VALUATIONS OF BUILDING PLOTS USING THE AHP METHOD

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Abstract. Predicting the value of real estate is a complex endeavor due to the abundance of subjective criteria. Objective consideration of the value-affecting criteria in real estate and regulation of decision support systems will enable the acquisition of more accurate results. In this study, analytic hierarchy process (AHP), a type of multi-criteria decision analysis (MCDA), is used to reproduce coefficients that serve as the basis for real estate valuation. A region in the Selcuklu district of Konya, Turkey was used to test the model created by AHP. Weighted criteria describing areas subjected to purchase/sale were generated by the AHP method and then validated. Additionally, a valuation model was created by the multiple regression analysis (MRA) method for comparison and performance analyses. Weighted values were transformed from AHP points and acquired from the MRA method and then joined with geographic information systems (GIS). Value maps of the study area and purchase/sale values were generated according to these newly created models. The performance comparison and value maps revealed that the AHP method is more successful than the MRA method. This study addressed the complexity of criteria issue by using the original hierarchical structure of AHP and thus contributes to the world economy by enabling the generation of more accurate estimations.

Keywords: Real estate valuation, MCDA, decision making, multiple regression analysis (MRA), analytic hierarchy process (AHP), geographic information systems (GIS).

Introduction

Real estate valuation is the process of assessing real estate accurately and objectively through consideration of its properties in accordance with the economic conditions of the time. Knowing the value of real estate facilitates many important related processes, including taxation, crediting, expropriation, zoning regulations, insurance, and customization. Real estate valuation represents a considerably determining factor for countries’ economic health and stability. For these reasons, the value of all real estate properties should be established both effectively and efficiently (Unel & Yalpir, 2013). Due to the increasing economic development of the countries and the increasing complexity of the appraisal problems, it is becoming increasingly necessary to generate more accurate valuations (Aragonés-Beltrán, García-Melón, Aznar, & Guijarro, 2009).

Real estate valuation is often considered to be a disordered, unregulated undertaking that lacks any specific legal foundation and is far from scientific or objective. This is likely due to the fact that this process is based on subjective perceptions that are not subjected to any oversight or inspection toward ensuring their consistency and equality (Yilmaz & Demir, 2011).

The need for mass appraisal systems in real estate valuation is increasing on a daily basis. However, universal valuation standards cannot be created due to the varying conditions of different countries and the lack of an agreed-upon method for property appraisal. Traditional valuation methods (comparison, income, and cost methods) are used in accordance with the real estate type (land and buildings) and characteristics (e.g. area, floor area coefficient). These methods are very suitable for a handful of properties. On the other hand, development methods are commonly used in mass appraisals because they take into account the characteristics of large properties and complex systems in their valuation of region, toward generating an appropriate mathematical model, and then crosscheck the predicted and actual values. Mass appraisal is enabled by modern computing technology and allows for the application of multiple methodologies due to the ever-growing ability to rapidly assessing large amounts of data. MRA has been the main method used for mass appraisal.
of real estate value (Ge & Runeson, 2004; Wilkowski & Budzyński, 2006; Abidoye & Chan, 2017). MRA is widely accepted by both practitioners and academics alike, and therefore remains the most commonly used and most popular approach (Zurada, Levitan, & Guan, 2011). MRA is the method recommended by the Brazilian committee (Brondino & Silva, 1999) and is also used by Northern Ireland to weigh physical and geographic characteristics (Barańska, 2013). Other countries that employ MRA for Computer Assisted Mass Appraisal (CAMA) systems include Australia, Sweden, Tasmania, New Zealand, Hong Kong, USA and Canada (Dimopoulos & Moulas, 2016).

MRA is a simple model function that can be used in the valuation of a variety of property types such as land, residential, and hospitality. MRA is used in hierarchical linear modeling with variables grouped into two hierarchical levels: house and neighbourhood characteristics (Arribas, García, Guijarro, Oliver, & Tamošiūnienė, 2016). Many researchers have begun to focus on comparing the performance of various algorithms (Kisilevich, Keim, & Rokach, 2013; D’Amato, 2010). MRA is often performed in the literature to evaluate artificial intelligence techniques such as Artificial Neural Network (ANN), Fuzzy Logic (FL), Support Vector Machine (SVM), and Support Vector Regression (SVR) (K. C. Lam, Yu, & C. K. Lam, 2009; Kontrimas & Verikas, 2011; Antipov & Pokryshevskaya, 2012). These methods are considered to be advanced techniques in real estate valuation and developed as valuation methods for mass appraisal of real estate property. The dataset is divided and then test the models’ performance (Worzala, Lenk, & Silva, 1995; Mora-Esperanza, 2004; Ozkan, Yalpir, & Uygunol, 2007). ANN outperforms MRA in analyzing data of moderate sample sizes (Nguyen & Cripps, 2001; Lokshina, Hammerslag, & Insinga, 2003). ANN can more aptly predict housing prices in mass appraisals (Selim, 2009; Lin, 2010; Sarac, 2012). Furthermore, a system that combines ANN with GIS was developed for real estate valuation (Garcia, Gamez, & Alfaro, 2008; Liu, Deng, & Wang, 2011).

Fuzzy modeling techniques are generally used to predict the prices of buildings, land, rural areas, and offices (Tepe, 2009; Karimov, 2010; Lughhofer, Trawinski, Trawinski, Kempa, & Lasota, 2011). The fuzzy results indicate that an expansive, enjoyable view could increase the price of a house by up to around 50%, while an unpleasant view could decrease a house’s value by about 25% (Damiagos & Anyfantis, 2011). A study by Nas (2011) found that SVM, one of the machine learning algorithms, is more accurate than both ANN and MRA. Similarly, it has been demonstrated that the market and predicted values are closer when the latter is generated with SVM or SVR compared to MRA (Yalpir & Tezel, 2013). These methods function while the value of the output variable exists. Additionally, a reliable dataset is needed to create a mathematical model using these methods. Models vary depending on the structure of the dataset, the environment in which it exists, and the type of the real estate. Valuation’s subjectivity arises from this variation.

However, the models of valuation include a search for model approaches based on objective criteria. Keeping the number of variables to a minimum is of high importance, especially for mass appraisals. As there may be one common model for more than one real estate property in mass appraisal, common criteria must be included in the model, which is then created in accordance with the used criteria. Estimation values can be reached in extreme situations by the requisite inclusion or exclusion of the results from the mass appraisal.

A very strong aspect of the AHP is that knowledgeable individuals, who usually supply the judgments that inform the pairwise comparisons, also play a prominent role in specifying an analytic hierarchy (Wong & Wu, 2002). Carrying out studies with datasets for valuation estimation has many disadvantages (e.g. incorrect data, failure to reach adequate data on the area or time, and cost problems associated with creating the dataset). So shaping the model through the integration of professional opinion is more advantageous. Multi-criteria decision analysis (MCDA) is an analysis method used for solving complex problems such as making value estimations notwithstanding of a dataset. The real estate valuation process is highly complex because it involves the consideration of many criteria that cannot be measured objectively. AHP, one of the disciplines of MCDA, is a method that facilitates decision making by comparing two or more criteria. The factors responsible for the frequent and continued use of AHP include its flexible structure and ability to provide consistent results (Maliene, 2011; Mulliner, Smallbone, & Maliene, 2013).

MCDA methods reveal relationships between different input variables and create models without output values. Therefore, the results of the weightings performed in collaboration with experts’ opinions constitute the total AHP points of real estate properties when making valuation using the AHP method.

The differences between the AHP method and other valuation methods include:

- Homogenization of the data.
- Evaluation with objective criteria which are used by everyone in the purchase and sale of the market making input from experts.
- Analysis not reliant on a dataset.
- Derivation of value coefficients without using market value.
- Clear expression of variables by grouping the criteria.
- Simplification of the complexity of valuation through reducing criteria.

Geographic information systems (GIS) provide the important function of for storing and analyzing spatial and non-spatial data. This system can be used in applications that involve spatial issues. GIS programs are required to determine real estate values, which represents one of the necessary data sources required to create land information systems and their usage within a given method. GIS and MCDA techniques can be used together for spatial decision problems. GIS and MCDA techniques process the
MCDA is typically used for (but not limited to) weighing cost against quality in many areas including industry, business, government, agriculture, medicine, and real estate. In real estate, one specific application is for industrial site selection, which is achieved by combining GIS and MCDA (Rikalovic, Cosic, & Lazarevic, 2014). In the textile industry, it is used to select the optimum maintenance (such as maintaining an equipment or plant) strategy and best-suited suppliers (Shyjith, Ilangkumaran, & Kumanan, 2008; Supciller & Capraz, 2011). For the construction industry, MCDA is used to make most economic decisions, such as doing an analysis of the available variants and making a proper choice in accordance with qualitative, technical, technological and other characteristics (Kaklauskas, Zavadskas, & Trinkunas, 2007). Also, the appraisal system was designed for residential housing valuation/price estimation by using cognitive maps, a categorical-based evaluation technique (MACBETH) and MCDA (Ferreira et al., 2016).

AHP, TODIM, TOPSIS, and COPRAS are frequently employed in land management decisions, which include real estate valuation, site selection, land use, and site planning. Specifically, AHP is used in land management toward strategically optimizing social livability. It was employed to analyze livability in Tehran by weighing criteria in regards to the fulfillment of biological needs in terms of land use for residential housing, urban infrastructures, sanitation, green spaces, industry, administration, transportation, military, and commercial purposes (Ghasemi, Hamzenejad, & Meshkini, 2018). These are all related to criteria that affect the market value of building plots. In real estate valuation, criteria are always very important for establishing the mathematical model. For example, AHP was used to assess how the quality of the building, location, and neighborhood affected housing prices in Malaysia (Masri, Nawawi, & Sipan, 2016). Characteristics affecting office space rentals, a specific type of real estate, were determined using AHP in the Malaysian office property market. In this study, AHP was used to generate a "weightage of importance" score for each characteristic (Safian, Nawawi, & Sipan, 2014).

The accurate valuation of real estate is required to obtain the best estimate for the transaction price of a property. Real estate valuation is achieved using MCDA informed by only two comparable criteria. In a study from Maliene (2011), the relative weight of 28 criteria was calculated with MCDA. The price for a property was estimated from known prices of two specialised properties. A building value was calculated by using ANP weighting ratios of six buildings, which were known property value (Aragonés-Beltrán et al., 2009). Ong and Chew (1996) determined that property prices are affected by many factors: economic, political, social, human and market-related factors. Residential property prices were first level of AHP hierarchy; second level was demand and supply; third and fourth levels were also their subcriteria. Bender, Din, Favarger, Hoelsli, and Laakso (1997) gained a better understanding of the characteristics related to the
environment of single-family houses. AHP method was performed with eight criteria by applying a questionnaire, which was sent to 850 owners of houses in Geneva, Switzerland. Apart from housing, urban commercial real estate was handled by Bender, Din, Hoesli, and Laakso (1999) and investigated locational attributes of it in the Geneva. Kauko (2002, 2003) also aimed to estimate real estate pricing using the AHP method; this work researched the AHP method substitutability and improvement upon it. A house’s locational (e.g. distance to the central business district and public transportation) and physical (e.g. housing quality) attributes were weighted in combination with expert’s judgments. This revealed that location was more important than the physical attributes of the house. Also, Kryvobokov (2005) applied AHP and direct questionnaire to estimate the weights of the most important location attributes influencing apartment prices. Two questionnaires were used and performed 20 respondents consisted of seven valuers, three realtors, four urban planners, and six land managers. According to experts who answered the first questionnaire, pairwise comparisons matrices of AHP were determined and the weights were calculated. The second questionnaire was directly applied via percentages. It determined that the results vary according to each expert group and distance to the CBD has the highest weight. AHP has been shown effective for mass appraisals in which more properties are valued, rather than a property (Yilmaz, 2010). Sale prices were appraised by calculating housing scores based on 11 criteria using the AHP method (Kavas, 2014). Gomes and Rangel (2009) determined the appropriate intervals for rental real estate values by calculating the relative weights of criteria and alternatives using TODIM. In a study by Ozer (2010), TOPSIS was used to establish real estate performance respective of relevant criteria. With New Multiple Criteria, a recently developed type of MCDA has been utilized to investigate how the market value of real estate is related to the price and whether it should be higher or lower. Bisello, Marella, and Grilli (2016) applied SINFONIA Project to develop a spatialized mass appraisal by linking results with GIS. They integrated hedonic price method and AHP to estimate the overall increase in retrofitted buildings value by using location, environmental, propriety and technological characteristics and completed in eight steps.

Farmland appraisals have been created with AHP based on the calculated weights of productivity, soil quality, and access criteria (Bellver & Mellado, 2005). Using more criteria and alternative farms, three models were later generated and compared by suitability index: the simplest network, ANP, and AHP. Unknown price values were estimated from known farm price values. It was proved that ANP model was better than the others (García-Melón, Ferrís-Óñate, Aznar-Bellver, Aragonés-Beltrán, & Poveda-Bautista, 2008). Aznar, Guijarro, and Moreno-Jímenez (2011) illustrated agricultural valuation through combining AHP and Global Programming. Additionally, AHP has been used to determine the location of each landowner in the new blocks in rural area where is the town of Alanozu applied land consolidation project (Cay & Uyan, 2014).

Studies have also presented models for the house selection process and environmental preferences that allow a buyer to evaluate real estate attributes with AHP (Ball & Srinivasan, 1994; Bender, Din, Hoesli, & Brocher, 2000). Parameters regarding homebuyers’ preferences were researched using AHP in a study in Chongqing, China. The Housing Preference Expert System (HPES) developed by AHP was designed to determine the criteria that affect homebuyers’ behavior. Criteria including architecture and structure, facility (such as kitchens), transportation, price, environment, decoration, and property management were thus defined. Based on their relative weight, HPES revealed order of priority that price, environment, and transportation were the most effectual criteria (Wong & Wu, 2002). Kauko (2004) generated preference profiles for actors with different institutional backgrounds using AHP in house price analysis. This study found that AHP was useful because it provides a qualitative—quantitative hybrid method and supplements hedonic modeling. The COPRAS method of MCDA was used to assess the affordability of sustainable housing. The results from three houses and 20 relevant criteria demonstrated that homebuyers’ decisions are mostly based on housing quality, location, and community sustainability (Mulliner et al., 2013).

AHP, developed by Saaty (1980), is also frequently used for site selection as a different study. For example, the site was chosen for a hospital and for the expansion of a limestone quarry using computer software with AHP (Cagrsir, 2005; Dey & Ramcharan, 2008). AHP was used for the best location selection in Chittagong city area, Bangladesh (Absar, Pathak, & Uddin, 2016). In addition, a hybrid approach that combines the fuzzy analytical hierarchy process (FAHP) with GIS was used to determine the optimum site selection of a new hospital in the urban area of Tehran. In this application, GIS was used to calculate and classify governing criteria while FAHP was used to evaluate the deciding factors and their impact on alternative sites (Vahidnia, Alesheikh, & Alimohammadi, 2009). In Shenzhen, the fuzzy mathematics approach was used to build a spatial weight matrix. Ten experts were selected to implement the AHP in order to determine the weights of each variable for the commercial properties (Zhang, Du, Geng, Liu, & Huang, 2015).

The use of the AHP method for real estate valuation has been reported in the in the mentioned studies. AHP evaluates the subjectivity of real estate valuation in combination with expert’s judgments. The AHP method is preferred for this application because it allows criteria classification to be structured hierarchically and it performs stepwise transactions when comparing two criteria in the decision-making process and calculating their weight. In the examples from the literature, the number of real estate-producing solutions is too low for model validation and mass appraisal. Therefore, a model that can be adapted to mass appraisal is put forth by this study that considers more than one model. In this study, AHP points are
identified that correspond to real estate values. The AHP method enables multiple criteria of real estate reaching its AHP values by transformation into numbers.

2. Methods

2.1. Analytic hierarchy process (AHP)

AHP is a method of measurement through pairwise comparisons that incorporates the judgments of experts in deriving priority scales. To make a decision in an organized way necessitates generating priorities; we need to deconstruct the decision into the following steps (Saaty, 2008):

1. Define the problem and determine the kind of knowledge needed. In this study: Determining and weighing the value-affecting criteria for parcel value estimation.

2. Structure the decision hierarchically from the highest level (goal of the decision and objectives from a broad perspective) to the intermediate level (criteria on which the top elements depend) and finally the lowest level (usually a set of alternatives). In the intermediate level of this study: the major categories of the criteria are Location, physical, and legal features. In addition, there are also subcriteria of the features.

3. Construct a set of pairwise comparison matrices (Equations 1 and 2). Each criterion is compared with the other criterion within its group. In this study, Pairwise Comparison Matrix: legal features (3×3), location features (7×7), physical features of parcel status (2×2) and road status (6×6).

\[
A = \begin{bmatrix}
1 & a_{12} & a_{13} & \ldots & a_{1n} \\
1/a_{12} & 1 & a_{23} & \ldots & a_{2n} \\
1/a_{13} & 1/a_{23} & 1 & \ldots & a_{3n} \\
\vdots & \vdots & \vdots & \ddots & \vdots \\
a_{1n} & 1/a_{2n} & 1/a_{3n} & \ldots & 1
\end{bmatrix}
\]

(1)

\[
a_{ij}^* = \frac{a_{ij}}{\sum_{i=1}^{n} a_{ij}}.
\]

(2)

4. Use the priorities obtained from the comparisons to weight the priorities in the level immediately below it for each element. Then, for each element, add its weighted values and obtain its overall priority. Continue this process of weighting and adding until the final priorities of the alternatives in the bottommost level are obtained.

\[
w_j = \frac{n}{\sum_{j=1}^{n} a_{ij}},
\]

where: \(a_{ij}\) – matrix elements of the pointed \((i,j)\); \(n\) – amount of criteria.

The processes described above should be applied and criteria that are taken into consideration should be assigned scale values in accordance with their degree of importance (Table 1). This decision is made either by an expert or in accordance with the results of the questionnaire. In this study, the decisions were given by experts who have been working as real estate appraisers in public institutions, professional organizations and private sector in Turkey. These consists of fifteen experts; three academists (Ac1-3), three members of the appraisal committee (Mb1-3), three different professions (Prf1-3), three valuators (Vlt1-3) and three realtors (Rlt1-3). The experts had made pairwise comparisons of criteria through survey by considering their effect on real estate value according to their observation and experience. If a pairwise comparison matrix of one of experts is inconsistent, the related survey was removed without evaluation and disabled in all processes.

2.1.1. Consistency ratio of AHP

With the pairwise comparison method, criteria and alternatives are paired with one or more referees (i.e. experts or decision makers). It is necessary to evaluate individual alternatives, derive weights for the criteria, construct the overall rating of the alternatives, and then identify the best one.

The matrix of pairwise comparisons \(A = \begin{bmatrix} a_{ij} \end{bmatrix}\) represents the intensities of the expert’s preferences between individual pairs of alternatives (Alonso & Lamata, 2006). The consistency ratio (CR) is determined in order to test

<table>
<thead>
<tr>
<th>Intensity of Importance</th>
<th>Definition</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Equal importance</td>
<td>Two activities contribute equally to the objective</td>
</tr>
<tr>
<td>2</td>
<td>Weak or slight</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Moderate importance</td>
<td>Experience and judgement slightly favour one activity over another</td>
</tr>
<tr>
<td>4</td>
<td>Moderate plus</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Strong importance</td>
<td>Experience and judgement strongly favour one activity over another</td>
</tr>
<tr>
<td>6</td>
<td>Strong plus</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Very strong or demonstrated importance</td>
<td>An activity is favoured very strongly over another; its dominance demonstrated in practice</td>
</tr>
<tr>
<td>8</td>
<td>Very, very strong</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Extreme importance</td>
<td>The evidence favouring one activity over another is of the highest possible order of affirmation</td>
</tr>
</tbody>
</table>
the consistency of the comparison matrices. Toward this end, it is necessary to calculate $\lambda$ using the following equations: (4), (5), and (6) (Tezcan, 2010).

$$D = [a_{ij}]_{nxn} = [w_i]_{nx1} = [d_i]_{nx1};$$

$$E = \frac{d_i}{w_i};$$

$$\lambda = \sum_{i=1}^{n} E_i \cdot \frac{1}{n}.$$  \hspace{1cm} (6)

After $\lambda$ determination, the consistency index (CI) (Equation 7) and CR (Equation 8) are calculated.

$$CI = \frac{\lambda - n}{n - 1};$$  \hspace{1cm} (7)

$$CR = \frac{CI}{RI};$$  \hspace{1cm} (8)

The random index (RI) is dependent on the number of decision options (see Table 2 from Saaty, 1980). If the $CR \leq 0.10$, the assessment is consistent; otherwise, it must be refreshed.

2.2. Multiple regression analysis (MRA)

The goal of a regression analysis is to obtain estimations of the unknown parameters. There are many factors affecting the valuation of real estate, each of which has a different effect on the value. In the literature, factors affecting the value and number of these criteria vary depending on the region of the study. It is seen in study of Yalpir and Unel (2016) in which the effective factors determined on the land values in academic studies, legislation, and international standards were examined. It has come to the conclusion that multiple criteria should be standardized for mass appraisal. A value estimation that considers multiple criteria can be made using a multiple regression analysis (MRA). In the linear regression model, the dependent variable is assumed to be a linear function of one or more independent variables plus the error introduced to account for all other factors (Equation 9):

$$y_i = \beta_0 + \beta_1x_{i1} + \beta_2x_{i2} + \ldots + \beta_kx_{ik} + u_i,$$  \hspace{1cm} (9)

where: $y_i$ is the dependent variable (in this study: the value of the real estate); $x_{i1}, x_{i2}, \ldots, x_{ik}$ are the independent or explanatory variables (in this study: criteria which affect the value of the real estate); $u_i$ is the disturbance or error term; $\beta_1, \beta_2, \ldots, \beta_k$ – indicate how a change in one of the independent variables (criteria) affects the dependent variable (Sykes, 1992).

3. Application

An application is created to collect accurate, complete, and current data on the properties of the reconstruction parcels to be valued; a $13 \times 250$ matrix of dataset was created using current market values of purchase/sale parcels from the study area. In the application, AHP methodology is developed initially without using the dataset and then verification of the methodology is performed using the data acquired from the area (Figure 1). Performance comparisons are achieved using the MRA method and map integrations are compared using spatial distribution.

3.1. The study region

The Yazir and Sancak neighborhoods and Selcuklu districts, located in the city of Konya, Turkey, are the areas of interests in this study (Figure 2). This represents a rapidly growing area far from the city center and close to Selcuk University, Alaaddin Keykubat Campus. Therefore, it is easy to find parcels of land, which are ready for reconstruction and there is ample purchase/sale activity of building plots. The reconstruction parcels that are close to the industrial area, bus station, and airport are located on the Konya-Afyon highway.

![Figure 1. The process flow diagram](image1)

![Figure 2. The study region in Selcuklu in Konya, Turkey](image2)

<table>
<thead>
<tr>
<th>$n$</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>13</th>
<th>14</th>
<th>15</th>
</tr>
</thead>
<tbody>
<tr>
<td>RI</td>
<td>0.00</td>
<td>0.00</td>
<td>0.58</td>
<td>0.90</td>
<td>1.12</td>
<td>1.24</td>
<td>1.32</td>
<td>1.41</td>
<td>1.45</td>
<td>1.49</td>
<td>1.51</td>
<td>1.48</td>
<td>1.56</td>
<td>1.57</td>
<td>1.59</td>
</tr>
</tbody>
</table>

Table 2. Random index (Saaty, 1980)
In the study region used to create the dataset that determines AHP performance, 250 building plots are subject to sale in 123 of 330 total reconstruction blocks. The study region is in a strategic area due to its location and social facility areas, which include 27 educational areas, 66 shopping areas, 14 sanctuary areas, one hospital and open areas of all sizes designated for sports and green areas (Figure 3). Additionally, the distance to the city center and the transportation network are included in the dataset. The city center comprises the area where the Selçuklu Municipality building is located, in addition to a big shopping and entertainment center, business district, and green area, which are represented as the drawing area. For the transportation network, each tramway station is included. Selected parcels indicate samples with known market values. A map based on all of the selected parcels within walking distance to all of the measured resources was added to the dataset for model verification. Furthermore, the basement area coefficient (BAC) and floor area coefficient (FAC) of the parcel, the position in the block (corner/break), and the wideness of road are incorporated to complete the dataset.

4. Results

A total of 12 criteria describe the area’s social facilities and other parameters that affect the value of building plots. These criteria were gathered into three groups and each group was weighted using the AHP method and experts’ opinions.

Subcriteria of legal features were related to the status of reconstruction. Status of reconstruction represents the BAC, FAC, and parcel area (Area). Location features were the distances to educational areas (Educ.), shopping centers (Shop), sanctuaries (Sanc.), healthcare organizations (Health), green areas (Green), the transportation network (Trans.), and the city center (Cent.). Subcriteria of physical features were the parcel status and the road status of the parcel. The subcriteria of the parcel status (i.e. the position within the reconstruction block) were designated as being either a corner or break. The subcriteria of the road status (i.e. the width of the road on which parcels have sides) was classified according to its width into: 5–10 m, 11–15 m, 16–20 m, 21–30 m, 31–40 m and 41 m and above.

While location features were evaluated on the basis of reconstruction block, legal and physical features were evaluated as parcels. The weights of the main criteria (location, legal, and physical features) are first calculated with the AHP method, then different weights from the subcriteria are found between them. Weights were organized by transferring subcriteria into main criteria groups. The final weights were then multiplied by the values from the normalized dataset to obtain the AHP points.

4.1. Calculations of AHP

The location features of the blocks, the physical and legal features of the parcels, and the weights of the subcriteria were calculated as described below.

I. Process: in the first step, weights of the legal, location and physical features are calculated. So Pairwise Comparison Matrix is created in accordance with the criteria as seen in Table 3. Points are determined by considering the scale dimensions of Saaty in Table 1. Scores of the diagonals of comparison matrices (3x3) are one and the values above the diagonal are given points by considering scale values in accordance with the experts’ opinions. The downside of the diagonal is found by taking the opposite values of upside values of the diagonal.

<table>
<thead>
<tr>
<th>Legal features</th>
<th>Location features</th>
<th>Physical features</th>
</tr>
</thead>
<tbody>
<tr>
<td>Legal features</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Location features</td>
<td>1/2</td>
<td>1</td>
</tr>
<tr>
<td>Physical features</td>
<td>1/7</td>
<td>1/9</td>
</tr>
<tr>
<td>Total of columns</td>
<td>1.643</td>
<td>3.111</td>
</tr>
</tbody>
</table>

Columns are summed in comparison matrix and each line is divided into sum of the column (Equation 2) and line processes are done (Table 4).

The average of the first three columns was used in Equation 3 and calculated weights of Legal, Location and Physical Features are indicated in the last column of the table. From Table 2: N = 3, RI = 0.58 and 0.0871 and CR ≤0.10, which was calculated according to Equations 4 and 8 and confirms that the weight results are consistent.
II. Process: as the reconstruction parcel is the area, which is ready for building construction, there are specific legal restrictions. These criteria foresee the legal conditions of the building; Base Area Coefficient (BAC) and Floor Area Coefficient (FAC). While BAC states the meter square of the ratio of land to be used for building construction, FAC is the coefficient that gives total area of floors of the building. These criteria are given in reconstruction application plans and vary depending on the parcel area. Criteria group weights, which are also stated as “Status of Reconstruction,” are indicated in Table 5.

Table 5. Weight of status of reconstruction

<table>
<thead>
<tr>
<th>CR = 0.0320</th>
<th>W₂</th>
</tr>
</thead>
<tbody>
<tr>
<td>BAC</td>
<td>0.055</td>
</tr>
<tr>
<td>FAC</td>
<td>0.358</td>
</tr>
<tr>
<td>Parcel area</td>
<td>0.587</td>
</tr>
<tr>
<td>Total of columns</td>
<td>1.000</td>
</tr>
</tbody>
</table>

III. Process: location features; education areas, shopping areas, sanctuaries, healthcare, green areas, transportation stations and distance to Selcuklu Municipality, which is the mobility center. Walking distance from reconstruction parcels to these criteria is taken into account. Location features of the study area are weighted in accordance with the effect of the blocks. The AHP weights are shown in Table 6 by applying the same form operation sequences used in Process I.

IV. Process: physical properties are divided into two as the parcel status and the road status and put into the consistency test in comparison matrix (Table 7). The parcel status has created subcriteria in accordance with the corner/break parcel, the road status is (5–10 m, 11–15 m, 16–20 m, 21–30 m, 31–40 m and 41 m and above) and weighted accordingly.

V. Process: after calculating main criteria and subcriteria separately, weights of the subcriteria are transformed into weights of the main criteria and weights written in red color in the Figure 4 calculated the weight of each sub-criteria which will be applied in study area.

VI. Process: it was elaborately explained that AHP weights of criteria were calculated according to an expert in I–V Processes. The other experts did pairwise comparison of criteria according to effects on real estate value. In VI. Process mean of weights calculated from opinions of all experts were given. However, responses of two experts (Vlt1 and Rlt1) were removed because their answers were inconsistencies. When creating AHP model, the mean was calculated by the opinions of remaining experts were taken into consideration.

Also, the criteria are arranged by taking into account their effect on the value for consistent of pairwise comparison matrices. Thus, it is more possible that CR is lower than 0.10.

In Correlations Analysis, it was used Pearson Correlation (2-tailed). Correlation with plot value of BAC, FAC, area, shopping centers, the transportation network, the parcel and road status was significant at the p < 0.01 level; education at the p < 0.05 level, but the others criteria were not significant. It was determined that there was a relationship between correlation coefficients (Corr.) and mean

Table 7. Weights of the subcriteria of physical properties

<table>
<thead>
<tr>
<th>Weights: parcel status and road status</th>
<th>Weights of sub-criteria of parcel status</th>
<th>Weights of sub-criteria of road status</th>
</tr>
</thead>
<tbody>
<tr>
<td>CR = 0.0000</td>
<td>W₄</td>
<td>CR = 0.0000</td>
</tr>
<tr>
<td>Parcel status</td>
<td>0.333</td>
<td>Corner</td>
</tr>
<tr>
<td>Road status</td>
<td>0.667</td>
<td>Break</td>
</tr>
<tr>
<td>Total of columns</td>
<td>1.000</td>
<td>Total of columns</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
AHP weights. For example, area which had the highest and significant correlation (0.721, p < 0.01) in Correlations Analysis, was also the highest between mean AHP weight (0.233). FAC was in second important row. While parcel and road status varied rows with a degree, there was not a relationship in the other criteria (Table 8).

VII. Transformation processes of value of the criteria to AHP points: raw data and market values of the 250 reconstruction parcels in the study area were arranged in matrix format. Textual data of “corner/break” criteria were converted into numeric form and descriptive statistics were presented in Table 9. Descriptive statistics have mean,
standard deviation, minimum and maximum. It was determined that the market values changed between 50,000 ₺ and 2,000,000 ₺ and their standard deviation was near their mean. In the modeling, their standard deviation and distribution of the minimal and maximal value range is appropriate for real estate value forecast. According to the corner/break, parcel status was assigned the value (1 and 0.50).

While organizing the dataset, for this study, two approaches are adopted; using AHP weights directly and normalization. AHP weights are used as they are for the parcel status and the road status (Figure 4). Dataset is organized by multiplying BAC and FAC ratios with weight values. Normalization is done for the criteria, which are big of digital value in dataset. As the parcel areas and the market value are very big, it is normalized by being divided to the biggest area and 1,000,000 ₺ respectively. 50 meters distance to education, shopping, sanctuary, healthcare, green areas, transportation stations and Selçuklu Municipality center areas are accepted as the biggest effect on the value and location criteria are normalized by dividing 50 meters to the distances. Criteria scores are reached by multiplying with AHP points in Figure 4.

Total AHP point of each parcel is found by multiplying the weighted criteria and transformed into value. After this process, it is seen that there is a linear relationship between the market conditions and total acquired AHP points (Equation 10). The AHP output is organized in accordance with this equation:

\[ \text{AHP Output} = 4.805 \cdot \text{AHP point} - 1.017. \] (10)

### 4.2. Calculations of MRA

The statistical software (SPSS, 2011) was used for MRA application and modeling results were presented in Table 10. The coefficient of determination (R^2), which originated in the research design of this study and adjusted R^2, which accounts for degrees of freedom according to high values, indicated that the criteria exhibited a strong and linear correlation to the market value. Durbin-Watson Test (1.485) score meant that residuals from MRA were independent.

<table>
<thead>
<tr>
<th>Model</th>
<th>R</th>
<th>R square</th>
<th>Adjusted R square</th>
<th>Std. error of the estimate</th>
<th>Durbin-Watson</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.939</td>
<td>0.882</td>
<td>0.876</td>
<td>0.29016</td>
<td>1.485</td>
</tr>
</tbody>
</table>

The structure of MRA equation (constant, coefficients of criteria, collinearity statistics) is presented in Table 11. It has been found that BAC, road status, education, shopping, sanctuary and green areas did not have a significant contribution to the model (p > 0.05), which may be due to the fact that BAC and FAC were related to each other and walking distances from education, shopping and sanctuary areas to selected parcels were approximately the same. No direct linear relationship between the estimation variables were observed in accordance with the Variance Inflation Factor (VIF) and tolerance statistics. In other words, regression products did not show any the multicollinearity in criteria.

In general sense, heteroscedasticity is a problem frequently seen in real estate valuation (Fletcher, Gallimore, & Mangan, 2000; Limsombunchai, 2004; Selim, 2009; Cingoz, 2010; Tastan, 2012; Chasco, Gallo, & López, 2018). The problem comes from the times of purchase-sale being different and that the value of real estate varies a lot according to the region where the real estate is located and depending on the density of social facility. The heteroscedasticity problem can be solved by choosing a small region where the values do not change to such an extreme degree. The other solution is to reapply MRA. The coefficients of variables are transformed by using methods of logarithmic, hyperbolic, square and square root (Albayrak, 2008) and the new model is thus acquired.

For the results of MRA, it is examined whether or not there is heteroscedasticity in the residuals and whether
or not the residuals normally dispersed. In first MRA application, it was encounter with a heteroscedasticity. The most common functional form recommended for the heteroscedasticity is the semi-logarithmic form (Halvorsen & Palmquist, 1980; Selim, 2009). Therefore, in this study market value was converted natural logarithmic form. This was taken into accountant as dependent variable and MRA model was created. In addition, the second MRA model is checked with the Breusch-Pagan-Godfrey Test for heteroscedasticity. F-statistic is not significant (p > 0.05) and R2 is lower than chi-square that corresponds to number of degrees of freedom (Equation 12) and p > 0.05. As seen from the results, there is not a heteroscedasticity and all was presented in Table 12.

Table 12. Breusch-Pagan-Godfrey test

<table>
<thead>
<tr>
<th>Model</th>
<th>Coefficientsa</th>
<th>Collinearity statistics</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Unstandardized coefficients</td>
<td>t</td>
</tr>
<tr>
<td>1 (Constant)</td>
<td>−3.991</td>
<td>0.273</td>
</tr>
<tr>
<td>BAC</td>
<td>−1.797</td>
<td>1.421</td>
</tr>
<tr>
<td>FAC</td>
<td>1.885</td>
<td>0.109</td>
</tr>
<tr>
<td>Area</td>
<td>3.047</td>
<td>0.127</td>
</tr>
<tr>
<td>Parcel status</td>
<td>8.241</td>
<td>2.381</td>
</tr>
<tr>
<td>Road status</td>
<td>−1.479</td>
<td>2.383</td>
</tr>
<tr>
<td>Education</td>
<td>−0.154</td>
<td>0.152</td>
</tr>
<tr>
<td>Shopping</td>
<td>0.242</td>
<td>0.148</td>
</tr>
<tr>
<td>Sanctuary</td>
<td>0.052</td>
<td>0.162</td>
</tr>
<tr>
<td>Healthcare</td>
<td>−1.287</td>
<td>0.448</td>
</tr>
<tr>
<td>Green areas</td>
<td>0.087</td>
<td>0.101</td>
</tr>
<tr>
<td>Transportation</td>
<td>2.928</td>
<td>0.382</td>
</tr>
<tr>
<td>Center</td>
<td>75.810</td>
<td>19.200</td>
</tr>
</tbody>
</table>

Note: a – dependent variable: Ln (market value).

A mathematical model has been created using coefficients of criteria in order to estimate the market values of real estate. The p-value of the F-statistic is extremely small (p < 0.0001) which means that the model fits the data very well (Equation 11).

\[
\text{Ln(MRA Output)} = -3.991 - 1.797 \cdot \text{BAC} + 1.885 \cdot \text{FAC} + 3.047 \cdot \text{Area} + 8.241 \cdot \text{Parcel Status} - 1.479 \cdot \text{Road Status} - 0.154 \cdot \text{Education} + 0.242 \cdot \text{Shopping} + 0.052 \cdot \text{Sanctuary} - 1.287 \cdot \text{Healthcare} + 0.087 \cdot \text{Green Areas} + 2.928 \cdot \text{Transportation} + 75.810 \cdot \text{Center}.
\]

As it is seen in MRA Output, BAC, road status, education and healthcare criteria have a negative effect while other variables have a positive effect. The variables which have the effect on the model are respectively center, parcel status, area and transportation. It was applied the model to dataset (Equation 11) and MRA Output was reached by making inverse process of ln. Then performance analyses were realized.

4.3. Performance analyses

Outputs acquired from the AHP and MRA methods were compared to market values and R2 (Equation 12), Mean Absolute Percentage Error (MAPE) (Equation 13), and the Root Mean Square Error (RMSE) (Equation 14) were analyzed for performance analysis.

\[
R^2 = 1 - \frac{\sum_{i=1}^{n} (x_p - x_i)^2}{\sum_{i=1}^{n} (x_i - \bar{x})^2}; \quad (12)
\]

\[
\text{MAPE} = \frac{1}{n} \sum_{i=1}^{n} \left| \frac{x_p - x_i}{x_p} \right|; \quad (13)
\]

\[
\text{RMSE} = \sqrt{\frac{1}{n} \sum_{i=1}^{n} (x_p - x_i)^2}. \quad (14)
\]

where: \(x_p\) is the market value; \(x_i\) is the value of the model, \(i = 1, 2, 3, \ldots n\); \(n\) is the total number of the reconstruction parcels in the dataset; \(\bar{x}\) is the mean of the market values.

MAPE shows that predicting value is closer to market value. The lower the MAPE, the more successful the model is. The RMSE value represents the prediction error, for example, the model with less RMSE value is more successful for prediction than the model with higher RMSE. R2 is the power measurement of the dependent variable of the equation obtained from the regression analysis.
Modeling approximation of the AHP and MRA models are contained in Figure 5. AHP output showed a higher approximation to the real estate values with $R^2$ closer to 1 (0.94), which is also supported by lower MAPE and RMSE values. Approximation levels indicated that, despite higher success of AHP, both models can actually be used in real estate valuation.

4.4. Value maps in GIS

GIS is a system that has been developed through computer technology and become a part of the daily life. GIS is necessary to show all information about the real estates and analyze them (Yomralioğlu, 2002). In this study, GIS was used in order to generate value map. The map base of study area, which was on CAD (NetCAD, 2008), was transferred into GIS software (ArcGIS, 2016) as reconstruction parcels and social facility areas. The parcels were related with the dataset in which there are attributes of the parcels (BAC, FAC, area, distances to education, shopping centers, sanctuary, healthcare organization, green areas, transportation network and center, parcel status and road status). Map and dataset were matched by using block/parcel numbers. The other words, the parcels and dataset were joined with the aid of block/parcel numbers. Market values of the parcels and AHP and MRA outputs were added to the dataset in the software. Different prediction maps were generated for market value, AHP and MRA outputs. Thus, all the parcel values were positionally distributed on the value maps. The maps were utilized for both comparison of the models and information on parcel values (Figure 6).

Discussion and conclusions

The importance of real estate valuation increases daily. While some of the developed countries have a base that can be considered as a value map, these studies are lacking for developing countries such as Turkey. It is necessary for Turkey to produce a value map as soon as possible but these remains difficult as there are a lot of non-objective criteria that determine the value. The aim of this study is to transform criteria that affect the value of real estate into a single coefficient and to prove that the coefficient is helping while the mathematical model creates the real estate valuation.

In Konya, Turkey, the dataset consisted of the legal, location, and physical features of 250 samples. These features included as independent variables, BAC, FAC, area, distances to education, shopping centers, sanctuary, healthcare organization, park areas, transportation network and center, parcel status, and road status. In addition, the dependent variable was the value of the parcel. After the dataset, which had $13 \times 250$ matrix size, was transformed to analysis format by making it numeric and normalizing, AHP and MRA were applied.

Among advanced real estate valuation methods, AHP is different because it can assign points to each other and assess criteria groups (location, physical, and legal) affecting the value within themselves. As the structures, units, importance, and values of subcriteria within criteria groups are different from each other, weight points calculated by AHP provide homogeneity with respect to units and their effect on value. For example, BAC and FAC are coefficients, while area of the reconstruction parcel is in square meters. While distance is denominated as meter,
corner/break parcel are qualitative concepts and there is no denomination for them. AHP method removes all these unit non-conformities and qualitative concepts convert to quantitative concepts with it. It is impossible that many criteria are evaluated at the same time. AHP processes are more comfortable realized because of pairwise assessment. It is a disadvantage of this method that AHP is a process decided only with expert judgment. It is especially difficult to decide between criteria that have similar importance. Therefore, the expert should have information about real estate, criteria, valuation, market value, and mass appraisal. AHP has a very different structure according to the other advanced methods such as ANN, FL, SVM, and SVR. AHP includes weights and hierarchy of criteria. There is input and output from a dataset in the others and no need for the expert judgment. AHP is independent from market value when MRA and the other methods consist of it. Consequently, MRA can give dependent results based only the value, as it cannot take into account in-group evaluation between legal, location, and physical features.

MRA and AHP consist of different model structures of the same criteria under equal conditions. Namely, the criteria and the number thereof are fixed in both models. The values of the parcels are predicted with the MRA and AHP models. Performance analyses are applied and statistically checked by the models. Although it is successful in results of $R^2$, for MAPE and RMSE, which are statistically demonstrated with the Breusch-Pagan-Godfrey Test. In addition the results of the Durbin-Watson test, collinearity statistics, and performance analyses were suitably found for second MRA.

It clearly seemed that the independent variables explained approximately 90% of the dependent variable in both methods. However, error rates of AHP are smaller than MRA. It was determined that success of AHP model results from separately reviews of criteria affecting real estate value in the study region. In all of the results, it is seen the AHP method performed better than the MRA method.

When criteria were arranged according to correlation coefficients and AHP weights, it was seen that area and FAC in legal features had the highest value and first line in both. Physical features showed similarity with one line difference. It was determined that last five lines had some criteria related location features in both.

The value of real estate is affected by many criteria; therefore it is difficult to determine important criteria and weight them. The criteria vary from country to country, from region to region and from person to person. In AHP, the process of real estate valuation starts with comparison of criteria and then obtains the mathematical model. It was determined that the criteria become different between experts in the survey applied for weight of AHP. Pairwise comparisons matrices which are applied by 15 experts who are from different branches of different professions are hard and time-consuming. AHP weights become a homogeneous state by blending survey data because of the fact that the experts are in different opinion on real estate valuation. In beginning of valuation process, AHP method may be an exhaustive process, but this process will only be performed once. In addition, the experts are tested with consistency ratio and unconsistecy decision is removed from AHP process. In other words, AHP requires too much elaborate information from each expert, and this may also lead to inconsistencies in making decision. To avoid this, the ranking of the criteria should be done according to affect on real estate value within each group. Handling of criteria in the form of a hierarchy by starting from the upper roof structure, cause produce of more meaningful results by being standardized within criteria themselves. Since total AHP point belonging to plot also reflects plot value, it can be reached from model to value in another time zone. It will be possible to achieve the value change coefficients in current conditions with much faster and at lower cost. MRA model is dependent on market value; for this reason, it needs that market data are again gathered for another time zone. There will be a requirement to constantly renew or update it in order to create data set in different time periods.

AHP as mass appraisal method may be used for modelling in real estate market where criteria are not extreme intense. It is also recommended using AHP in the other regions after criterion reduction is made. AHP easily and simply solves problems in complex decision making which involve many criteria.

GIS has an important role of relating location to value in mass appraisal. Outputs of AHP and MRA, which are used for real estate valuation, are joined with parcels in the GIS software and their comparisons are done by creating visual prediction maps. It is seen that the most successful output, which is the closest to the value map, is the map that is created by the value acquired from AHP, which gives closer output than MRA.

This study revealed that the AHP method is a good assistive method for creating a model of real estate valuation. The study shows that the hierarchical structure of AHP is original because it is the first application within the literature and AHP output is more successful than MRA output when validating the model. The other methods (ANN, FL, SVM, SVR, and MRA) used in mass appraisal will be difficult in terms of time and cost for creating the model and the required dataset. Therefore, it seems
that AHP is a quickly method than the other methods in model validation phase. Apart from the hierarchical structure of the AHP, weights are determined according to expert judgements. The model's success has been high because of opinions based on real estate value of the experts who scored the study. It is recommended that AHP can be carried out hybrid as fuzzy AHP. It will be able to be used in a multitude of processes including expropriation, taxation, insurance, privatization, planning, land use, land readjustment, land administration and management, and valuation and it will serve as a base for the use of value maps created by GIS integration.

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