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Location Selection for A Covid-19 Field Hospital Using Fuzzy Choquet Integral Method

Bulanık Choquet İntegral Yöntemini Kullanarak Bir Covid-19 Sahra Hastanesi İçin Yer Seçimi

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Abstract

The need for field hospitals increased drastically during COVID-19 pandemic. Location of a field hospital is probably the most critical decision taken by government authorities since it directly affect the patients' access to the hospital. Field hospitals have an important share for emergency response to patients during the COVID-19 epidemic. The unpredictable increase in the number of patients creates a serious burden in existing hospitals. The most appropriate solution to alleviate this burden is to build field hospitals. This study aims to determine the most suitable location for a COVID-19 field hospital to be constructed in İzmir, the third largest city of Turkey. Fuzzy Choquet integral multi criteria decision making technique that allows for linguistic assessments is used to evaluate the alternative locations for the field hospital. This method also obtains a general weight by taking into account the interaction between the criteria. Besides, decision-makers can use interval values while evaluating each criterion and thus this process eliminates errors in subjective decision-making. Moreover it is also possible to obtain the result for which alternative is the best preferred for each of criterion. Overall weight values of four alternative locations in İzmir (i.e., Bornova, Karsiyaka, Konak and Buca) were determined and Bornova alternative with the highest overall weight value was proposed as the most suitable location for the field hospital.

Keywords: *Field hospital, COVID-19, Pandemic, Fuzzy Choquet integral, Multi-Criteria Decision Making*

Öz

COVID-19 salgını sırasında sahra hastanelerine olan ihtiyaç büyük ölçüde artmıştır. Bir sahra hastanesinin yeri, hastaların hastaneye erişimini doğrudan etkilediği için yetkililerin aldığı muhtemelen en kritik karardır. COVID-19 salgını döneminde hastalara acil müdahale için sahra hastaneleri önemli bir paya sahiptir. Hasta sayılarındaki tahmin edilemeyen artış mevcut hastanelerde ciddi yük oluşturmaktadır. Bu yükün hafifletilmesi için en uygun çözüm sahra hastanelerini inşa etmektedir. Bu çalışma, Türkiye'nin üçüncü büyük şehri olan İzmir'de kurulacak COVID-19 sahra hastanesi için en uygun konumu belirlemeyi amaçlamaktadır. Dilsel değerlendirmelere izin veren bir çok kriterli karar verme tekniği olan Bulanık Choquet integrali, sahra hastanesi için alternatif konumları değerlendirmek için kullanılmıştır. Bu yöntem ayrıca kriterler arasındaki etkileşimi de dikkate alarak genel bir ağırlık elde etmektedir. Bununla birlikte karar vericilerin her bir kriteri değerlendirirken aralıklı değerler kullanabilmesi öznel karar verme aşamasındaki hataları ortadan kaldırmaktadır. Yöntemde son olarak her bir kriterin hangi alternatif için en iyi tercih edilebileceği sonucu da elde edilebilmektedir. Çalışmada, İzmir'deki dört alternatif konumun (Bornova, Karşıyaka, Konak ve Buca) genel ağırlık değerleri belirlenmiş ve en yüksek genel ağırlık değerine sahip olan Bornova alternatifi en uygun konum olarak önerilmiştir.

Anahtar Kelimeler: *Sahra hastanesi, COVID-19, Pandemi, Bulanık Choquet integrali, Çok Kriterli Karar Verme*

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Introduction

COVID-19 pandemic started in China has affected nearly all countries in the world. Governments imposed new regulations and precautions on every aspect of human life including transportation, education and trade. All industries implemented fundamental changes in their work procedures in order to keep up with the rules of the pandemic period.

Among all sectors, the most heavily impacted sector is health sector. The capacity of the existing hospitals in many countries has become insufficient especially at the peak periods of the pandemic. The central and local governments at these countries established field hospitals to deal with the increased number of patients. The determination of an appropriate location for a field hospital is one of the most critical decisions taken by government authorities since this decision directly affects the accessibility of field hospital by patients.

The determination of a suitable location for a field hospital requires the simultaneous consideration of various factors such as site purchase cost, construction costs and closeness to public transportation. Moreover, some of these factors are conflicting. For instance, if an alternative location is close to public transportation, purchase cost of this location will probably be high. Multi-Criteria Decision Making (MCDM) methodologies are very effective in dealing with this type of decision making problems because they have the ability of dealing with multiple and often conflicting criteria. However, classical MCDM techniques do not let decision makers express their preferences in linguistic terms. On the other hand, they are not effective in modeling the vagueness and uncertainty associated with the linguistic assessments of alternatives and criteria. That is why, fuzzy Choquet integral MCDM technique that allows for linguistic assessments, is used in this study to evaluate the alternative locations for a field hospital to be built for COVID-19 patients.

The remainder of the study is organized as follows. The literature on hospital location selection is detailed in section 1. Section 2 presents brief introduction to fuzzy Choquet integral. Section 3 presents case study details involving the selection of an appropriate location for a field hospital. Conclusions and future research directions are provided in final section.

1. Literature Review

Researchers developed various hospital location selection methodologies in recent years. Majority of these methodologies are based on MCDM techniques including Analytical Hierarchy Process (AHP) (Şahin et al., 2019: 42), TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) and Analytical Network Process (Adalı and Tuş, 2019: 1; Lin and Tsai, 2010: 375), CODAS (Combinative Distance Based Assessment) and EDAS (Evaluation based on Distance from Average Solution) (Adalı and Tuş, 2019: 1).

In some studies, fuzzy versions of commonly used MCDM techniques are employed so as to consider the uncertainty and vagueness regarding hospital location selection process. Fuzzy AHP(Vahidnia et al., 2009: 3048), fuzzy TOPSIS(Miç and Antmen, 2019: 750; Senvar et al., 2016: 1140), Fuzzy ELECTRE(Kumar et al., 2016: 115) and fuzzy EDAS(Kutlu et al., 2018: 6353) are the fuzzy MCDM techniques used in these studies.

Fuzzy Choquet integral methodologyl is used in thermal power plant selection (Wu et al., 2014: 303), software development risk assessment problem (Wu et al., 2013: 509), ERP software seelction (Gurbuz et al., 2012: 206), sustainable energy plan (Zhang et al., 2014: 197), assess software quality (Pasrija et al., 2012: 153), partner and configuration selection (Cebi, 2013: 124), continuous shapely operations (Meng and Zhang, 2014: 42), customer preference analysis (Vu et al., 2013: 247), group decision making problems (Singh and Kumar, 2020: 1).

The number of studies on the location selection for field hospitals is very limited. Aydin (Aydin, 2016: 85) determines the number and locations of field hospitals in İstanbul by developing a two-stage stochastic model. The allocation of injured victims to these field hospitals is also considered. (Zolfani et al., 2020: 886) study the temporary hospital location selection problem for İstanbul. They use CRITIC to determine the criteria weights. Then, Gray-Based Combined Compromise Solution method is employed to evaluate the alternative locations for a temporary hospital. As seen in these studies, the fuzzy Choquet integral method has not been used in the field of hospital selection before. In this study, fuzzy Choquet integral MCDM technique is used to determine the most suitable location for a COVID-19 field hospital. It represents the first application of fuzzy Choquet integral to a field hospital selection problem.

2. Fuzzy Choquet Integral

This section provides brief information on Choquet integral, fuzzy arithmetic, generalized fuzzy Choquet integral and generalized fuzzy Choquet integral algorithms.

2.1. Choquet Integral

With X as the power set, X = {x_1, x_2, ..., x_n} and R(X) is a fuzzy measure h that is non-additive and has the following properties: R(X) ⟶ [0, 1].

With R (X) and X = {x_1, x_2, ...,x_n} the power set of X, a fuzzy measure h that is not additive and has the following properties: R (X) ⟶ [0, 1] is the expression for the function.

1. h (Ø) = 0;
2. h (X) = 1;
3. if L is C∈R(X) and $L \subset C$ then h (L) ≤ h (C);
4. in the set R(X), if $L_1 \subset L_2 \subset L_3 \subset$... and $U_{i=1}^{\infty} L_i \in$ R(X) then $\lim_{i\to\infty} h(L_i) = h(\, U_{i=1}^{\infty} L_i);$
5. in the set R(X), if $L_1 \supset L_2 \supset L_3 \supset$... and $\cap_{i=1}^{\infty} Li \in$ R(X) then $\lim_{i\to\infty} h(L_i) = h(\, \cap_{i=1}^{\infty} L_i).$

2.2. Fuzzy Arithmetic

In the universe of verbal expressions, let S be a subset of M: The membership function $\tilde{L}$ = {(x, $\mu\tilde{L}$ (s)) | s ∈S}, is expressed as follows in the fuzzy set L consisting of ordered pairs in S = {s_1, s_2, ...,s_n}:

$\mu\tilde{L}$ (s) : S ⟶ [0, 1].

The average values of $\tilde{C}$ fuzzy numbers, $\tilde{L}$ = (l_1, l_2, l_3, l_4), are calculated using the equation below, which was used to clarify the Trapezoidal Fuzzy Numbers (TFN) (Fortemps and Roubens, 1996: 319).

$$F(\tilde{L}) = \frac{l_1 + l_2 + l_3 + l_4}{4} \tag{1}$$

2.3. Generalized Fuzzy Choquet Integral

If it is assumed that h over X is a fuzzy measure; Choquet integral $h_i = h(\{t_i\})$, $0 \le f(t_{1)}) \le f(t_{(2)}) \le ... \le f(t_{(n)}) \le 1$ and $f(t_{0)}) = 0$, then $f(t_{(i)})$, h_i and λ are monotonously growing functions. With the following situations, the standard Choquet integral is generalized (Auephanwiriyakul et al., 2002: 69).

Situation 1. The Choquet integral $\bar{f}$ corresponding to the fuzzy measure h with the interval number is determined as follows in the case of $\bar{f} \in \bar{F}(X)$ and $\bar{h} \in \bar{K}(X)$.

$$(C)\int \bar{f} d\bar{h} = [(C)\int f^{-} dh^{-},\ \ (C)\int f^{+} dh^{+}] \tag{2}$$

Situation 2. It is possible to state the following equation in the condition of $\tilde{f} \in \tilde{F}(T)$ and $\tilde{h} \in \tilde{K}(T)$.

$$((C)\int \tilde{f} d\tilde{h})_{\propto} = \left[(C)\int f_{\propto}^{-}, dh_{\propto}^{-},\ \ (C)\int f_{\propto}^{+}, dh_{\propto}^{+}\right] \tag{3}$$

Situation 3. The equation is calculated as follows when the values of $0 \le \alpha_1 \le \alpha_2 \le ... \le \alpha_n \le 1$ are acquired.

$$((C)\int \tilde{f} d\tilde{h})_{\propto_1} \supset ((C)\int \tilde{f} d\tilde{h})_{\propto_2} \supset \cdots \supset ((C)\int \tilde{f} d\tilde{h})_{\propto_n} \tag{4}$$

Situation 4. Taking into account Situations 2 and 4, the following equation is computed.

$$(C)\int \tilde{f} d\tilde{h} = ||_{\propto \in [0,1]}[(C)\int f_{\propto}^{-}, dh_{\propto}^{-}, (C)\int f_{\propto}^{+}, dh_{\propto}^{+}] \tag{5}$$

2.4. Generalized Fuzzy Choquet Integral Algorithm

This section gives information on fuzzy Choquet integral algorithm where *i* is the index for the criteria and n_i is the total number of criteria. The steps are as follows (Tsai and Lu, 2006):

1. Step: Decision-makers define their linguistic preferences on the importance of criteria and locations using Table 1 (Delgado et al., 1998: 177). This table allows decision-makers to define their choice as linguistically as well as trapezoidal fuzzy numbers.

2. Step: The linguistic preferences of decision makers are quantified using the TFN presented in Table 1. The fuzzy number of $\widetilde{K}_i^t$ is the degree of importance, $\tilde{p}_i^t$ is the actual field hospital location performance and the fuzzy number $\tilde{e}_i^t$ corresponds to the tolerance range, where *t* is the index for decision makers, *k* is the total number of decision makers and *i* is the index for the criteria.

Table 1. The Relationship Between Degrees of Linguistic Importance and TFN Scale (Delgado et al., 1998: 177).

Low/high levels		The degrees of importance		Trapezoidal fuzzy numbers
Label	Linguistic terms	Label	Linguistic terms	
EL	Extra low	EU	Extra unimportant	(0.00, 0.00, 0.00, 0.00)
VL	Very low	VU	Very unimportant	(0.00, 0.01, 0.02, 0.07)
L	Low	U	Unimportant	(0.04, 0.10, 0.18, 0.23)
SL	Slightly low	SU	Slightly unimportant	(0.17, 0.22, 0.36, 0.42)
M	Middle	M	Middle	(0.32, 0.41, 0.58, 0.65)
SH	Slightly high	SI	Slightly important	(0.58, 0.63, 0.80, 0.86)
H	High	HI	High important	(0.72, 0.78, 0.92, 0.97)
VH	Very high	VI	Very important	(0.93, 0.98, 0.98, 1.00)
EH	Extra high	EI	Extra important	(1.00, 1.00, 1.00, 1.00)

3. Step: $\widetilde{K}_i^t$,$\tilde{p}_i^t$ and $\tilde{e}_i^t$are averaged and $\widetilde{K}_i$, $\tilde{p}_i$and $\tilde{e}_i$values are calculated using Equation (6),

$$\widetilde{M}_i = \frac{\sum_{t=1}^{k} K_i^t}{k} = \left[\frac{\sum_{t=1}^{k} \widetilde{K}_{i1}^t}{k}, \frac{\sum_{t=1}^{k} \widetilde{K}_{i2}^t}{k}, \frac{\sum_{t=1}^{k} \widetilde{K}_{i3}^t}{k}, \frac{\sum_{t=1}^{k} \widetilde{K}_{i4}^t}{k}\right] \tag{6}$$

4. Step: Normalizes the influence of each criterion on location performance using Equation (7).

$$\tilde{f}_i = ||_{\propto\in[0,1]} \bar{f}_i^{\propto} = ||_{\propto\in[0,1]} \left[f_{i,\propto}^{-}, f_{i,\propto}^{+}\right] \tag{7}$$

5. Step: For any $\alpha \in [0,1]$ with the α-level segments of $\bar{p}_i^{\propto} i$ and $\bar{e}_i^{\propto}$ the set of all $\tilde{f}$ functions becomes $\widetilde{F}(S)$, and the following equation is derived.

$$\bar{f}_i^{\propto} = \left[f_{i,\propto}^{-}, f_{i,\propto}^{+}\right] = \frac{\bar{p}_i^{\propto} - \bar{e}_i^{\propto} + [1+1]}{2} \tag{8}$$

6. Step: The i^{th} criterion is used to calculate location performance using Equation (9).

$$(C)\int \tilde{f} d\tilde{h} = ||_{\propto\in[0,1]} [(C)\int f_{\propto}^{-}, dh_{\propto}^{-}, (C)\int f_{\propto}^{+}, dh_{\propto}^{+}] \tag{9}$$

7. Step: By examining the two stage hierarchical process of the generalized choquet integral, the entire location performance obtained from all criteria is reduced to a fuzzy number $\tilde{L}$.

8. Step: The fuzzy number $\tilde{L}$ can be defuzzified using Equation (1) and overall location performances compared if $\mu_{\tilde{L}}(x)$ is the membership function of$\tilde{L}$.

3. Field Hospital Location Selection Using Fuzzy Choquet Integral

In this section, the field hospital location selection problem is defined. Then, the details on the application of fuzzy Choquet integral methodology to this problem are presented and the obtained results are discussed.

3.1. Problem Definition

COVID-19 virus has caused millions of people to be infected and millions of people to die since the day it emerged. Millions of people in Turkey have been exposed to this virus and thousands of people died. Therefore, combating the virus has become the most important agenda for Turkey like many other countries. Undoubtedly, one of the most important elements in the fight against this virus is the construction of field hospitals dedicated to COVID-19 patients. In this study, a field hospital location selection problem is analyzed for Turkey's 3rd largest city of Izmir where the population is almost 4.5 million.

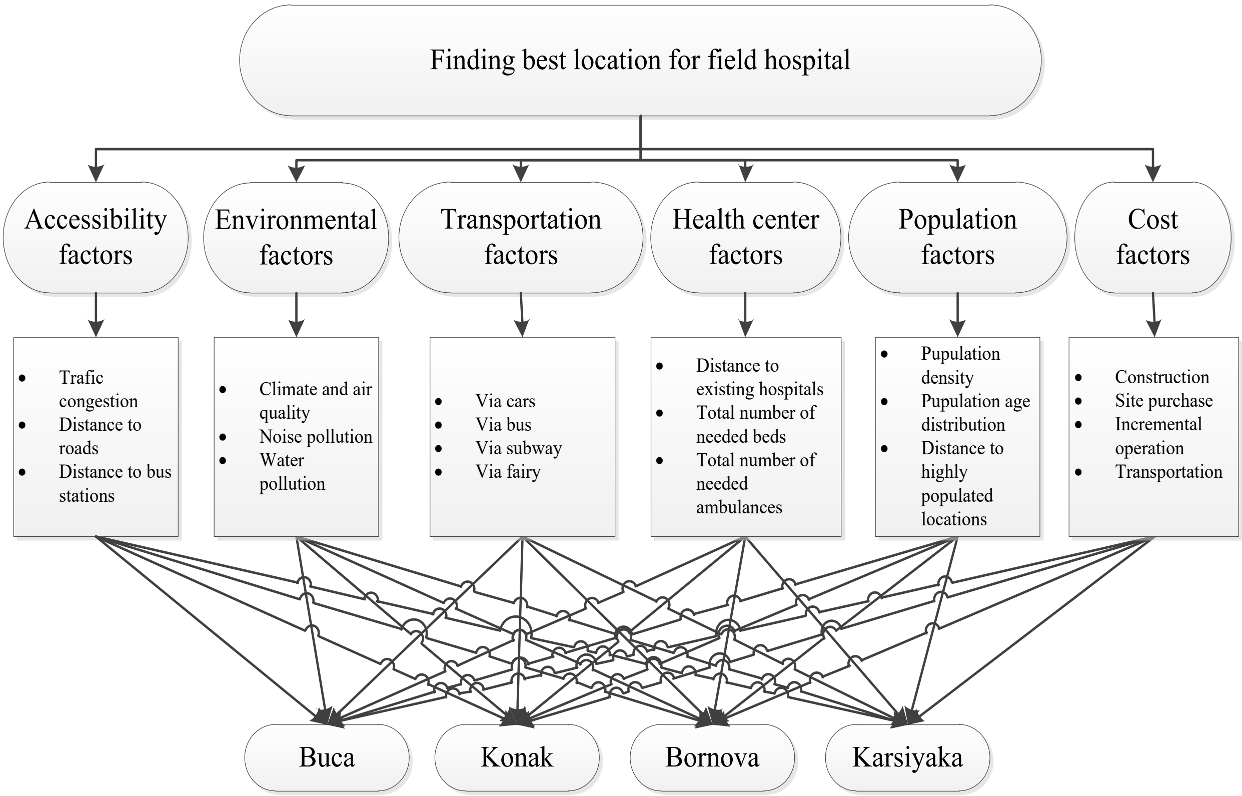

Figure 1. Hierarchical Structure of the Field Hospital Location Problem

As shown in Figure 1, there are 6 main-criteria and 20 sub-criteria determined by five experts. These five experts are experienced and working in health sector. This number of experts was selected in order to obtain results in a reasonable time. Besides, Figure 1 also presents the hierarchical structure of the problem. The four alternative locations in İzmir (i.e., Bornova, Buca, Karsiyaka, and Konak) are considered (see Figure 2). The experts provide their assessments on criteria and alternatives using the scale presented in Table 1.

Field hospital location selection criteria were decided from (Behzadi and Alesheikh, 2013: 36; Kim et al., 2015: 2730; Vahidnia et al., 2009: 3048; Moradian et al., 2017 9). Besides, the views of experts who experienced in health sector were also considered during the decision of the criteria and the hierarchical structure. Four different alternative locations were also determined by the experts for the construction of the field hospital. The descriptions of criteria are expressed as follows:

Accessibility Factors: People should be able to reach the field hospital quickly in case of an emergency. Hence, the field hospital should be close to roads and bus stops. Moreover, the selected location of the field hospital should not have high traffic congestion.

Environmental Factors: The location of the field hospital should have suitable environmental conditions as it will provide long-term service since it is not known when the pandemic conditions will end. Among these conditions, climate and air quality, noise pollution and water pollution are the sub-criteria considered under environmental factors. It must be away from industrial zones on the grounds that these zones generally have high levels of air, water and noise pollution.

Transportation Factors: Transportation factors are one of the most important factors in deciding the location of the field hospital. Field hospital should be accessible. People should be able to reach the field hospital whenever they want via car, bus, subway or fairy.

Health Center Factors: The field hospital is expected to serve a high number of patients since İzmir is a highly populated city. That is why it is possible that the capacity of the field hospital may not be enough for all patients at the peak periods of the pandemic. Hence, it should be constructed at a location which is not far from the existing hospitals. Besides, the number of needed beds and the number of needed ambulances must also be considered under health center factors.

Population Factors: The field hospital is constructed to provide treatment to people's emergent health problems during the pandemic period. Therefore, it should not be constructed in a location which is very far from the city center. Besides, the average age of the population must be considered. It is known that the rate of hospital admissions of the young population is very low.

Cost Factors: There are various costs (i.e., costs associated with construction workers and materials, land purchase cost and incremental operation cost) associated with the construction of a field hospital. The location that satisfies these cost factors at the most appropriate level should be selected.

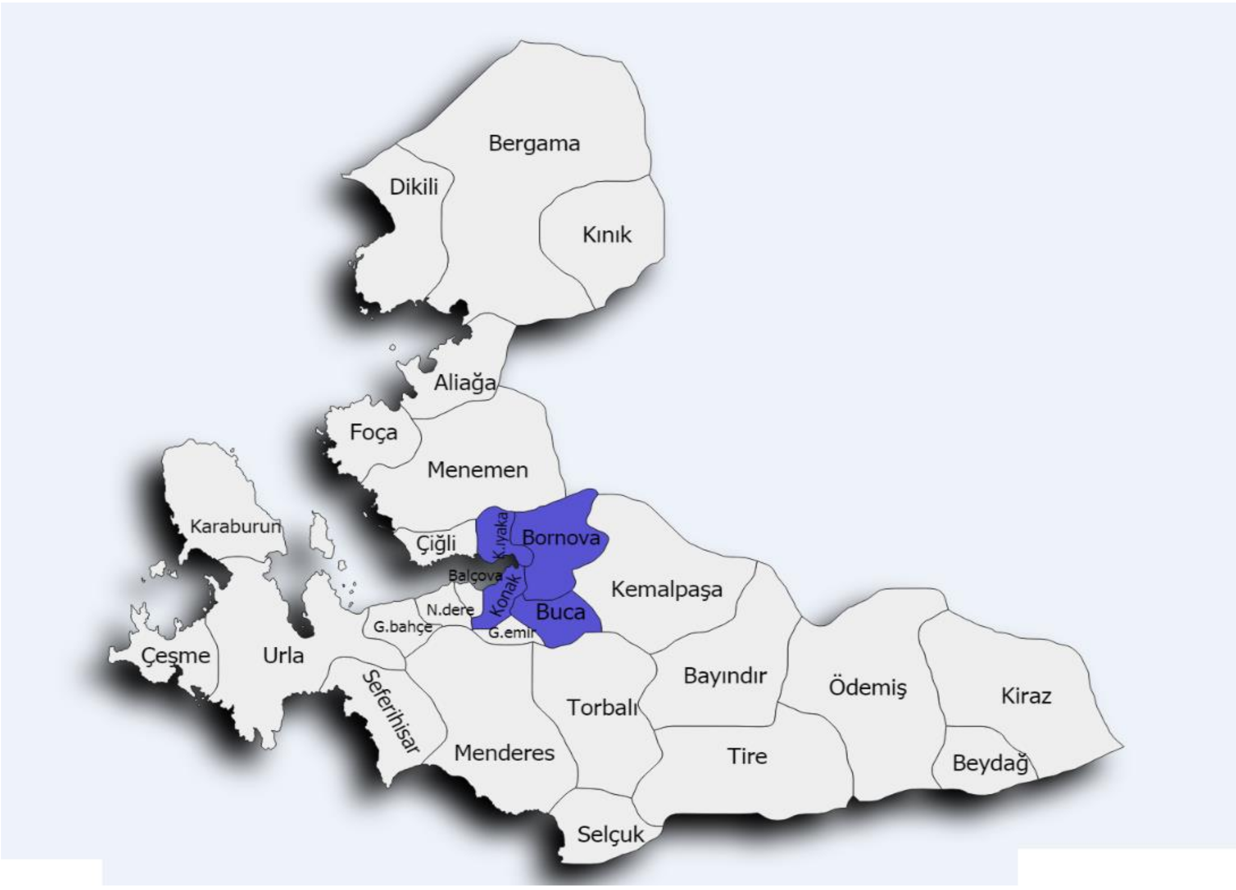

Figure 2. Field Hospital Location Alternatives

The symbols in Table 2 were employed in order to define sub-criteria easier. Experts created the individual importance of sub-criteria and main criteria as well as tolerance intervals. They also evaluated each alternative field hospital location linguistically (see Table 3).

TFNs are used in order to evaluate the linguistic terms. The tolerance intervals in Table 3 are gathered in that way: the first two numerical values of the lower linguistic value of a tolerance interval in Table 3 are combined with the last two numerical values of the upper linguistic value of the same tolerance interval. Consider the tolerance interval [M, EH]. The corresponding numerical values of M and EH are (0.32, 0.41, 0.58, 0.65) and (1.00, 1.00, 1.00, 1.00), respectively. After combining these values, the tolerance interval is determined as (0.32, 0.41, 1.00, 1.00). Five experts' compromised evaluations are presented in Table 4. In order to combine the separate evaluation of each expert, arithmetic mean of the values was taken into consideration.

3.2. Application of the Steps of Fuzzy Choquet Integral

Evaluation results with respect to $\alpha = 0$ are given in Table 5. Equations (2) and (3) are used for the sub-criteria and main criteria respectively. As an example, the value [0.24, 0.76] of "sub-criterion A_1 and location 1 (Buca)" is calculated as follows:

$$f, f_i^{\alpha} = [f_{i,\alpha}^{-}, f_{i,\alpha}^{+}] = \frac{[0.48, 0.77] - [0.25, 1.00] + [1,1]}{2} = [0.24, 0.76]$$

The other normalized discrepancies between for location 1 (Buca) and main criterion *A* at $\alpha = 0$ are $\overline{f}_2^0 = [0.39, 0.73]$ and $\overline{f}_3^0 = [0.31, 0.67]$. Their corresponding degrees of individual importance are $\overline{g}_1^0 = [0.57, 0.82], \overline{g}_2^0 = [0.83, 0.96]$ and $\overline{g}_3^0 = [0.61, 0.88]$. First, the sequence $\overline{f}_{i,0}^{-}$ is sorted, where *i*=1, 2 and 3, as follows:

$$f_{\overline{A}_1} = 0.24 < f_{\overline{A}_3} = 0.31 < f_{\overline{A}_2} = 0.39$$

$$h_{\overline{A}_1} = 0.57, h_{\overline{A}_3} = 0.61, h_{\overline{A}_2} = 0.83$$

$$h_1 = 0.57, h_2 = 0.61, h_3 = 0.83$$

Table 2. Field Hospital Location Criteria Along with Their Short Forms

Criteria	Short forms of criteria	
Accessibility	*A*	
1. Traffic congestion		A_1
2. Distance to roads		A_2
3. Distance to bus stations		A_3
Environmental	*E*	
1. Climate and air quality		E_1
2. Noise pollution		E_2
3. Water pollution		E_3
Health center	*HC*	
1. Distance to existing hospitals		HC_1
2. Total number of needed beds		HC_2
3. Total number of needed ambulances		HC_3
Transportation	*T*	
1. Via cars		T_1
2. Via bus		T_2
3. Via subway		T_3
4. Via fairy		T_4
Population	*P*	
1. Population density		P_1
2. Population age distribution		P_2
3. Distance to highly populated locations		P_3
Costs	*C*	
1. Construction		C_1
2. Site purchase		C_2
3. Incremental operation		C_3
4. Transportation		C_4

By solving the following equation for λ the fuzzy measures $h(N_{(i)}), i = 1, 2, ..., n$ are obtained as follows:

$$1 = h(S) = \frac{1}{\lambda}\{[(1+0.57)+(1+0.61)+(1+0.83)]-1\}$$

That is,

$$\lambda = -0.9625$$

The fuzzy measures are,

$$h(N_{(3)}) = h_3 = 0.61$$

$$h(N_{(2)}) = h_2 + h(N_{(3)}) + \lambda h_2 h(N_{(3)}) = 0.96$$

$$h(N_{(1)}) = h_1 + h(N_{(2)}) + \lambda h_1 h(N_{(2)}) = 1$$

Tables 6 and 8 summarize the all fuzzy measures and λ values, which are calculated in the same way above.

The aggregated Choquet integral values for the main criterion *A* are calculated as follows:

$$(A) = \int f^{-}_{\alpha=0} dh^{-}_{\alpha=0} = 1(0.24) + 0.96(0.31 - 0.24) + 0.61(0.39 - 0.31) = 0.355$$

$$(A) = \int f^{+}_{\alpha=0} dh^{+}_{\alpha=0} = 0.747$$

That is,

$$(A) = \int \tilde{f} d\tilde{h} = [0.355, 0.747]$$

The normalized discrepancies and location values are presented in Tables 5 and 7. The Overall Location Value (OLV) is calculated by using the last step of Choquet integral algorithm (see Table 9). Table 9 also presents the defuzzified OLVs using Choquet integral. For example, the overall Choquet integral value at $\alpha = 0$ for location 1 (Buca) is calculated as follows:

$\lambda = -0.99, h(N_{(6)}) = 0.87, h(N_{(5)}) = 0.96, h(N_{(4)}) = 0.99, h(N_{(3)}) = 1.0, h(N_{(2)}) = 1.0, h(N_{(1)}) = 1.0$ and finally, $(A) = \int \tilde{f} d\tilde{h} = [0.353, 0.798]$.

From Table 9, the defuzzified OLVs of Bornova, Karsiyaka, Konak and Buca using generalized Choquet Integral were calculated as 0.675, 0.630, 0.591 and 0.585, respectively. This means that the ranking order from the best to the worst is Bornova, Karsiyaka, Konak and Buca. The best alternative Bornova has the largest weights for *accessibility*, *health center* and *transportation* while Buca is the best alternative for two main criteria: p*opulation and cost.* Karsiyaka is better than the other alternative locations for only one main criterion (i.e. *environment*). Similar comments can be made for the sub-criteria based on the results presented in Table 9. As a result, it can be stated Bornova is the most suitable location for the field hospital.

Conclusions

The COVID-19 pandemic started in China at the end of 2019 affected the health systems of nearly all countries in the world. Hospitals experienced capacity shortages due to an ever-increasing number of patients. Local and central governments established field hospitals to ensure that all patients receive the necessary medical treatment. One of the most important factors affecting the utilization of a field hospital is its location. Hence all relevant criteria must be considered while determining the location of a field hospital. Classical MCDM techniques can be used for this location problem. However, preferences of decision makers cannot be represented linguistically in these techniques. Therefore, the decision-maker has the advantage of evaluating the criteria by using linguistic expressions in this method. Another advantage of this method is that although it takes into account the interaction between the criteria, obtaining a solution in a long time can be expressed as the limitation of the study. In this study, we use fuzzy Choquet integral, a MCDM technique allowing for linguistic assessments, in order to determine the most suitable location for a field hospital to be built for COVID- 19 patients. The current study can be extended in several directions. First, the most suitable medical equipment to be used in field hospitals can be evaluated by using fuzzy Choquet integral. Second, multi objective decision making techniques such as goal programming and linear physical programming can be employed to determine the most suitable locations for field hospitals. Finally, the interrelationships among the factors that affect the location choice for field hospitals can be analyzed using interpretive structural modeling (ISM) or Decision Making Trial and Evaluation Laboratory (DEMATEL).

Table 3. The Evaluation Form of Decision-Maker 1

Criteria	Individual importance	The tolerance interval of the decision maker	Linguistic evaluation			
			Buca	Konak	Bayrakli	Karsiyaka
Accessibility	EH					
1. Traffic congestion	H	[M, EH]	M	SH	EH	H
2. Distance to roads	VH	[H, EH]	H	H	EH	VH
3. Distance to bus stations	M	[SL, H]	SL	VH	H	H
Environmental	H					
1. Climate and air quality	VH	[H, EH]	H	VH	EH	H
2. Noise pollution	SH	[M, H]	H	M	H	M
3. Water pollution	H	[SH, VH]	SH	H	VH	VH
Health center	M					
1. Distance to existing hospitals	SH	[M, VH]	M	H	VH	SH
2. Total number of needed beds	VH	[SH, EH]	SH	VH	EH	H
3. Total number of ambulances	H	[M, EH]	M	H	EH	VH
Transportation	EH					
1. Via cars	H	[SL, VH]	SL	M	VH	H
2. Via public transportation	M	[L, EH]	H	SL	EH	M
3. Via subway	SH	[VL, VH]	M	SL	VH	M
4. Via fairy	SH	[VL, VH]	M	SH	VH	H
Population	H					
1. Population number/density	VH	[H, EH]	H	VH	EH	H
2. Population age distribution	M	[M, EH]	H	M	EH	VH
3. Distance to population	VH	[H, EH]	VH	H	EH	VH
Costs	H					
1. Construction	VH	[M, VH]	H	M	VH	H
2. Site purchase	EH	[SL, VH]	VH	SL	VH	M
3. Incremental operation	H	[H, EH]	EH	H	EH	VH
4. Transportation	M	[M, VH]	H	H	VH	VH

Table 4. Comprised Evaluation of Five Experts

Criteria	Individual importance	The tolerance interval of the experts	Linguistic evaluation			
			Buca	Konak	Bornova	Karsiyaka
A	(0.87, 0.90,0.96, 0.98)					
A_1	(0.57, 0.64,0.77, 0.82)	(0.25, 0.33, 0.98, 1.00)	(0.48, 0.55, 0.71, 0.77)	(0.50, 0.56, 0.71, 0.77)	(0.94, 0.98, 0.98, 1.00)	(0.65, 0.71, 0.84, 0.89)
A_2	(0.83, 0.87,0.93, 0.96)	(0.46, 0.51, 0.99, 1.00)	(0.78, 0.83, 0.89, 0.92)	(0.58, 0.63, 0.78, 0.83)	(0.97, 0.99, 0.99, 1.00)	(0.68, 0.75, 0.82, 0.86)
A_3	(0.61, 0.67,0.82, 0.88)	(0.43, 0.48, 0.97, 0.99)	(0.61, 0.65, 0.74, 0.78)	(0.73, 0.79, 0.90, 0.95)	(0.91, 0.94, 0.97, 0.99)	(0.84, 0.91, 0.95, 0.98)
E	(0.64, 0.70,0.85, 0.90)					
E_1	(0.68, 0.75,0.82, 0.86)	(0.47, 0.54, 0.99, 1.00)	(0.69, 0.75, 0.89, 0.94)	(0.75, 0.79, 0.84, 0.87)	(0.68, 0.74, 0.86, 0.91)	(0.98, 0.99, 0.99, 1.00)
E_2	(0.60, 0.66,0.82, 0.87)	(0.24, 0.29, 0.95, 0.98)	(0.53, 0.60, 0.76, 0.82)	(0.34, 0.40, 0.56, 0.62)	(0.44, 0.52, 0.66, 0.72)	(0.84, 0.91, 0.95, 0.98)
E3	(0.68, 0.74,0.86, 0.91)	(0.47, 0.53, 0.98, 1.00)	(0.63, 0.69, 0.84, 0.89)	(0.76, 0.82, 0.93, 0.97)	(0.88, 0.94, 0.96, 0.99)	(0.94, 0.98, 0.98, 1.00)
HC	(0.72, 0.78,0.87, 0.91)					
HC_1	(0.64, 0.69,0.82, 0.85)	(0.30, 0.37, 0.98, 1.00)	(0.53, 0.60, 0.76, 0.82)	(0.61, 0.66, 0.80, 0.86)	(0.93, 0.98, 0.98, 1.00)	(0.73, 0.79, 0.86, 0.89)
HC_2	(0.66, 0.72,0.82, 0.87)	(0.45, 0.52, 0.96, 0.98)	(0.69, 0.75, 0.89, 0.93)	(0.57, 0.64, 0.74, 0.79)	(0.88, 0.91, 0.96, 0.98)	(0.60, 0.67, 0.79, 0.84)
HC_3	(0.70, 0.76,0.88, 0.93)	(0.38, 0.44, 0.97, 0.99)	(0.57, 0.64, 0.77, 0.82)	(0.53, 0.59, 0.74, 0.79)	(0.91, 0.94, 0.97, 0.99)	(0.68, 0.75, 0.82, 0.86)
T	(0.91, 0.94,0.97, 0.99)					
T_1	(0.77, 0.83,0.92, 0.96)	(0.46, 0.51, 0.99, 1.00)	(0.58, 0.63, 0.75, 0.80)	(0.69, 0.75, 0.85, 0.89)	(0.97, 0.99, 0.99, 1.00)	(0.76, 0.82, 0.93, 0.97)
T_2	(0.52, 0.58,0.75, 0.81)	(0.13, 0.18, 0.96, 0.98)	(0.56, 0.63, 0.78, 0.84)	(0.23, 0.29, 0.44, 0.51)	(0.86, 0.90, 0.96, 0.98)	(0.32, 0.41, 0.58, 0.65)
T_3	(0.62, 0.68,0.81, 0.85)	(0.24, 0.28, 0.98, 1.00)	(0.53, 0.59, 0.74, 0.79)	(0.46, 0.52, 0.64, 0.69)	(0.94, 0.98, 0.98, 1.00)	(0.60, 0.67, 0.79, 0.84)
T_4	(0.59, 0.65,0.79, 0.83)	(0.21, 0.24, 0.97, 0.99)	(0.60, 0.67, 0.79, 0.84)	(0.47, 0.53, 0.69, 0.75)	(0.91, 0.94, 0.97, 0.99)	(0.60, 0.67, 0.79, 0.84)
P	(0.73, 0.79,0.88, 0.91)					
P_1	(0.67, 0.73,0.86, 0.91)	(0.33, 0.40, 0.98, 1.00)	(0.95, 0.98, 0.98, 1.00)	(0.73, 0.79, 0.90, 0.95)	(0.41, 0.48, 0.64, 0.71)	(0.77, 0.83, 0.92, 0.96)
P_2	(0.65, 0.71,0.84, 0.89)	(0.46, 0.52, 0.99, 1.00)	(0.98, 0.99, 0.99, 1.00)	(0.57, 0.63, 0.75, 0.80)	(0.72, 0.76, 0.86, 0.89)	(0.76, 0.82, 0.88, 0.92)
P_3	(0.70, 0.76,0.88, 0.93)	(0.27, 0.32, 0.99, 1.00)	(0.97, 0.99, 0.99, 1.00)	(0.66, 0.72, 0.87, 0.92)	(0.44, 0.52, 0.66, 0.72)	(0.84, 0.91, 0.95, 0.98)
C	(0.83, 0.86,0.95, 0.98)					
C_1	(0.70, 0.76,0.88, 0.93)	(0.25, 0.33, 0.97, 0.99)	(0.48, 0.55, 0.71, 0.77)	(0.39, 0.46, 0.62, 0.68)	(0.91, 0.94, 0.97, 0.99)	(0.56, 0.63, 0.78, 0.84)
C_2	(0.90, 0.94,0.97, 0.99)	(0.52, 0.57, 0.99, 1.00)	(0.67, 0.73, 0.86, 0.91)	(0.69, 0.74, 0.83, 0.87)	(0.97, 0.99, 0.99, 1.00)	(0.72, 0.78, 0.87, 0.91)
C_3	(0.53, 0.60,0.76, 0.82)	(0.37, 0.44, 0.97, 0.99)	(0.50, 0.56, 0.68, 0.73)	(0.76, 0.82, 0.93, 0.97)	(0.91, 0.94, 0.97, 0.99)	(0.81 0.87, 0.93, 0.96)
C_4	(0.57, 0.64,0.77, 0.82)	(0.41, 0.47, 0.98, 1.00)	(0.73, 0.79, 0.88, 0.91)	(0.61, 0.66, 0.80, 0.86)	(0.95, 0.98, 0.98, 1.00)	(0.80, 0.86, 0.91, 0.93)

Table 5. Generalized Choquet Integral Calculation Results for α= 0.

Dimensions and Criteria	Individual importance of criteria $\bar{h}_i = [h_i^-, h_i^+]$	The alternative value $[(C)\int f^- dh^-, (C)\, f^+ dh^+]$ and normalized discrepancy $\bar{f}_i = [f_i^-, f_i^+]$			
		Linguistic evaluation			
		Buca	Konak	Bornova	Karsiyaka
Accessibility		(0.355, 0.747)	(0.337, 0.754)	(0.482, 0.863)	(0.388, 0,809)
A_1	(0,57. 0,82)	(0.24, 0.76)	(0.25, 0.76)	(0.47, 0.875)	(0.325, 0.82)
A_2	(0,83. 0,96)	(0.39, 0.73)	(0.29, 0.685)	(0.485, 0.77)	(0.34, 0.7)
A_3	(0,61. 0,88)	(0.31, 0.675)	(0.37, 0.76)	(0.46, 0.78)	(0.425, 0.775)
Environmental		(0.327, 0,782)	(0.362, 0.745)	(0.399, 0.758)	(0.480, 0.856)
E_1	(0,68. 0,86)	(0.345, 0.735)	(0.375, 0.7)	(0.34, 0.72)	(0.49, 0.765)
E_2	(0,60. 0,87)	(0.275, 0.79)	(0.18, 0.69)	(0.23, 0.74)	(0.43, 0.87)
E_3	(0,68. 0,91)	(0.315, 0.71)	(0.38, 0.75)	(0.44, 0.76)	(0.47, 0.765)
Health center		(0.327, 0.757)	(0.297, 0.768)	(0.462, 0.843)	(0.355, 0.786)
HC_1	(0,64. 0,85)	(0.265, 0.76)	(0.305, 0.78)	(0.465, 0.85)	(0.365, 0.795)
HC_2	(0,66. 0,87)	(0.355, 0.74)	(0.295, 0.67)	(0.45, 0.765)	(0.31, 0.695)
HC_3	(0,70. 0,93)	(0.29, 0.72)	(0.27, 0.705)	(0.46, 0.805)	(0.345, 0.74)
Transportation		(0.289, 0.776)	(0.228, 0.715)	(0.4597, 0.880)	(0.297, 0.760)
T_1	(0,77. 0,96)	(0.29, 0.67)	(0.345, 0.715)	(0.485, 0.77)	(0.38, 0.755)
T_2	(0,52. 0,81)	(0.29, 0.855)	(0.125, 0.69)	(0.44, 0.925)	(0.17, 0.76)
T_3	(0,62. 0,85)	(0.265, 0.775)	(0.23, 0.725)	(0.47, 0.88)	(0.3, 0.8)
T_4	(0,59. 0,83)	(0.305, 0.815)	(0.24, 0.77)	(0.46, 0.89)	(0.305, 0.815)
Population		(0.487, 0.862)	(0.370, 0.823)	(0.309, 0.724)	(0.409, 0.852)
P_1	(0,67. 0,91)	(0.475, 0.835)	(0.365, 0.81)	(0.205, 0.69)	(0.385, 0.815)
P_2	(0,65. 0,89)	(0.49, 0.77)	(0.285, 0.67)	(0.36, 0.715)	(0.38, 0.73)
P_3	(0,70. 0,93)	(0.485, 0.865)	(0.33, 0.825)	(0.22, 0.725)	(0.42, 0.855)
Costs		(0.256, 0.695)	(0.304, 0.715)	(0.460, 0.795)	(0.359, 0.759)
C_1	(0,70. 0,93)	(0.245, 0.76)	(0.2, 0.715)	(0.46, 0.87)	(0.285, 0.795)
C_2	(0,90. 0,99)	(0.335, 0.695)	(0.345, 0.675)	(0.485, 0.74)	(0.36, 0.695)
C_3	(0,53. 0,82)	(0.255, 0.68)	(0.385, 0.8)	(0.46, 0.81)	(0.41, 0.795)
C_4	(0,57. 0,82)	(0.365, 0.75)	(0.305, 0.725)	(0.475, 0.795)	(0.4, 0.76)

Table 6. Fuzzy Measures for α = 0.

Buca		Konak		Bornova		Karsiyaka	
$h^- = (K_{(i)})$	$h^+ = (K_{(i)})$	$h^- = (K_{(i)})$	$h^+ = (K_{(i)})$	$h^- = (K_{(i)})$	$h^+ = (K_{(i)})$	$h^- = (K_{(i)})$	$h^+ = (K_{(i)})$
fuzzy measures							
λ= -0,9625	λ= -0,9991	λ= -0,9625	λ= -0,9991	λ= -0,9625	λ= -0,9991	λ= -0,9625	λ= -0,9991
$h^-(K_{(3)})$=0,61	$h^+(K_{(3)})$=0,82	$h^-(K_{(3)})$=0,61	$h^+(K_{(3)})$=0,88	$h^-(K_{(3)})$=0,83	$h^+(K_{(3)})$=0,875	$h^-(K_{(3)})$=0,61	$h^+(K_{(3)})$=0,82
$h^-(K_{(2)})$=0,956	$h^+(K_{(2)})$=0,994	$h^-(K_{(2)})$=0,953	$h^+(K_{(2)})$=0,979	$h^-(K_{(2)})$=0,945	$h^+(K_{(2)})$=0,986	$h^-(K_{(2)})$=0,953	$h^+(K_{(2)})$=0,979
$h^-(K_{(1)})$=1	$h^+(K_{(1)})$=1	$h^-(K_{(1)})$=1	$h^+(K_{(1)})$=1	$h^-(K_{(1)})$=1	$h^+(K_{(1)})$=1	$h^-(K_{(1)})$=1	$h^+(K_{(1)})$=1
λ= -0,9445	λ= -0,9982	λ= -0,9445	λ= -0,9982	λ= -0,9445	λ= -0,9982	λ= -0,9445	λ= -0,9982
$h^-(K_{(3)})$=0,68	$h^+(K_{(3)})$=0,87	$h^-(K_{(3)})$=0,68	$h^+(K_{(3)})$=0,91	$h^-(K_{(3)})$=0,68	$h^+(K_{(3)})$=0,91	$h^-(K_{(3)})$=0,68	$h^+(K_{(3)})$=0,87
$h^-(K_{(2)})$=0,923	$h^+(K_{(2)})$=0,983	$h^-(K_{(2)})$=0,923	$h^+(K_{(2)})$=0,989	$h^-(K_{(2)})$=0,923	$h^+(K_{(2)})$=0,990	$h^-(K_{(2)})$=0,923	$h^+(K_{(2)})$=0,990
$h^-(K_{(1)})$=1	$h^+(K_{(1)})$=1	$h^-(K_{(1)})$=1	$h^+(K_{(1)})$=1	$h^-(K_{(1)})$=1	$h^+(K_{(1)})$=1	$h^-(K_{(1)})$=1	$h^+(K_{(1)})$=1
λ= -0,9513	λ= -0,9985	λ= -0,9513	λ= -0,9985	λ= -0,9513	λ= -0,9985	λ= -0,9513	λ= -0,9985
$h^-(K_{(3)})$=0,66	$h^+(K_{(3)})$=0,85	$h^-(K_{(3)})$=0,64	$h^+(K_{(3)})$=0,85	$h^-(K_{(3)})$=0,64	$h^+(K_{(3)})$=0,85	$h^-(K_{(3)})$=0,64	$h^+(K_{(3)})$=0,85
$h^-(K_{(2)})$=0,920	$h^+(K_{(2)})$=0,982	$h^-(K_{(2)})$=0,898	$h^+(K_{(2)})$=0,991	$h^-(K_{(2)})$=0,914	$h^+(K_{(2)})$=0,991	$h^-(K_{(2)})$=0,914	$h^+(K_{(2)})$=0,991
$h^-(K_{(1)})$=1	$h^+(K_{(1)})$=1	$h^-(K_{(1)})$=1	$h^+(K_{(1)})$=1	$h^-(K_{(1)})$=1	$h^+(K_{(1)})$=1	$h^-(K_{(1)})$=1	$h^+(K_{(1)})$=1
λ= -0,98	λ= -0,9998	λ= -0,98	λ= -0,9998	λ= -0,98	λ= -0,9998	λ= -0,98	λ= -0,9998

$h^-(K_{(4)})=0,59$	$h^+(K_{(4)})=0,855$	$h^-(K_{(4)})=0,77$	$h^+(K_{(4)})=0,83$	$h^-(K_{(4)})=0,77$	$h^+(K_{(4)})=0,83$	$h^-(K_{(4)})=0,77$	$h^+(K_{(4)})=0,83$
$h^-(K_{(3)})=0,915$	$h^+(K_{(3)})=0,975$	$h^-(K_{(3)})=0,915$	$h^+(K_{(3)})=0,975$	$h^-(K_{(3)})=0,915$	$h^+(K_{(3)})=0,975$	$h^-(K_{(3)})=0,915$	$h^+(K_{(3)})=0,975$
$h^-(K_{(2)})=0,969$	$h^+(K_{(2)})=0,996$	$h^-(K_{(2)})=0,979$	$h^+(K_{(2)})=0,999$	$h^-(K_{(2)})=0,979$	$h^+(K_{(2)})=0,995$	$h^-(K_{(2)})=0,979$	$h^+(K_{(2)})=0,995$
$h^-(K_{(1)})=1$	$h^+(K_{(1)})=1$	$h^-(K_{(1)})=1$	$h^+(K_{(1)})=1$	$h^-(K_{(1)})=1$	$h^+(K_{(1)})=1$	$h^-(K_{(1)})=1$	$h^+(K_{(1)})=1$
$\lambda= -0,9546$	$\lambda= -0,9992$	$\lambda= -0,9546$	$\lambda= -0,9992$	$\lambda= -0,9546$	$\lambda= -0,9992$	$\lambda= -0,9546$	$\lambda= -0,9992$
$h^-(K_{(3)})=0,65$	$h^+(K_{(3)})=0,93$	$h^-(K_{(3)})=0,67$	$h^+(K_{(3)})=0,93$	$h^-(K_{(3)})=0,65$	$h^+(K_{(3)})=0,93$	$h^-(K_{(3)})=0,70$	$h^+(K_{(3)})=0,93$
$h^-(K_{(2)})=0,916$	$h^+(K_{(2)})=0,994$	$h^-(K_{(2)})=0,922$	$h^+(K_{(2)})=0,994$	$h^-(K_{(2)})=0,916$	$h^+(K_{(2)})=0,993$	$h^-(K_{(2)})=0,922$	$h^+(K_{(2)})=0,994$
$h^-(K_{(1)})=1$	$h^+(K_{(1)})=1$	$h^-(K_{(1)})=1$	$h^+(K_{(1)})=1$	$h^-(K_{(1)})=1$	$h^+(K_{(1)})=1$	$h^-(K_{(1)})=1$	$h^+(K_{(1)})=1$
$\lambda= -0,9933$	$\lambda= -0,9999$	$\lambda= -0,9933$	$\lambda= -0,9999$	$\lambda= -0,9933$	$\lambda= -0,9999$	$\lambda= -0,9933$	$\lambda= -0,9999$
$h^-(K_{(4)})=0,57$	$h^+(K_{(4)})=0,93$	$h^-(K_{(4)})=0,53$	$h^+(K_{(4)})=0,82$	$h^-(K_{(4)})=0,90$	$h^+(K_{(4)})=0,87$	$h^-(K_{(4)})=0,53$	$h^+(K_{(4)})=0,93$
$h^-(K_{(3)})=0,960$	$h^+(K_{(3)})=0,987$	$h^-(K_{(3)})=0,956$	$h^+(K_{(3)})=0,968$	$h^-(K_{(3)})=0,960$	$h^+(K_{(3)})=0,977$	$h^-(K_{(3)})=0,800$	$h^+(K_{(3)})=0,987$
$h^-(K_{(2)})=0,985$	$h^+(K_{(2)})=1$	$h^-(K_{(2)})=0,983$	$h^+(K_{(2)})=0,998$	$h^-(K_{(2)})=0,985$	$h^+(K_{(2)})=0,998$	$h^-(K_{(2)})=0,985$	$h^+(K_{(2)})=0,998$
$h^-(K_{(1)})=1$	$h^+(K_{(1)})=1$	$h^-(K_{(1)})=1$	$h^+(K_{(1)})=1$	$h^-(K_{(1)})=1$	$h^+(K_{(1)})=1$	$h^-(K_{(1)})=1$	$h^+(K_{(1)})=1$

Table 7. Generalized Choquet Integral Calculation Results for α = 1.

Dimensions and Criteria	Individual importance of criteria	The alternative value $[(C)\int f^- dh^-, (C) f^+ dh^+]$ and normalized discrepancy $\bar{f_i} = [f_i^-, f_i^+]$			
	$\bar{h}_i = [h_i^-, h_i^+]$	Buca	Konak	Bornova	Karsiyaka
Accessibility		(0.407, 0.689)	(0. 379, 0.704)	(0.500, 0.811)	(0.439, 0.747)
A_1	(0,64, 0,77)	(0.285, 0.69)	(0.29, 0.69)	(0.5, 0.825)	(0.365, 0.755)
A_2	(0,87, 0,93)	(0.42, 0.69)	(0.32, 0.635)	(0.5, 0.74)	(0.38, 0.655)
A_3	(0,67, 0,82)	(0.34, 0.63)	(0.41, 0.71)	(0.448, 0.710)	(0.499, 0.812)
Environmental		(0.372, 0.724)	(0.406, 0.693)	(0.375, 0.66)	(0.5, 0.725)
E_1	(0,75, 0,82)	(0.38, 0.675)	(0.4, 0.65)	(0.285, 0.685)	(0.48, 0.83)
E_2	(0,66, 0,82)	(0.325, 0.735)	(0.225, 0.635)	(0.48, 0.715)	(0.5, 0.725)
E_3	(0,74, 0,86)	(0.355, 0.655)	(0.42, 0.7)	(0.5, 0.725)	(0.48, 0.715)
Health center		(0.377, 0.693)	(0.337, 0.702)	(0.495, 0.797)	(0.398, 0.734)
HC_1	(0,69, 0,82)	(0.31, 0.695)	(0.34, 0.715)	(0.5, 0.805)	(0.405, 0.745)
HC_2	(0,72, 0,82)	(0.395, 0.685)	(0.34, 0.61)	(0.475, 0.72)	(0.355, 0.635)
HC_3	(0,76, 0,88)	(0.335, 0.665)	(0.31, 0.65)	(0.485, 0.765)	(0.39, 0.69)
Transportation		(0.342, 0.792)	(0.361, 0.714)	(0.499, 0.886)	(0.402, 0.769)
T_1	(0,83, 0,92)	(0.32, 0.62)	(0.38, 0.67)	(0.5, 0.74)	(0.415, 0.71)
T_2	(0,58, 0,75)	(0.335, 0.8)	(0.165, 0.63)	(0.47, 0.89)	(0.225, 0.7)
T_3	(0,68, 0,81)	(0.305, 0.73)	(0.27, 0.68)	(0.5, 0.85)	(0.345, 0.755)
T_4	(0,65, 0,79)	(0.35, 0.775)	(0.28, 0.725)	(0.485, 0.865)	(0.35, 0.775)
Population		(0.500, 0.828)	(0.391, 0.770)	(0.349, 0.669)	(0.451, 0.807)
P_1	(0,73, 0,86)	(0.5, 0.79)	(0.405, 0.75)	(0.25, 0.62)	(0.425, 0.76)
P_2	(0,71, 0,84)	(0.5, 0.735)	(0.32, 0.615)	(0.385, 0.67)	(0.415, 0.68)
P_3	(0,76, 0,88)	(0.5, 0.835)	(0.365, 0.775)	(0.265, 0.67)	(0.46, 0.815)
Costs		(0.391, 0.700)	(0.403, 0.724)	(0.499, 0.793)	(0.439, 0.740)
C_1	(0,76, 0,88)	(0.29, 0.69)	(0.245, 0.645)	(0.485, 0.82)	(0.33, 0.725)
C_2	(0,94, 0,97)	(0.37, 0.645)	(0.375, 0.63)	(0.5, 0.71)	(0.395, 0.65)
C_3	(0,6, 0,76)	(0.295, 0.62)	(0.425, 0.745)	(0.485, 0.765)	(0.45, 0.745)
C_4	(0,64, 0,77)	(0.405, 0.705)	(0.34, 0.665)	(0.5, 0.755)	(0.44, 0.72)

Table 8. Fuzzy Measures for α = 1.

Buca		Konak		Bornova		Karsiyaka	
$h^- = (K_{(i)})$	$h^+ = (K_{(i)})$	$h^- = (K_{(i)})$	$h^+ = (K_{(i)})$	$h^- = (K_{(i)})$	$h^+ = (K_{(i)})$	$h^- = (K_{(i)})$	$h^+ = (K_{(i)})$
fuzzy measures							
$\lambda= -0,9813$ $h^-(K_{(3)})=0,87$ $h^-(K_{(2)})=0,968$ $h^-(K_{(1)})=1$	$\lambda= -0,9969$ $h^+(K_{(3)})=0,93$ $h^+(K_{(2)})=0,986$ $h^+(K_{(1)})=1$	$\lambda= -0,9813$ $h^-(K_{(3)})=0,67$ $h^-(K_{(2)})=0,968$ $h^-(K_{(1)})=1$	$\lambda= -0,9969$ $h^+(K_{(3)})=0,82$ $h^+(K_{(2)})=0,960$ $h^+(K_{(1)})=1$	$\lambda= -0,9813$ $h^-(K_{(3)})=0,87$ $h^-(K_{(2)})=0,964$ $h^-(K_{(1)})=1$	$\lambda= -0,9969$ $h^+(K_{(3)})=0,825$ $h^+(K_{(2)})=0,970$ $h^+(K_{(1)})=1$	$\lambda= -0,9813$ $h^-(K_{(3)})=0,67$ $h^-(K_{(2)})=0,968$ $h^-(K_{(1)})=1$	$\lambda= -0,9969$ $h^+(K_{(3)})=0,77$ $h^+(K_{(2)})=0,960$ $h^+(K_{(1)})=1$
$\lambda= -0,9729$ $h^-(K_{(3)})=0,75$ $h^-(K_{(2)})=0,950$ $h^-(K_{(1)})=1$	$\lambda= -0,9551$ $h^+(K_{(3)})=0,82$ $h^+(K_{(2)})=0,970$ $h^+(K_{(1)})=1$	$\lambda= -0,9729$ $h^-(K_{(3)})=0,74$ $h^-(K_{(2)})=0,950$ $h^-(K_{(1)})=1$	$\lambda= -0,9551$ $h^+(K_{(3)})=0,86$ $h^+(K_{(2)})=0,978$ $h^+(K_{(1)})=1$	$\lambda= -0,9729$ $h^-(K_{(3)})=0,75$ $h^-(K_{(2)})=0,750$ $h^-(K_{(1)})=1$	$\lambda= -0,9551$ $h^+(K_{(3)})=0,91$ $h^+(K_{(2)})=0,971$ $h^+(K_{(1)})=1$	$\lambda= -0,9729$ $h^-(K_{(3)})=0,75$ $h^-(K_{(2)})=0,950$ $h^-(K_{(1)})=1$	$\lambda= -0,9551$ $h^+(K_{(3)})=0,83$ $h^+(K_{(2)})=0,979$ $h^+(K_{(1)})=1$
$\lambda= -0,9746$ $h^-(K_{(3)})=0,72$ $h^-(K_{(2)})=0,947$ $h^-(K_{(1)})=1$	$\lambda= -0,9958$ $h^+(K_{(3)})=0,82$ $h^+(K_{(2)})=0,970$ $h^+(K_{(1)})=1$	$\lambda= -0,9746$ $h^-(K_{(3)})=0,72$ $h^-(K_{(2)})=0,925$ $h^-(K_{(1)})=1$	$\lambda= -0,9958$ $h^+(K_{(3)})=0,82$ $h^+(K_{(2)})=0,981$ $h^+(K_{(1)})=1$	$\lambda= -0,9746$ $h^-(K_{(3)})=0,69$ $h^-(K_{(2)})=0,938$ $h^-(K_{(1)})=1$	$\lambda= -0,9958$ $h^+(K_{(3)})=0,82$ $h^+(K_{(2)})=0,981$ $h^+(K_{(1)})=1$	$\lambda= -0,9746$ $h^-(K_{(3)})=0,69$ $h^-(K_{(2)})=0,938$ $h^-(K_{(1)})=1$	$\lambda= -0,9958$ $h^+(K_{(3)})=0,82$ $h^+(K_{(2)})=0,981$ $h^+(K_{(1)})=1$
$\lambda= -0,9912$ $h^-(K_{(4)})=0,65$ $h^-(K_{(3)})=0,853$ $h^-(K_{(2)})=0,981$ $h^-(K_{(1)})=1$	$\lambda= -0,9991$ $h^+(K_{(4)})=0,80$ $h^+(K_{(3)})=0,958$ $h^+(K_{(2)})=0,992$ $h^+(K_{(1)})=1$	$\lambda= -0,9912$ $h^-(K_{(4)})=0,83$ $h^-(K_{(3)})=0,945$ $h^-(K_{(2)})=0,988$ $h^-(K_{(1)})=1$	$\lambda= -0,9991$ $h^+(K_{(4)})=0,79$ $h^+(K_{(3)})=0,960$ $h^+(K_{(2)})=0,997$ $h^+(K_{(1)})=1$	$\lambda= -0,9912$ $h^-(K_{(4)})=0,89$ $h^-(K_{(3)})=0,985$ $h^-(K_{(2)})=0,997$ $h^-(K_{(1)})=1$	$\lambda= -0,9991$ $h^+(K_{(4)})=0,83$ $h^+(K_{(3)})=0,974$ $h^+(K_{(2)})=0,995$ $h^+(K_{(1)})=1$	$\lambda= -0,9912$ $h^-(K_{(4)})=0,83$ $h^-(K_{(3)})=0,945$ $h^-(K_{(2)})=0,988$ $h^-(K_{(1)})=1$	$\lambda= -0,9991$ $h^+(K_{(4)})=0,79$ $h^+(K_{(3)})=0,960$ $h^+(K_{(2)})=0,997$ $h^+(K_{(1)})=1$
$\lambda= -0,9774$ $h^-(K_{(3)})=0,76$ $h^-(K_{(2)})=0,947$ $h^-(K_{(1)})=1$	$\lambda= -0,9971$ $h^+(K_{(3)})=0,88$ $h^+(K_{(2)})=0,985$ $h^+(K_{(1)})=1$	$\lambda= -0,9774$ $h^-(K_{(3)})=0,73$ $h^-(K_{(2)})=0,947$ $h^-(K_{(1)})=1$	$\lambda= -0,9971$ $h^+(K_{(3)})=0,88$ $h^+(K_{(2)})=0,985$ $h^+(K_{(1)})=1$	$\lambda= -0,9774$ $h^-(K_{(3)})=0,71$ $h^-(K_{(2)})=0,916942$ $h^-(K_{(1)})=1$	$\lambda= -0,9971$ $h^+(K_{(3)})=0,88$ $h^+(K_{(2)})=0,982$ $h^+(K_{(1)})=1$	$\lambda= -0,9774$ $h^-(K_{(3)})=0,76$ $h^-(K_{(2)})=0,947$ $h^-(K_{(1)})=1$	$\lambda= -0,9971$ $h^+(K_{(3)})=0,88$ $h^+(K_{(2)})=0,985$ $h^+(K_{(1)})=1$
$\lambda= -0,9978$ $h^-(K_{(4)})=0,64$ $h^-(K_{(3)})=0,979$ $h^-(K_{(2)})=0,993$ $h^-(K_{(1)})=1$	$\lambda= -0,9997$ $h^+(K_{(4)})=0,77$ $h^+(K_{(3)})=0,972$ $h^+(K_{(2)})=0,999$ $h^+(K_{(1)})=1$	$\lambda= -0,9978$ $h^-(K_{(4)})=0,60$ $h^-(K_{(3)})=0,977$ $h^-(K_{(2)})=0,993$ $h^-(K_{(1)})=1$	$\lambda= -0,9997$ $h^+(K_{(4)})=0,76$ $h^+(K_{(3)})=0,944$ $h^+(K_{(2)})=0,993$ $h^+(K_{(1)})=1$	$\lambda= -0,9978$ $h^-(K_{(4)})=0,94$ $h^-(K_{(3)})=0,979$ $h^-(K_{(2)})=0,996$ $h^-(K_{(1)})=1$	$\lambda= -0,9997$ $h^+(K_{(4)})=0,82$ $h^+(K_{(3)})=0,957$ $h^+(K_{(2)})=0,990$ $h^+(K_{(1)})=1$	$\lambda= -0,9978$ $h^-(K_{(4)})=0,60$ $h^-(K_{(3)})=0,856$ $h^-(K_{(2)})=0,993$ $h^-(K_{(1)})=1$	$\lambda= -0,9997$ $h^+(K_{(4)})=0,76$ $h^+(K_{(3)})=0,992$ $h^+(K_{(2)})=0,998$ $h^+(K_{(1)})=1$

Table 9. Defuzzified Overall Alternative Location Values

Criteria	$(C)\int \tilde{f} d\tilde{h}$				Defuzzified$(C)\int \tilde{f} d\tilde{h}$			
	Buca	Konak	Bornova	Karsiyaka	Buca	Konak	Bornova	Karsiyaka
OLV	(0.353,0.406,0.784,0.798)	(0.373,0.407,0.766,0.818)	(0.488,0.450,0.880,0.882)	(0.411,0.451,0.809,0.850)	0,585	0,591	**0,675***	0,630
A	(0.355,0.407,0.689,0.747)	(0.337,0. 379,0.704,0.754)	(0.482, 0.5, 0.811,0.863)	(0.388,0.439,0.747,0,809)	0,550	0,544	**0,664***	0,596
A_1	(0.24,0.285, 0.69, 0.76)	(0.25, 0.29, 0.69, 0.76)	(0.47, 0.5,0.825,0.875)	(0.325, 0.365,0.755, 0.82)	0,494	0,498	0,668	0,566
A_2	(0.39,0.42, 0.69,0.73)	(0.29, 0.32, 0.635, 0.685)	(0.485, 0.5, 0.74, 0.77)	(0.34, 0.38, 0.655,0.7)	0,558	0,483	0,624	0,519
A_3	(0.31,0.34,0.63,0.675)	(0.37, 0.41, 0.71, 0.76)	(0.46, 0.485, 0.745, 0.78)	(0.425,0.47,0.735,0.775)	0,489	0,563	0,618	0,601
E	(0.327,0.372,0.724,0.782)	(0.362,0.406,0.693,0.745)	(0.399,0.448,0.710,0.758)	(0.480,0.499,0.812,0.856)	0,551	0,552	0,579	**0,662***
E_1	(0.345,0.38,0.675, 0.735)	(0.375,0.4,0.65,0.7)	(0.34,0.375,0.66,0.72)	(0.49,0.5,0.725,0.765)	0,534	0,531	0,524	0,620
E_2	(0.275,0.325,0.735, 0.79)	(0.18,0.225,0.635,0.69)	(0.23,0.285,0.685,0.74)	(0.43,0.48,0.83,0.87)	0,531	0,347	0,485	0,653
E_3	(0.315,0.355,0.655, 0.71)	(0.38,0.42,0.7,0.75)	(0.44,0.48,0.715,0.76)	(0.47,0.5,0.725,0.765)	0,509	0,563	0,599	0,615
HC	(0.327,0.377,0.693,0.757)	(0.297,0.337,0.702,0.768)	(0.462,0.495,0.797,0.843)	(0.355,0.398,0.734,0.786)	0,539	0,526	**0,649***	0,568
HC_1	(0.265,0.31,0.695,0.76)	(0.305,0.34,0.715,0.78)	(0.465,0.5,0.805,0.85)	(0.365,0.405,0.745,0.795)	0,508	0,535	0,655	0,578
HC_2	(0.355,0.395,0.685, 0.74)	(0.295,0.34,0.61,0.67)	(0.45,0.475,0.72,0.765)	(0.31,0.355,0.635,0.695)	0,544	0,479	0,603	0,499
HC_3	(0.29, 0.335, 0.665, 0.72)	(0.27, 0.31, 0.65, 0.705)	(0.46, 0.485, 0.765, 0.805)	(0.345, 0.39, 0.69, 0.74)	0,503	0,484	0,629	0,541
T	(0.289,0.342,0.792,0.776)	(0.228,0.361,0.714,0.715)	(0.459,0.499,0.886,0.880)	(0.297,0.402,0.769,0.760)	0,550	0,505	**0,681***	0,557
T_1	(0.29,0.32,0.62,0.67)	(0.345,0.38,0.67,0.715)	(0.485,0.5,0.74,0.77)	(0.38,0.415,0.71,0.755)	0,475	0,528	0,624	0,565
T_2	(0.29,0.335,0.8 0.855)	(0.125, 0.165, 0.63, 0.69)	(0.44,0.47,0.89, 0.925)	(0.17,0.225,0.7,0.76)	0,570	0,403	0,681	0,464
T_3	(0.265,0.305,0.73,0.775)	(0.23, 0.27, 0.68, 0.725)	(0.47,0.5,0.85,0.88)	(0.3,0.345,0.755,0.8)	0,519	0,476	0,675	0,550
T_4	(0.305,0.35,0.775, 0.815)	(0.24, 0.28, 0.725,0.77)	(0.46, 0.485,0.865,0.89)	(0.305,0.35,0.775,0.815)	0,561	0,504	0,675	0,561
P	(0.487,0.5,0.828,0.862)	(0.370,0.391,0.770,0.823)	(0.309,0.349,0.669,0.724)	(0.409,0.451,0.807,0.852)	**0,669***	0,589	0,513	0,630
P_1	(0.475,0.5,0.79,0.835)	(0.365,0.405,0.75,0.81)	(0.205,0.25,0.62,0.69)	(0.385,0.425,0.76,0.815)	0,650	0,583	0,441	0,596
P_2	(0.49,0.5, 0.735, 0.77)	(0.285,0.32,0.615,0.67)	(0.36,0.385,0.67,0.715)	(0.38,0.415, 0.68, 0.73)	0,624	0,473	0,533	0,551
P_3	(0.485,0.5, 0.835,0.865)	(0.33, 0.365, 0.775,0.825)	(0.22,0.265,0.67,0.725)	(0.42,0.46, 0.815, 0.855)	0,671	0,574	0,470	0,638
C	(0.256,0.391,0.700,0.695)	(0.304,0.403,0.724,0.715)	(0.460,0.499,0.793,0.795)	(0.359,0.439,0.740,0.759)	**0,511***	0,537	0,637	0,574
C_1	(0.245,0.29,0.69,0.76)	(0.2, 0.245, 0.645, 0.715)	(0.46,0.485, 0.82, 0.87)	(0.285,0.33,0.725,0.795)	0,496	0,451	0,659	0,534
C_2	(0.335,0.37,0.645, 0.695)	(0.345, 0.375, 0.63, 0.675)	(0.485, 0.5, 0.71, 0.74)	(0.36, 0.395, 0.65, 0.695)	0,511	0,506	0,609	0,525
C_3	(0.255, 0.295, 0.62, 0.68)	(0.385, 0.425, 0.745, 0.8)	(0.46, 0.485, 0.765, 0.81)	(0.41, 0.45, 0.745, 0.795)	0,463	0,589	0,630	0,600
C_4	(0.365, 0.405,0.705, 0.75)	(0.305, 0.34, 0.665, 0.725)	(0.475, 0.5, 0.755, 0.795)	(0.4, 0.44, 0.72, 0.76)	0,556	0,509	0,631	0,580

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