Determination of the locational, physical and legal status of parcels using the AHP method and GIS in real estate valuation

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Abstract

Real estate valuation is an important topic that is needed to be studied carefully and, because of that, a lot of subjective criteria have been individualized. The Analytic Hierarchy Process (AHP) method removes subjectivity. In this study AHP, which is one of the Multi-Criteria Decision Analysis (MCDA) methods, was used to reproduce coefficients that would be central to real estate valuation. A region in Selcuklu district in Konya/Turkey was determined as the study area. Ten reconstruction islands were selected in the region. The first weights that were calculated with AHP were appointed in the form of coefficients to the reconstruction islands by using locational factors. To put forward differences of value that result from the physical and legal status of parcels in the islands, the second weights that would be used in determining the value of parcels were derived by considering factors such as their reconstruction status (legal), the location of the parcel and the road status of the parcel (physical) with AHP. At the same time, the weights obtained are integrated into Geographic Information Systems (GIS).

Keywords: Real estate valuation, Analytic Hierarchy Process, Geographic Information Systems.

WIT Transactions on Information and Communication Technologies, Vol 63,
www.witpress.com, ISSN 1743-3517 (on-line)
doi:10.2495/CEEIT140461

1 Introduction

Real estate valuation is the process of assessing a real estate accurately and objectively by considering its properties according to the economical conditions in a specific time. Knowing the value of a real estate will facilitate a lot of process about the real estate. For instance, taxation of real estates, crediting, socialization, zoning regulations, insuring, customizing and even more processes will be easier. In this context, the values of all real estates should be determined [1]. It becomes more and more necessary to make better and more accurate valuations [2].

Real estate valuation processes appear as a chaotic situation which does not have a specific legal basis, far from being scientific and objective and sustained via subjective decisions and judgments, whose control mechanism is conducted through personal perceptions, whose consistency is not inspected and in which equality is not questioned [3].

Multi-Criteria Decision Analysis (MCDA) is applicable in the solution of complex problems. The common branch of MCDA is the Analytic Hierarchy Process (AHP), which helps real estate valuation. AHP is a method, which is helpful in making decisions upon the assessment of the weights of multiple criteria.Wide use of AHP stems mostly from ease of its operation, its flexible structure, and yield of accurate outcomes therefrom. AHP, in the meantime, is far from subjective values, and may be digitalized in consideration of the objective values. "A very strong aspect of the AHP is that the knowledgeable individuals who supplies judgments for the pair-wise comparisons usually also play a prominent role in specifying the hierarchy" [4]. Having been developed by Saaty [18], AHP has been applied in numerous applications. It is applicable especially in the site selection process of the real estate development projects [5–9].

In terms of real estate valuation, on the other hand, use of AHP, TODIM (Tomada de Decisão Interativa e Multicritério), and COPRAS (Complex Proportional Assessment) among MCDAs is found widely within the literature [10–16].

GIS and MCDA can benefit from each other. On the one hand, GIS techniques and procedures have an important role to play in analyzing decision problems. Indeed, GIS is often recognized 'as a decision support system involving the integration of spatially referenced data in a problem solving environment'. On the other hand, MCDA provides a rich collection of techniques and procedures for structuring decision problems, and designing, evaluating and prioritizing alternative decisions [17].

The criteria being grouped under three main titles (location, legal, physical) herein have been mapped in GIS, upon being weighed by expert opinion within AHP system. The thematic map, having been drawn up from the determined field as an outcome of the conducted study, is suggested to constitute the basis for all the applications in which valuation is in question.

2 Method

2.1 Analytic hierarchy process

AHP is a theory of measurement through pairwise comparisons and relies on the judgements of experts to derive priority scales. It is in the meantime among the methods which may be helpful in value estimation. To make a decision in an organised way to generate priorities, we need to decompose the decision into the following steps [18].

1. Define the problem and determine the kind of needed knowledge. *(Problem in this study: Presence of more than one criteria, as being effective on the values of the real estates, different structures of the criteria, and their bases on subjective reasons*).
2. Structure the decision hierarchy from the top with the goal of the decision, then the objectives from a broad perspective, through the intermediate levels (criteria on which subsequent elements depend) to the lowest level (which usually is a set of the alternatives – *location, physical and legal features*).
3. Construct a set of pairwise comparison matrices (1–2). Each element in an upper level is used to compare the elements in the level immediately below with respect to it. *Pairwise Comparison Matrix; (locational features 10X10, legal features 3X3, physical features locational of parcel 2X2 and status of roads 5X5 Pairwise Comparison Matrix.)*

$$A = \left[a_{ij} \right] = \begin{bmatrix} 1 & a_{12} & a_{13} & \dots & a_{1n} \\ 1/a_{12} & 1 & a_{23} & \dots & a_{2n} \\ 1/a_{13} & 1/a_{23} & 1 & \dots & a_{3n} \\ \dots & \dots & \dots & \dots & \dots \\ 1/a_{1n} & 1/a_{2n} & 1/a_{3n} & \dots & 1 \end{bmatrix}_{n \times n} \tag{1}$$

$$a_{ij}^{*} = \frac{a_{ij}}{\sum_{i=1}^{n} a_{ij}} \tag{2}$$

4. Use the priorities obtained from the comparisons to weight the priorities in the level immediately below (3). Do this for every element. Then for each element in the level below add its weighted values and obtain its overall or global priority. Continue this process of weighting and adding until the final priorities of the alternatives in the bottom most level are obtained.

$$w_i = \frac{\sum_{j=1}^{n} a_{ij}^{*}}{n} \tag{3}$$

a_{ij} **:** Matrix elements of the pointed the reconstruction islands

n : Amount of the reconstruction island and criteria

$i, j = 1, 2, 3, ..., n$

The processes above should be applied one-to-one and criteria that are taken in hand should be given scale values according to their degree of importance (Table 1). This decision is made by an expert.

Table 1: The fundamental scale of absolute numbers.

Intensity of Importance	Definition	Explanation
1	Equal Importance	Two activities contribute equally to the objective
3	Moderate importance	Experience and judgment slightly favour one activity over another
5	Strong importance	Experience and judgement strongly favour one activity over another
7	Very strong or demonstrated importance	An activity is favoured very strongly over another; its dominance demonstrated in practice
9	Extreme importance	The evidence favouring one activity over another is of the highest possible order of affirmation
2, 4, 6, 8	Intermediate values	

2.2 Consistency ratio of AHP

In the pairwise comparison method, criteria and alternatives are presented in pairs of one or more referees (e.g. experts or decision makers). It is necessary to evaluate individual alternatives, deriving weights for the criteria, constructing the overall rating of the alternatives and identifying the best one. The matrix of pairwise comparisons $A = \left[a_{ij} \right]$ represents the intensities of the expert's preference between individual pairs of alternatives [19]. Consistency Ratio (CR) is found in order to test the consistency of the comparison matrices. To do this, it is necessary to calculate λ by using the following equations which are taken from [20].

$$D = \left[a_{ij} \right]_{n \times n} \times \left[w_i \right]_{n \times 1} = \left[d_i \right]_{n \times 1} \tag{4}$$

$$E = \frac{d_i}{w_i} \tag{5}$$

$$\lambda = \frac{\sum_{i=1}^{n} E_i}{n} \tag{6}$$

After λ is calculated, Consistency Index (CI) (7) and Consistency Ratio (CR) (8) are calculated.

$$CI = \frac{\lambda - n}{n - 1} \tag{7}$$

$$CR = \frac{CI}{RI} \tag{8}$$

Random Index (RI) is taken according to the number of decision options from Random Index by Saaty [18]. If CR is calculated as $CR \leq 0.10$, the assessment is consistent. However, if CR is calculated as $CR > 0.10$, the assessment is not consistent, and must thus be refreshed.

3 Application

3.1 The study region

The field of study was designated as Yazır Quarter of Selçuklu District of the City of Konya in Turkey. 10 reconstruction islands were identified in the field of study for being in strategic locations as per both locational and social facility conditions (Fig. 1).

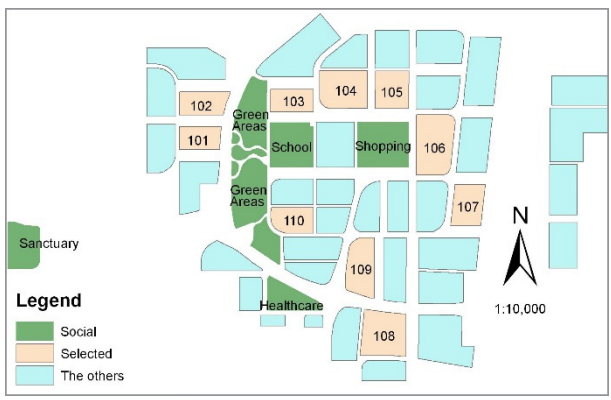

Figure 1: The reconstruction island and criteria.

3.2 Calculations of AHP

Upon the designation of the field of study, the facilities and other criteria, which may affect the values of the real estates in the region, are identified. There are a total of 12 criteria taken into consideration in the region. These criteria are grouped under 3 groups. Groups were weighed in themselves via expert opinion, and within AHP method. Outcomes of the conducted applications were discussed in GIS.

Subcriteria of *location features* is distances to transportation network, healthcare organization, school, sanctuary, green areas, shopping center and busy parts of the city. Subcriteria of *physical features* are location of parcel and road

status of parcel. The location of parcel subcriteria is also corner parcel and break parcel. Status of the road are also 5m–10m, 11m–15m, 16m–20m, 21m–30m and 31m–40m which are width of the roads. *Legal features* are related with status of reconstruction. Status of the reconstruction is BAC- Basement Area Coefficient, FAC – Floor Area Coefficient and areas of parcel (Fig. 2).

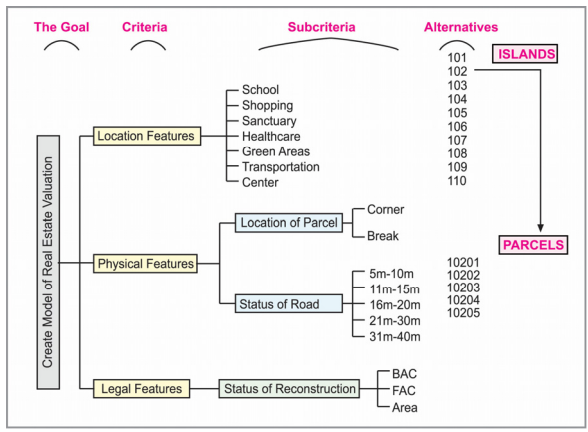

Figure 2: The hierarchical structure of AHP.

The weights of the sub-criteria were calculated as follows:

I. Process: While weights of the islands as per their locational features were found in the work of Ünel and Yalpır (2013) [1], named as "Positional Determination of Real Estates with Analytic Hierarchy Process", and they are as being shown in Table 2.

Table 2: Weights of reconstruction islands.

Reconstruction islands	Weight	Percents
101	0.066	6.6%
102	0.057	5.7%
103	0.068	6.8%
104	0.069	6.9%
105	0.084	8.4%
106	0.124	12.4%
107	0.180	18.0%
108	0.148	14.8%
109	0.094	9.4%
110	0.110	11.0%

Weights of the reconstruction islands were found upon taking their locational features into consideration. Weights of the parcels are to be calculated in consideration of the physical and legal features. Reconstruction parcel is a plot,

which is arranged as ready to be built thereon. How many floors will the building have, what the base area and floor area coefficients (while BAC (Base Area Coefficient) is the coefficient which indicates how many m² of the plot will be utilized as construction area, FAC (Floor Area Coefficient) indicates the total of the construction area) are given in the reconstruction plans.

II. Process: Pairwise Comparison Matrix is created according to Saaty's scale measurements. It was processed as being specified in Equation 3. While the consistency ratio, having been calculated according to n = 2 (RI = 0), is $CR \leq 0.10$, it is consistent for Process I.

Having the weights of each and every criterion with the weights of their sub-criteria, actual weights of the sub-criteria as it is revealed in Table 3.

Table 3: Multiplication of weights.

Criteria	**W_1**	**Subcriteria**	**W_2**	**$W_i = W_1 X W_2$**
Location of parcel	0.333	Break	0.333	0.111
		Corner	0.667	0.222
Status of road	0.667	5m–10m	0.035	0.023
		11m–15m	0.068	0.045
		16m–20m	0.134	0.090
		21m–30m	0.260	0.173
		31m–40m	0.503	0.335

III. Process: Having generated the dual matrices of the criteria required for building structures on the reconstruction parcel, their weights in themselves were thereby calculated (Table 4).

Table 4: Weight of status of reconstruction.

Status of reconstruction	**W**
BAC	0.106
FAC	0.261
Area of Parcel	0.633
Total of columns	**1**

3.3 Integrating AHP and GIS

Upon the addition of the details of the islands, selected locational AHP values of which were specified by making use of the respective island/parcel numbers, thematic map was drawn up by means of these locational values for the islands lacking AHP location points in ArcGIS (Fig. 3).

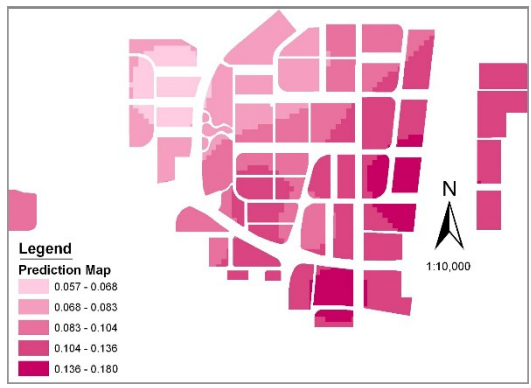

Figure 3: Thematic map of AHP.

The point of the parcel no. 10205 in island no. 102, received from the physical conditions and legal rights of the parcel, are shown in Fig. 4.

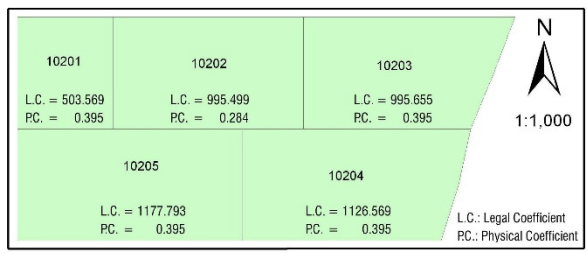

Figure 4: Parcel information in 102.

4 Results and discussion

The issue of real-estate valuation grows in importance with each passing day. Many foreign countries possess bases, which may be called maps of value. Turkey is to draw up a map of value as soon as possible. However, presence of numerous criteria which have impacts on the value, lack of any basis of objective causes, etc., altogether make it difficult to draw up the aforementioned map. What has been intended in this study is to convert all these criteria, which have impacts on the value, into a single coefficient, and to cause these coefficients facilitate the setting of a mathematical model for real estate valuation.

The most important difference from other methods of AHP is to be appraised criterion groups (location, physical and legal) within their own and assign the points to each criterion. Because structures, units, importances and values of subcriteria within criterion groups are be different, the using criteria of weight points calculated by AHP are brought homogeneity in respect to units and values. GIS is a system which develops in parallel with the computer technology, and becomes a part of our daily lives. GIS is necessary for the instant display of all

details of the real estates at a time, and for conducting the analyses thereof. Results of the AHP method, which are applicable for real estate valuation, have been integrated in GIS software, and thematic map has visually been drawn up.

Acknowledgement

This work is supported by the Coordinatorship of Selcuk University's Scientific Research Project (13701574).

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