Research Article

A New Hybrid Decision Making Approach for Housing Suitability Mapping of an Urban Area

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In urban planning, housing evaluation of residential areas plays a critical role in promoting economic efficiency. This study produced an evolutionary-based map through the combination of hybrid Multicriteria Decision Making (MCDM) and Geographical Information System (GIS) by assessing suitability of housing location. Suitable locations were modelled and determined with the present study from very low suitability to very high suitability. In the first stage, Fuzzy DEMATEL (the Decision Making Trial and Evaluation Laboratory) and Covariance Matrix Adaptation Evolutionary Strategy (CMA-ES) under fuzzy conditions as a subjective and an objective (model-based) technique, respectively, were employed to find the weights of criteria which are critical part of decision making. In the second stage, housing evaluation map for these two approaches was drawn and their performances were classified and measured with WLC (Weighted Linear Combination) method. 29 criteria determined were prioritized as judgment of urban planning and real estate experts for Fuzzy DEMATEL and CMA-ES. After having been coded to MATLAB for obtaining optimum weights in CMA-ES, all collected data for 160 houses were mapped as vectorial (positional) and transformed to raster (pixel) data by getting entered in ArcGIS 10.4 software. We achieved CMA-ES-WLC maximization values for 104 alternatives with (positive value) 65% performance, but we obtained FDEMATEL-WLC maximization values for 56 alternatives with (negative value) 35% performance. WLC values calculated with CMA-ES and FDEMATEL weights allowed us to conclude that the houses with the highest suitability in terms of investment are in Alpaslan, Kösök, and Melikgazi streets. The result shows that the methodology used in the application of this study performed in Turkey is an important and powerful technology in providing decision support for spatial planning.

1. Introduction

As urban population living in cities increases rapidly, it is crucial to preserve environmental values and improve quality of urban service and quality of life. In this context, the concept of the land use and development of urban areas in accordance with this goal is one of the topics discussed in the urbanization literature [1]. Land use planning includes decisions about interdependent and multilayered issues affecting air and water quality, access to transportation options, economic viability, and quality of life [2–5]. Creating planned areas that include types and uses of buildings and places to meet needs of residents’ daily lives has a critical viewpoint. Primary types of planning areas that need to be supplied to residents by municipalities are classified as residential, commercial, industrial, green, and agricultural areas [6, 7]. Land use, once considered as a local environmental issue, is now regarded as a driving force of global importance. Regulation of land use is the main function of local governments whose planning departments monitor many regulations related to land acquisition, including land master planning, transport, housing, economic development, and reconstruction [8]. Suitability evaluation is of considerable use for land use planning and development [9]. The development of land use policies and related coordination in Turkey has come to the fore after 1980s. Urban Land Use and Planning Act was renovated in 1985 [10] since migrations, urban population growth, increasing population density in city center, infrastructure problems, use of fertile agricultural land, industrialization, and other factors reveal necessity of producing policies for
land use planning [11]. Regional, environmental, master, and implementation plan hierarchy for physical planning was foreseen. The law was designed in order to ensure that the settlements and the structures in these places are in accordance with the plan, science, health, and environment conditions [10, 12]. Policies made for this purpose generally bring temporary solutions together with socially meaningful housing and social and spatial-functional injustice accompanied by the release of slum dwellings on one hand. In general, it has been observed that applications for urban land use and housing production are primarily due to technical and legal problems of ownership structure and fail to produce sustainable land use and housing policies [13]. The basic aim of housing policies is to get at the price that they will be able to pay for “good and adequate housing” for entire segment of society from lowest income group to top income group. Nevertheless, housing problem (especially, for low income families) has not been fully resolved in both developed and developing countries from past to present [14]. In countries such as Turkey where housing is seen as a guarantee, demand for investment by high income group is very important. In this case, there may be more than one housing in their ownership, except for the house that the individual uses. The majority of these dwellings are offered on the market as rental housing stocks. For middle and lower income groups, purchasing a house is still an important problem. Especially, housing supply for lower income group is a serious problem and policies for purchasing house of lower income group are still insufficient. In this sense, housing loan system is not yet able to run for its purpose. The main reason for this failure is that the interest rates on housing loans are still quite high in today’s conditions [15]. Turkey real estate sector is a significant driving force in its economy due to employment along with many subsectors such as tourism and building. To choose a suitable location for investors who want to purchase a house has become a crucial matter since price and demand as well as gross domestic product per capita are increasing. Site selection literature [2–5, 16–18], opinions of housing development and valuation experts, and a Ph.D. Thesis [19] were used for selection of criteria and, finally, 29 criteria with evaluations of authors were determined. Our study focuses on selection problem of best suitable among existing ones for sale with the help of housing suitability evaluation whenever a customer wants to buy a house depending on 29 criteria which are related to distance, building, and surrounding properties among others. To solve this problem MCDM and Evolutionary Algorithm (EA) approaches can be considered with weighting of criteria to either single or multiple sets of objectives [20]. However, these methods used alone reveal serious deficiencies from the view of geographical aspects [21] and are eliminated to a large extent with Spatial Decision Support System (SDSS) technique considering heterogeneity in environment [22]. Many studies have used the MCDM techniques like ordered weighted averaging (OWA) [23], analytical hierarchy/network [24] process, ELECTRE (elimination and choice expressing reality) [25], PROMETHEE (the preference ranking organization method for enrichment of evaluations) [26], EA [27], Combined Decision Making Trial and Evaluation Laboratory (DEMATEL), the Analytic Network Process (ANP) and Multiattributive Border Approximation area Comparison (MABAC) [16], and Multiattributive Ideal-Real Comparative Analysis (MAIRCA) [17]. SDSS has been carried out by using Geographic Information System (GIS) together with MCDM and EA techniques [28]. This approach reduces deficiencies in combination of geographical features of subjective values and preferences [29]. GIS as an ideal tool to analyze and solve multicriteria problems can easily update the existing information upon the availability of new or better information [30, 31]. Researchers working on SDSS to solve site selection problems have been investigating various methods to integrate MCDM or/and EA techniques into GIS [16–18, 20, 32, 33]. Location or site selection problem which involves the evaluation of multiple criteria is still one of the significant decision parameters for decision makers. More recently, we have faced a few studies in the literature about combined GIS and EA solving site selection problems [34–37]. The main objective of our study was to produce a suitability map through the combination of MCDM and GIS by assessing suitability of housing location. At the end of the study, we obtained the map having the highest housing suitability evaluation value with combined CMA-ES-WLC approach by comparing an objective (mathematical) and a subjective method.

2. Materials and Methods

As a result of field work conducted in Kayseri city of Turkey, dwellings used in this study were specified on the basis of housing for sale. Criteria employed were determined by the study on real estate development. Locations of the houses were taken from Google Earth (Figure 1). Target population of the study is approximately 2000 residential units sold in Kayseri during the last one month. In order to gather information about housing criteria shown in Table 1, a questionnaire was done with customers. The sample size data found pertaining to 160 dwellings was collected from different districts of Kayseri. Housing site selection is the most critical strategic decision a customer has to make. Because of the significance of site location in the quality of life, customers carefully evaluate many variables and competitive housing sites before selecting.
### Table 1: Definition of the criteria.

<table>
<thead>
<tr>
<th>No</th>
<th>Criteria</th>
<th>Description of the criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1</td>
<td>Topographic Structure</td>
<td>Physical features of the area</td>
</tr>
<tr>
<td>C2</td>
<td>Structural Density</td>
<td>The ratio of the total ground floor area of a building to the total land area</td>
</tr>
<tr>
<td>C3</td>
<td>Landscape</td>
<td>All the visible features of an area of land</td>
</tr>
<tr>
<td>C4</td>
<td>Distance to City Center</td>
<td>Distance to center according to transportation network with reference to the Governorate</td>
</tr>
<tr>
<td>C5</td>
<td>Distance to Elementary School</td>
<td>Specified distance according to nearest primary school</td>
</tr>
<tr>
<td>C6</td>
<td>Distance to Secondary School</td>
<td>Specified distance according to secondary school</td>
</tr>
<tr>
<td>C7</td>
<td>Distance to University</td>
<td>Specified distance according to Erciyes University</td>
</tr>
<tr>
<td>C8</td>
<td>Distance to Shopping Center</td>
<td>Specified distance according to 2 large shopping malls</td>
</tr>
<tr>
<td>C9</td>
<td>Arrival Time to City Center</td>
<td>Estimated transportation time from residential to city center</td>
</tr>
<tr>
<td>C10</td>
<td>Impurity</td>
<td>Pollution level of the area where housing is located</td>
</tr>
<tr>
<td>C11</td>
<td>Age of Building</td>
<td>Actual age of the building</td>
</tr>
<tr>
<td>C12</td>
<td>Building Land Area</td>
<td>Land area where housing is located</td>
</tr>
<tr>
<td>C13</td>
<td>Warm-up Type</td>
<td>Evaluation of warm-up type in terms of cost and air pollution</td>
</tr>
<tr>
<td>C14</td>
<td>Fuel Type</td>
<td>Evaluation of fuel used in terms of preference</td>
</tr>
<tr>
<td>C15</td>
<td>Building Security</td>
<td>The level of building security</td>
</tr>
<tr>
<td>C16</td>
<td>Satellite Access</td>
<td>Evaluation of satellite or terrestrial broadcasting status</td>
</tr>
<tr>
<td>C17</td>
<td>Housing Front</td>
<td>Evaluation of residential ceiling in terms of preference</td>
</tr>
<tr>
<td>C18</td>
<td>Residential Area</td>
<td>Housing area based on m²</td>
</tr>
<tr>
<td>C19</td>
<td>Monthly Rent</td>
<td>Rent value of the housing</td>
</tr>
<tr>
<td>C20</td>
<td>Building Fees</td>
<td>Money collected for building expenses</td>
</tr>
<tr>
<td>C21</td>
<td>Number of Rooms</td>
<td>Total number of rooms excluding lounge</td>
</tr>
<tr>
<td>C22</td>
<td>Number of Bathrooms</td>
<td>Total number of bathrooms</td>
</tr>
<tr>
<td>C23</td>
<td>Housing Value</td>
<td>Up-to-date sales value of the estate</td>
</tr>
<tr>
<td>C24</td>
<td>Is Housing in Housing Estate</td>
<td>State of settlement of site type</td>
</tr>
<tr>
<td>C25</td>
<td>Garden</td>
<td>Garden area</td>
</tr>
<tr>
<td>C26</td>
<td>Percentage of Green Space</td>
<td>Percentage of green space in the neighborhood</td>
</tr>
<tr>
<td>C27</td>
<td>Infrastructure</td>
<td>Percentage of green space in the neighborhood</td>
</tr>
<tr>
<td>C28</td>
<td>Parking</td>
<td>Percentage of green space in the neighborhood</td>
</tr>
<tr>
<td>C29</td>
<td>Income Level</td>
<td>Housing monthly income level as households</td>
</tr>
</tbody>
</table>
In order to better understand the material and the methodology used, housing suitability flow diagram employed in the study is given in Figure 2.

2.1. Weights of Criteria Estimation

2.1.1. CMA-ES Algorithm and Optimization. As an evolutionary approach to solve housing location site selection problem, we considered CMA-ES algorithm under fuzzy conditions necessary. Since EAs for local and global optimization solutions are fast and robust computation methods, they have been widely used as a state of the art method. CMA-ES as a class of continuous EAs was proposed by Hansen [38]. In particular, CMA-ES which is one of the most effective EAs due to its self-training behaviour is often preferred to other ES (Evolutionary Strategy) techniques for continuous objective functions [39]. Compared to other EAs, invariability against the linear transformations in the search space is an important characteristic of CMA-ES which is a stochastic method generating new population member by sampling from a probability distribution that is constructed during the optimization process. Training process of correlations between parameters and use of the correlations to accelerate convergence of the algorithm are key concepts of this algorithm. In recent years, there have been many studies about CMA-ES or hybrid CMA-ES approach. These studies in the literature proved that CMA-ES is a more efficient EA than others in improving performance of systems [40]. CMA-ES is one of the most efficient metaheuristics for dealing with difficult numerical optimization problems [41]. Another reason to prefer such algorithm is that a modification of the constraints may not require a reformulation of the problem, which, in practice, may be of considerable usefulness [42]. This choice may thus also have some operational advantages. CMA-ES are generally the most effective strategies on non seperable and badly scaled problems and advantages, showing in particular
In our study, CMA-ES under fuzzy conditions was used to make clear the optimization problem formulated in (3). The quality of a solution is defined by the fitness function. The problem was coded and solved by MATLAB 2011 in 2016. Elapsed time for solution and the number of iteration were 188.86 seconds and 197218, respectively. CMA-ES algorithm has been explained by many sources in detail [38, 46]. Besides, the steps of algorithm are given in the Supplementary Materials (available here).

2.1.2. Fuzzy DEMATEL (FDEMATEL). FDEMATEL was used first by Lin and Wu [47] while DEMATEL was developed by Gabus and Fontela [48]. It is helpful for monitoring the structure of complex causal relationships with matrices or digraphs. FDEMATEL is a method which gathers group ideas and analyzes the cause and effect relationship of complicated problems in fuzzy environments. Shieh et al. [49] evaluated the importance of the criteria and constructed the causal relationships among the criteria with FDEMATEL. Converting Fuzzy Data into Crisp Scores (CFCS) defuzzification method generated by Opricovic and Tzeng [50] was employed in this paper. Since Fuzzy DEMATEL method can get an intelligible structural model of the system by transforming the relationship between the causes and effects of criteria [51–53], this method has been chosen for weighing the criteria [54]. The procedure for weighing criteria of the FDEMATEL method is shortly explained below [55] and given in the Supplementary Materials as detailed.

Step 1. Identify the decision aim and establish a committee.

Step 2. Develop the assessment criteria and design the fuzzy linguistic range.

Step 3. Acquire and average the evaluations of decision makers.

Step 4. Steps of Converting Fuzzy data into Crisp Scores defuzzification Method

Step 5. Acquire the normalized direct-relation fuzzy matrix. (̃\( \mathbf{X} \))

Step 6. Acquire the total-relational fuzzy matrix (\( \mathbf{T} \))

Step 7. Determine the criteria weights. (\( w_i \))

2.2. Combination of MCDM and WLC. Our problem is to find the best one among the existing housing for the customer who wants to purchase a house. Generally, MCDM techniques are required to answer this problem. This study combines the spatial analyst of GIS and multicriteria decision analysis in the housing evaluation site selection model. The choice of weights and weighting techniques has an important effect on decision making. In MCDM methods, the most important point is to find criteria weights especially objective. While criteria weights determined with subjective decision making methods depend on decision makers’ preferences, weights with objective decision making are obtained from

\[
G(\omega_1, \omega_2, \ldots, \omega_n) = \min_{i < j} \left( \mu_{i2}, \mu_{i3}, \ldots, \mu_{ij}, \ldots, \mu_{(n-1)n} \right)
\]

The problem of obtaining a priority vector of n criteria can be determined in the following optimization problem defined in (3).

\[
\text{Maximize } G(\omega_1, \omega_2, \ldots, \omega_n)
\]

\[
\text{Subject to } \sum_{i=1}^{n} \omega_i = 1
\]

\[
\text{Where } G(\omega_1, \omega_2, \ldots, \omega_n)
\]
where $S$ is the suitability, $W_i$ the weight of factor $i$, $n$ the number of factors, $X_i$ the criterion score of factor $i$ in continued range, and $C_j$ restricted state for any area. WLC function of ArcGIS model builder has been applied to generate housing evaluation suitability map. Malczewski and Rinner [61] highlighted WLC as the most popular MCE (Multicriteria Evaluation) method about suitability analysis with GIS on location which was developed by Voogd [62]. In order to find the suitable alternatives for housing site selection, WLC models have been commonly used in SDSS. Generally, SDSS considers many criteria to make a decision. Since determining the factor weights of WLC effectively and in a realistic style without user bias is difficult as a weakness point, different MCDM methods have been used to find the weights of criteria with the combination of WLC. The outcomes exhibited the capability of the model to eliminate human interference. Suitability score indicates which locations or areas are particularly well suited for a specific purpose. A suitability map is created as a result of obtaining the suitability score. The evaluation was done by intersecting 29 criteria such as social, economic, ecologic, and environmental as given in Table 1. We assumed that suitability is linear with respect to scores and that variables are independent. Organizing a single index of evaluation combined by MCDA provides information about several criteria. To combine continuous factors by applying a weight to each factor, a linear combination is used to get a suitability map [63, 64]. One of the significant applications for spatial planning and management is GIS-based land suitability mapping [65]. Score values in decision matrix are standardized as defined in

$$S = \sum_{i=1}^{n} W_i X_i \prod_{j=1}^{m} C_j$$

(4)

$$V(a^{ij}_k) = \begin{cases} \frac{a^{ij}_k - \min_k [a^{ij}_k]}{r^{ij}_k} & \text{for the } k-th \text{ criterion to be maximized} \\ \frac{\max_k [a^{ij}_k] - a^{ij}_k}{r^{ij}_k} & \text{for the } k-th \text{ criterion to be minimized} \end{cases}$$

(5)

where $\min [a^{ij}_k]$ and $\max [a^{ij}_k]$ are the values of minimum and maximum criterion for the $k$-th criterion, respectively, and $r_k = \max [a^{ij}_k] - \min [a^{ij}_k]$ is the global range of the $k$-th criterion. In the standardized score values $V(a^{ij}_k)$, ranging from 0 to 1, 0 is the least suitable value while 1 is the most desired score.

3. Results

According to the linguistic variables in Table 2, real estate experts and decision makers selected randomly from houses evaluated decision criteria. The data were obtained from housing based different locations.

To determine the weighting of criteria is a significant point in MCDM. Many researchers have accepted direct and indirect way for deciding the value of criteria weighting.
Table 2: Linguistic scales for criteria weights and alternatives.

<table>
<thead>
<tr>
<th>Linguistic variables Fuzzy (FDEMATEL)</th>
<th>Triangular fuzzy number</th>
<th>Linguistic variable (CMA-ES)</th>
<th>Triangular Fuzzy Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Impact (N)</td>
<td>(0.00, 0.00, 0.25)</td>
<td>Equally strong</td>
<td>(1, 1)</td>
</tr>
<tr>
<td>Very Low Impact (VL)</td>
<td>(0.00, 0.25, 0.50)</td>
<td>Intermediate</td>
<td>(1, 2, 3)</td>
</tr>
<tr>
<td>Low Impact (L)</td>
<td>(0.25, 0.50, 0.75)</td>
<td>Moderately strong</td>
<td>(2, 3, 4)</td>
</tr>
<tr>
<td>High Impact (H)</td>
<td>(0.50, 0.75, 1.00)</td>
<td>Intermediate</td>
<td>(3, 4, 5)</td>
</tr>
<tr>
<td>Very High Impact (VH)</td>
<td>(0.75, 1.00, 1.00)</td>
<td>Strong</td>
<td>(4, 5, 6)</td>
</tr>
</tbody>
</table>

Housing Value (1000TL)

| 110 | 130 | 80 | 120 | 0.25 | 0.42 | 0.00 | 0.33 |
| 100 | 120 | 90 | 195 | 0.17 | 0.33 | 0.08 | 0.96 |
| 120 | 160 | 90 | 200 | 0.33 | 0.67 | 0.08 | 1.00 |
| 95  | 100 | 87 | 125 | 0.13 | 0.17 | 0.06 | 0.38 |

Landscape Score

| 110 | 130 | 80 | 120 | 0.00 | 0.67 | 0.67 | 0.67 |
| 100 | 120 | 90 | 195 | 0.67 | 0.00 | 0.67 | 0.67 |
| 120 | 160 | 90 | 200 | 1.00 | 0.00 | 0.67 | 0.37 |
| 95  | 100 | 87 | 125 | 1.00 | 0.67 | 0.37 | 1.00 |

Parking

| 4   | 3   | 4   | 4   | 1.00 | 0.00 | 1.00 | 1.00 |
| 4   | 4   | 3   | 4   | 1.00 | 1.00 | 0.00 | 1.00 |
| 4   | 4   | 4   | 4   | 1.00 | 1.00 | 1.00 | 1.00 |
| 4   | 3   | 4   | 4   | 1.00 | 0.00 | 1.00 | 1.00 |

* Best Cell

Figure 4: The effect of scale on WLC suitability value.

were obtained from the questionnaire data relying on 160 houses as a sample.

A location of houses and information based on criteria was determined with positional database logic using on ArcGIS raster map. The 3 most commonly used interpolation methods in the ArcGIS program have been investigated by comparing RMSE values. These values were mapped as vectorial (positional) and transformed to raster (pixel) data using IDW (Inverse Distance Weighting) interpolation as a deterministic spatial interpolation model adopted by geoscientists to find the unknown location method. In order to predict the unknown interval values, the points close to each other were clustered together. According to the IDW method, the highest weight is assigned to the nearest one where the
Table 3: The importance weight of each criterion by methods.

<table>
<thead>
<tr>
<th>Criteria</th>
<th>C1</th>
<th>C2</th>
<th>C3</th>
<th>C4</th>
<th>C5</th>
<th>C6</th>
<th>C7</th>
<th>C8</th>
<th>C9</th>
<th>C10</th>
</tr>
</thead>
<tbody>
<tr>
<td>FDEMATEL</td>
<td>0.034</td>
<td>0.064</td>
<td>0.043</td>
<td>0.042</td>
<td>0.011</td>
<td>0.011</td>
<td>0.012</td>
<td>0.016</td>
<td>0.038</td>
<td>0.035</td>
</tr>
<tr>
<td>CMA-ES</td>
<td>0.082</td>
<td>0.000</td>
<td>0.005</td>
<td>0.000</td>
<td>0.010</td>
<td>0.016</td>
<td>0.017</td>
<td>0.020</td>
<td>0.010</td>
<td>0.005</td>
</tr>
<tr>
<td>Criteria</td>
<td>C11</td>
<td>C12</td>
<td>C13</td>
<td>C14</td>
<td>C15</td>
<td>C16</td>
<td>C17</td>
<td>C18</td>
<td>C19</td>
<td>C20</td>
</tr>
<tr>
<td>FDEMATEL</td>
<td>0.029</td>
<td>0.042</td>
<td>0.021</td>
<td>0.021</td>
<td>0.027</td>
<td>0.006</td>
<td>0.020</td>
<td>0.044</td>
<td>0.064</td>
<td>0.058</td>
</tr>
<tr>
<td>CMA-ES</td>
<td>0.006</td>
<td>0.004</td>
<td>0.004</td>
<td>0.011</td>
<td>0.003</td>
<td>0.005</td>
<td>0.040</td>
<td>0.013</td>
<td>0.021</td>
<td></td>
</tr>
<tr>
<td>Criteria</td>
<td>C21</td>
<td>C22</td>
<td>C23</td>
<td>C24</td>
<td>C25</td>
<td>C26</td>
<td>C27</td>
<td>C28</td>
<td>C29</td>
<td></td>
</tr>
<tr>
<td>FDEMATEL</td>
<td>0.035</td>
<td>0.034</td>
<td>0.083</td>
<td>0.030</td>
<td>0.026</td>
<td>0.033</td>
<td>0.037</td>
<td>0.026</td>
<td>0.053</td>
<td></td>
</tr>
<tr>
<td>CMA-ES</td>
<td>0.012</td>
<td>0.038</td>
<td>0.019</td>
<td>0.012</td>
<td>0.575</td>
<td>0.012</td>
<td>0.002</td>
<td>0.030</td>
<td>0.001</td>
<td></td>
</tr>
</tbody>
</table>
The smallest weight value is assigned to the farthest one. As a result, IDW interpolation method was chosen because IDW RMSE: 0.2501, RBF RMSE: 0.2536, and Ordinary Kriging RMSE: 0.2725 were obtained. Two different raster maps were produced by applying the IDW interpolation method based on WLC suitability values obtained from the residential basis. The WLC classification was made to be very low suitability from 0 to 0.20, low suitability from 0.20 to 0.40, moderate suitability from 0.4 to 0.60, high suitability from 0.60 to 0.80, and very high suitability from 0.80 to 1. Raster map obtained from CMA-ES weights was divided into 5 classes but that produced by FDEMATEL weights was divided into 3 classes for WLC suitability values (Figures 5 and 6).

When comparing between Figures 4 and 5, areas with very high suitability on the map obtained from CMA-ES weights seems to be similar to the high suitability areas obtained by FDEMATEL weights. The low suitability area in the northeast of CMA-ES weights and the low suitability area of FDEMATEL weights were identical. The map obtained from FDEMATEL weights has not shown very high and very low suitability areas. It seems to be a medium-suitability (yellow) area in large proportion. Accordingly, the suitability map obtained from CMA-ES weights has shown all classes and produced more sensitive map.

In this context, the WLC was employed in the criteria aggregation, producing a priority map for Kayseri that was classified into five priority levels: very low, low, medium, high, and very high. It seems clear that these weights will have full effect with WLC operator. The suitability status of all the dwelling units assessed for the WLC values calculated with CMA-ES and FDEMATEL weights is shown on the Kayseri neighbourhood map (Figure 7). According to this map, it has been seen that the houses with the highest suitability in terms of investment are in Alpaslan, Köşk, and Melikgazi streets. This shows that the suitability maps obtained with the weights in these areas and the housing values are compatible with each other.

Our goal from a performance criterion measuring the weighting efficiency is to maximize the WLC value for 160 alternatives. We achieved CMA-ES-WLC maximization values for 104 alternatives but we obtained FDEMATEL-WLC maximization values for 56 alternatives as shown in Table 4. Thus, housing suitability map was performed with CMA-ES weighting model approach. Since the WLC value close to 1 is
4. Discussion and Conclusions

This paper has shown that evolutionary-based map production in the evaluation of housing as an objective approach is likely more efficient than subjective approaches. We propose CMA-ES-WLC as a new hybrid EA for the solution of site selection problem with respect to performance evaluation based on suitability value. In order to produce housing suitability raster map, WLC approach was applied successfully by measuring performance of criteria weights. Successful implementation of this study would enable decision makers to follow a comprehensive easy-to-use procedure to make the correct decision. The criterion number 25 described as garden is the most important factor for CMA-ES in maximizing the decision goal. Therefore, today and in the future, decision maker should firstly take this factor into consideration in urban planning because of priority preference of customers. IDW interpolation method was employed to determine appropriate region in the mapping. The problem of optimizing housing and regional selection was solved in terms of individual and institutional investment. By setting their own criteria on these maps in accordance with their own goals, anybody can determine the most suitable housing or the area where their residence is located. Local governments will be able to adjust their services accordingly by determining which criteria are the most important. Local taxation coefficients can be obtained to increase wealth by making classifications on the map developed by the local governments in determining property taxes as a result of this study. Development of a regional housing evaluation map will help determine service quality standards in fulfilling responsibilities of central and local governments. Governments will be able to distribute services provided by local authorities on an equal basis across their city. Aforementioned features are useful for a municipal agency to do a housing evaluation map for planning purposes. In Table 5, we found some classification dimension from the results obtained and some interpretation can be made about housing location areas (zones) as follows:

S1: When WLC classification is made according to both weight methods, there is no worst zone in terms of housing evaluation and selection.

S2: According to both weighting methods in terms of housing evaluation and selection, a region of about 10% is worse based on WLC classification. In the classification map obtained from the FDEMATEL method, only the marginal
areas which are east of Kayseri were found as poor regions. According to the CMA-ES method, some of the old streets in the city and the streets in the east of the city were identified as poor districts. They are the areas where people who have a low income level live and which are generally unplanned.

S3: According to FDEMATEL weights and WLC classification, 80% of the residential areas fall into this area. In the CMA-ES weights and WLC classification, 22% of the residential areas are located in this region. Even though these areas are planned, they are now developing regions according to the plan of the city of 30-40 years ago and where the people belonging to low-middle-income level live.

S4: These regions are good areas for housing quality and planned settlements. Generally, the income levels are in the regions where people live on average of about $1000 a month. According to the CMA-ES weighting method, 51% of the entire area is available as a suitable region. This situation is consistent with Turkey's economic realities and Kayseri.

S5: This region did not occur in the FDEMATEL method and the WLC classification. According to the CMA-ES method and WLC classification, the most suitable areas include Kayseri's most prestigious streets such as Alpaslan, Küş, Melikgazi, and Gültepe. They are the most beautiful regions of the city in terms of planning and have shown great development since 2000's. Housing values are also high in the region. They are close to Sivas street and tram line which provide main transportation of the city. The income level of people living in this region is about 2000 dollars a month.

Nowadays, the development of web-based data collection systems is necessary to apply for all countries since they will bring a new perspective in the evaluation and selection of housing. Raster maps can be drawn in the future by calculating web-based suitability values. In the future study, different evolutionary/hybrid evolutionary algorithms (such as RAND: a random search algorithm, FFGA: Fonseca and Fleming’s multiobjective EA, NPGA: the Niched Pareto Genetic Algorithm, HLGA: Hajela and Lin's weighted-sum based approach, VEGA: the Vector Evaluated Genetic Algorithm, NSGA: the Nondominated Sorting Genetic Algorithm, SOEA: a single-objective evolutionary algorithm using weighted-sum aggregation, and SPEA: the Strength Pareto Evolutionary Algorithm) can be used for housing evaluation [66–73]. With the help of this approach, producers and consumers can invest by specifying their streets or residence by entering their own benchmark values.

Data Availability
The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest
The authors declare that they have no conflicts of interest.

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Supplementary Materials
This section is used for finding the weighting of criteria (factors) by application of Fuzzy DEMATEL and CMA-ES Method. (Supplementary Materials)

References


