weight	CR
Human Resources (C1)	0.368	0.074	Population (I_1)	0.390	0.067
			Non-farm payrolls (I_2)	0.157	
			Educated population (I_3)	0.058	
			Population growth rate (I_4)	0.131	
			Youthful population (I_5)	0.104	
			Unemployment rate (I_6)	0.082	
			Presence of higher education institutions (I_7)	0.026	
			Number of employees in the sector (I_8)	0.052	
Economic (C2)	0.550		Income per capita (I_9)	0.571	0.067
			Investment incentives (I_{10})	0.044	
			Land cost (I_{11})	0.253	
			Labor cost (I_{12})	0.132	
Regional Conditions (C3)	0.082		Transportation (I_{13})	0.833	0
			Climate (I_{14})	0.167	

Table 4. An objective hierarchy for call center site selection.

		Alternatives								
Criteria	Indices	A1	A2	A3	A4	A5	A6	A7	A8	A9
C1	I_1	595261	534205	1592167	1799558	124320	773026	1762075	466982	310879
	I_2	118856	76564	198272	340341	24803	113874	199728	63374	44189
	I_3	103028	77633	232994	262940	7393	102154	158493	53595	33077
	I_4	P(0.3)	G(0.7)	M(0.5)	G(0.7)	P(0.3)	M(0.5)	G(0.7)	G(0.7)	P(0.3)
	I_5	117285	112399	333345	316305	22944	164997	350141	111396	70153
	I_6	10.0	11.4	13.2	13.1	9.9	8.9	12.1	10.9	12.4
	I_7	1	1	2	3	1	1	1	1	1
	I_8	E(0.9)	E(0.9)	M(0.5)	E(0.9)	E(0.9)	E(0.9)	E(0.9)	E(0.9)	E(0.9)
C2	I_9	9521	10609	10678	11022	11397	9164	8041	6068	9115
	I_{10}	G(0.7)	E(0.9)	E(0.9)	P(0.3)	G(0.7)	E(0.9)	E(0.9)	E(0.9)	E(0.9)
	I_{11}	110	265	250	149	163	368	168	107	60
	I_{12}	G(0.7)	G(0.7)	G(0.7)	G(0.7)	G(0.7)	G(0.7)	G(0.7)	G(0.7)	G(0.7)
C3	I_{13}	M(0.5)	M(0.5)	E(0.9)	G(0.7)	M(0.5)	G(0.7)	G(0.7)	P(0.3)	M(0.5)
	I_{14}	G(0.7)	G(0.7)	G(0.7)	E(0.9)	E(0.9)	E(0.9)	E(0.9)	P(0.3)	M(0.5)

Accordingly, the subjection grade is 0.9, 0.7, 0.5, 0.3 and 0.1, respectively [21]. The data in Table 4 was studied for the purpose of applying hierarchy GRA. Eq. 8 is used for the cost indices (I_8, I_9, I_{11}, I_{12}) and Eq. 9 for the rest of the indices as benefit formula. The normalized values of all indices can be found in Table 5.

Table 5 shows the required data for computation of primary and secondary grey relational coefficients. These are calculated by using Eq. 10 and ρ as 0,5.

Achieved data are displayed in Table 6 and Table 7. At the end, the aggregated grey relational grade vector can be obtained by multiplying the resulting secondary grey relational coefficient matrix in Table 7 by the weighting vector as shown in Eq. 11 for the criterion level (level 2) with respect to the overall objective.

As illustrated in Table 8, the nine alternative sites, that is A1 (Adıyaman), A2 (Batman), A3 (Diyarbakır), A4 (Gaziantep), A5 (Kilis), A6 (Mardin), A7 (Şanlıurfa), A8 (Şırnak) and A9 (Siirt), are ranked 7, 8, 3, 1, 9, 6, 2, 4 and 5, respectively. Therefore, Gaziantep as A4 is the optimal alternative among the others for the call center site.

Table 5. Normalized data of alternatives for index level.

Criteria	Indices	Alternatives								
		A1	A2	A3	A4	A5	A6	A7	A8	A9
C1	I_1	0.33	0.30	0.88	1.00	0.07	0.43	0.98	0.26	0.17
	I_2	0.35	0.22	0.58	1.00	0.07	0.33	0.59	0.19	0.13
	I_3	0.39	0.29	0.87	0.98	0.03	0.38	0.59	0.20	0.12
	I_4	0.33	0.78	0.56	0.78	0.33	0.56	0.78	0.78	0.33
	I_5	0.33	0.32	0.95	0.90	0.07	0.47	1.00	0.32	0.20
	I_6	0.59	0.67	0.78	0.77	0.58	0.52	0.71	0.64	0.73
	I_7	0.33	0.33	0.67	1.00	0.33	0.33	0.33	0.33	0.33
	I_8	0.11	0.11	0.20	0.11	0.11	0.11	0.11	0.11	0.11
C2	I_9	0.53	0.48	0.47	0.46	0.44	0.55	0.63	0.83	0.56
	I_{10}	0.78	1.00	1.00	0.33	0.78	1.00	1.00	1.00	1.00
	I_{11}	0.51	0.21	0.22	0.38	0.34	0.15	0.33	0.52	0.93
	I_{12}	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43
C3	I_{13}	0.56	0.56	1.00	0.78	0.56	0.78	0.78	0.33	0.56
	I_{14}	0.78	0.78	0.78	1.00	1.00	1.00	1.00	0.33	0.56

Table 6. Primary grey relational coefficients for index level.

Criteria	Indices	Alternatives								
		A1	A2	A3	A4	A5	A6	A7	A8	A9
C1	I_1	0.42	0.41	0.81	1.00	0.34	0.46	0.96	0.40	0.37
	I_2	0.43	0.39	0.54	1.00	0.35	0.42	0.54	0.38	0.36
	I_3	0.44	0.41	0.79	0.97	0.33	0.44	0.55	0.38	0.36
	I_4	0.42	0.69	0.52	0.69	0.42	0.52	0.69	0.69	0.42
	I_5	0.42	0.42	0.91	0.84	0.34	0.48	1.00	0.42	0.38
	I_6	0.54	0.60	0.69	0.68	0.54	0.51	0.63	0.58	0.64
	I_7	0.42	0.42	0.59	1.00	0.42	0.42	0.42	0.42	0.42
	I_8	0.36	0.36	0.38	0.36	0.36	0.36	0.36	0.36	0.36
C2	I_9	0.51	0.48	0.48	0.47	0.47	0.52	0.57	0.75	0.52
	I_{10}	0.69	1.00	1.00	0.42	0.69	1.00	1.00	1.00	1.00
	I_{11}	0.50	0.38	0.39	0.44	0.43	0.37	0.42	0.51	0.87
	I_{12}	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46
C3	I_{13}	0.52	0.52	1.00	0.69	0.52	0.69	0.69	0.42	0.52
	I_{14}	0.69	0.69	0.69	1.00	1.00	1.00	1.00	0.42	0.52

Table 7. Secondary grey relational coefficients for criterion level.

	Weighted primary grey relational coefficients								
	A1	A2	A3	A4	A5	A6	A7	A8	A9
C_1	0.429	0.458	0.701	0.881	0.371	0.460	0.767	0.449	0.398
C_2	0.509	0.475	0.477	0.459	0.468	0.495	0.536	0.662	0.622
C_3	0.548	0.548	0.948	0.742	0.600	0.742	0.742	0.420	0.520
	Secondary grey relational coefficients								
	A1	A2	A3	A4	A5	A6	A7	A8	A9
C_1	0.370	0.385	0.595	1.000	0.342	0.387	0.698	0.381	0.355
C_2	0.466	0.437	0.439	0.424	0.431	0.454	0.494	0.671	0.602
C_3	0.417	0.417	1.000	0.581	0.451	0.581	0.581	0.351	0.400

Table 8. Grey relational grades for alternatives.

Alternatives	Grey relational grade	Rank
A1	0.427	7
A2	0.416	8
A3	0.542	3
A4	0.649	1
A5	0.400	9
A6	0.440	6
A7	0.576	2
A8	0.538	4
A9	0.495	5

5. CONCLUSION

The call center site selection problem is a difficult multi-criteria decision making process to handle. The most crucial features of this process are complexity and uncertainty. As a novel approach for solution, hierarchy GRA (HGRA), based on AHP and GRA, has been utilized to determine the facility location for call center. The proposed model comprises two parts.

The first part applies conventional AHP to determine the relative weights of the criteria. And the second part applies GRA to rank the alternatives and then selects the optimum site for call center. The different priorities given to the criteria by experts or decision makers are reflected through the weights, so the bias arising from subjective judgments and random effects can be prevented.

The cities in southeastern Anatolia are used to demonstrate the effectiveness of the proposed methodology for selecting the best call center site. The method provides an objective and effective decision model for selecting the most appropriate location. The analytical results reveal that such an approach can cope with complicated multi-criteria decision making processes and provide scientific and reasonable results for decision makers. Furthermore, companies, local policy makers and other decision makers can use this method in any field in relation to multi-criteria decision making problems.

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