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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 charateristics 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

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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 to train 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; Lughofer, 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% (Damigos & 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 data and provide information to aid with decision making, illustrating how GIS and MCDA can benefit from each other (Malczewski, 1999; Ozturk & Batuk, 2011). GIS are often recognized 'as a decision support system involving the integration of spatially referenced data in a problem-solving environment' (Cowen, 1988) and plays important role in decision- making. MCDA provides a rich collection of techniques for structuring decisions in addition to designing, evaluating, and prioritizing alternative solutions in GIS (Malczewski, 2006). As applied to real estate valuation, MCDA may improve price estimation accuracy (Ferreira, Spahr, & Sunderman, 2016).

In this study, a real estate valuation model was fictionalized using objective criteria with the AHP method of developing a novel valuation method for mass appraisal. In this fictionalized model, a value coefficient is generated that replaces the concept of price. Since AHP is a new method, it requires value transformation in order to be compared with market values. Hence, value points produced by AHP are transformed into values and compared to market equivalents; performance analyses are executed with the MRA method, which is well established in the literature.

In this study, criteria are collected under three major categories which are location, legal, and physical features; and subcriteria of the features are weighted using experts' opinions in the AHP system. Value-affecting criteria are assigned a weight for real estate valuation in AHP and the related mathematical model is then created. Value responses based on the acquired weights of the real estate in the area of interest that are obtained using AHP methodology are compared to the purchases and sales in actual market conditions. Additionally, performance analyses are conducting using a model created by the MRA method with the data gathered from the area of interest. Market values, AHP and MRA outputs are mapped in GIS and the accuracy of the AHP and MRA models is validated using maps.

1. Multi-criteria decision analysis (MCDA) in literature

Decision analysis is defined as a systematic, quantitative, and interactive approach to finding solutions for complex problems and usually involves mathematical models and statistical scrutiny (Malczewski, 1999). MCDA is a type of decision analysis that specifically involves two or more conflicting criteria. Examples of MCDA methods include (Yilmaz, 2010; Mulliner et al., 2013):

- Weighted sum method (WSM).
- Weighted multiplying method (WMM).
- Analytical hierarchy process (AHP).
- Analytical network process (ANP).
- Elimination and choice expressing REality (ELECTRE).
- Interactive and multi-criteria decision making (TODIM).
- Technique for order of preference by similarity to ideal solution (TOPSIS).
- Complex proportional assessment (COPRAS).

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, TOPSİS, 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, Hoesli, 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 valuated, 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-Oñate, Aznar-Bellver, Aragonés-Beltrán, & Poveda-Bautista, 2008). Aznar, Guijarro, and Moreno-Jiménez (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 (Cagsir, 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).*

$$A = \left[a_{ij}\right] = \begin{bmatrix} 1 & a_{12} & a_{13} & \dots & a_{1n} \\ 1/a_{12} & 1 & a_{23} & \dots & a_{2n} \\ 1/a_{13} & 1/a_{23} & 1 & \dots & a_{3n} \\ \dots & \dots & \dots & \dots & \dots \\ 1/a_{1n} & 1/a_{2n} & 1/a_{3n} & \dots & 1 \end{bmatrix}_{nxn}; \quad (1)$$

$$a_{ij}^{*} = \frac{a_{ij}}{\sum_{i=1}^{n} a_{ij}}. \quad (2)$$

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 bottom-most level are obtained.

$$w_i = \frac{\sum_{j=1}^{n} a_{ij}^{*}}{n}, \quad (3)$$

where: a_{ij} – matrix elements of the pointed (i,j = 1,2,3,…n); 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 questionary. 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 (Acd1-3), three members of the appraisal committee (Mmb1-3), 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 $A = \left[a_{ij}\right]$ 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 1. The fundamental scale of absolute numbers (Saaty, 2008)

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

the consistency of the comparison matrices. Toward this end, it is necessary to calculate λ using the following equations: (4), (5), and (6) (Tezcan, 2010).

$$D = \left[a_{ij}\right]_{nxn} \cdot \left[w_i\right]_{nx1} = \left[d_i\right]_{nx1}; \tag{4}$$

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

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

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

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

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

The random index (RI) is dependent on the number of decision options (see Table 2 from Saaty, 1980). If the $CR \le 0.10$, 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):

$$y_i = \beta_0 + \beta_1 x_{i1} + \beta_2 x_{i2} + \ldots + \beta_k x_{ik} + u_i, \tag{9}$$

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 13×250 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.

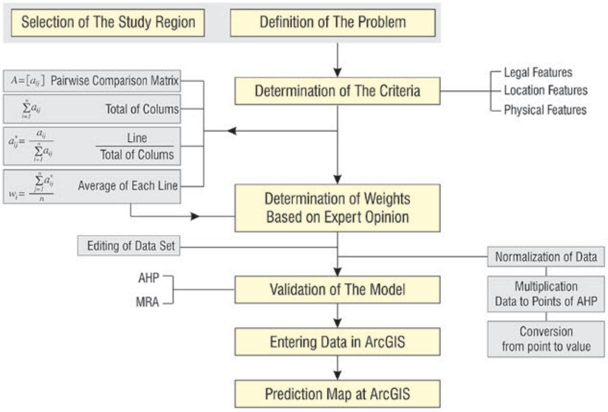

Figure 1. The process flow diagram

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.

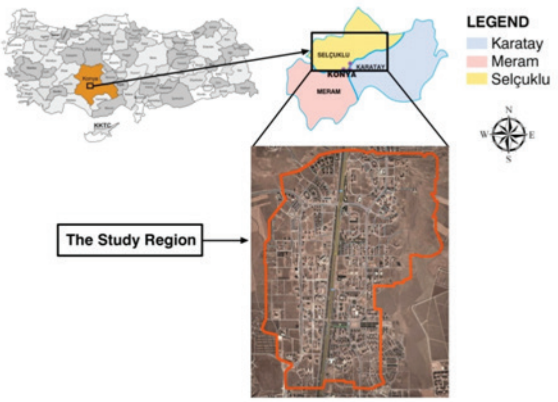

Figure 2. The study region in Selcuklu in Konya, Turkey

Table 2. Random index (Saaty, 1980)

n	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
RI	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49	1.51	1.48	1.56	1.57	1.59

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 Selcuklu 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.

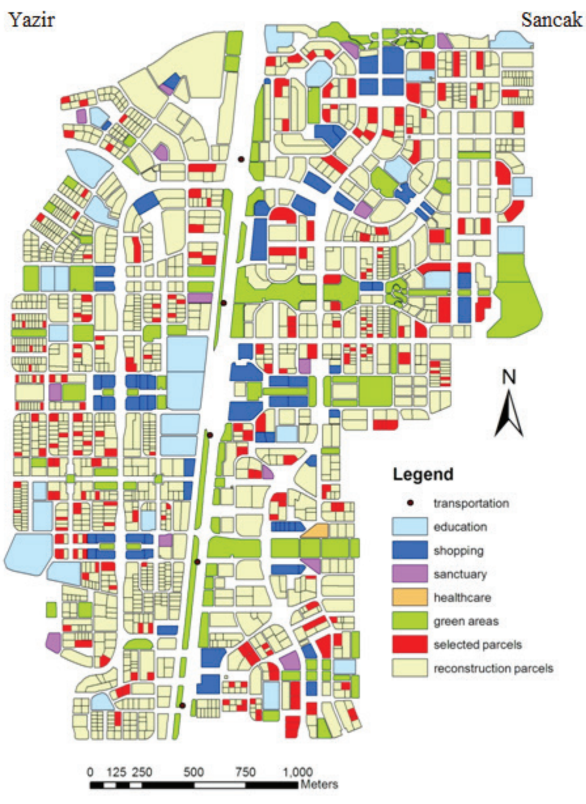

Figure 3. The building plots (reconstruction parcels) and social facility areas

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 (3×3) 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 3. Pairwise comparison matrix of legal, locational and physical features

	Legal features	Location features	Physical features
Legal features	1	2	7
Location features	1/2	1	9
Physical features	1/7	1/9	1
Total of columns	*1.643*	*3.111*	*17.000*

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 $CR \leq 0.10$, which was calculated according to Equations 4 and 8 and confirms that the weight results are consistent.

Table 4. Line processes

CR = 0.0871	Legal features	Location features	Physical features	Weight (W_1)
Legal features	0.609	0.643	0.412	0.554
Location features	0.304	0.321	0.529	0.385
Physical features	0.087	0.036	0.059	0.061
Total of columns	*1.000*	*1.000*	*1.000*	*1.000*

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 of 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

CR = 0.0320	W_2
BAC	0.055
FAC	0.358
Parcel area	0.587
Total of columns	*1.000*

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.

Table 6. Weights of the location features

CR = 0.0378	W_3
Education	0.035
Shopping	0.108
Sanctuary	0.035
Healthcare	0.036
Green areas	0.091
Transportation	0.486
Center	0.209
Total of columns	*1.000*

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 Rlt 1) 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

Weights: parcel status and road status

CR = 0.0000	W_4
Parcel status	0.333
Road status	0.667
Total of columns	*1.000*

Weights of sub-criteria of parcel status

CR = 0.0000	W_5
Corner	0.667
Break	0.333
Total of columns	*1.000*

Weights of sub-criteria of road status

CR = 0.0557	W_6
5–10 m	0.026
11–15 m	0.046
16–20 m	0.085
21–30 m	0.176
31–40 m	0.295
41–over	0.372
Total of columns	*1.000*

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,

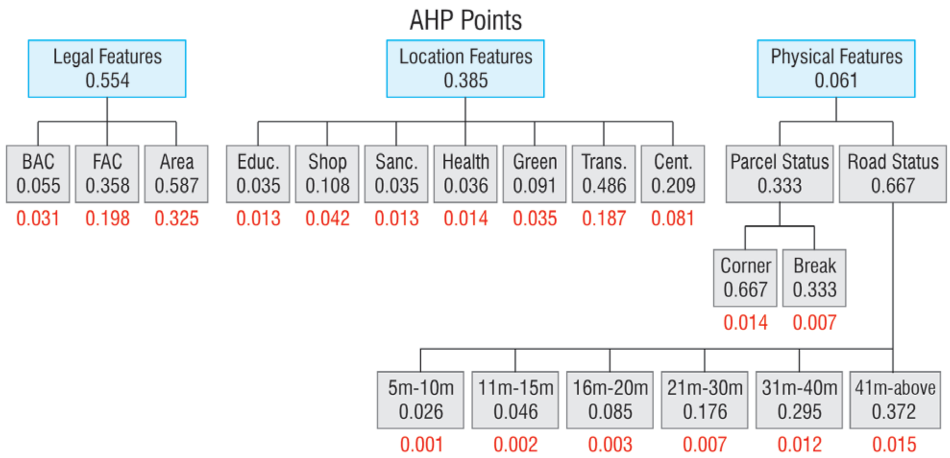

Figure 4. Weights of criteria

Table 8. Mean AHP weights and correlation coefficients

	Acd1	Acd2	Acd3	Mmb1	Mmb2	Mmb3	Prf1	Prf2	Prf3	Vlt1	Vlt2	Vlt3	Rlt1	Rlt2	Rlt3	Mean	Corr.
BAC	0.031	0.067	0.180	0.058	0.127	0.052	0.095	0.035	0.062	0.076	0.119	0.013	0.146	0.072	0.032	0.072	0.254**
FAC	0.198	0.165	0.180	0.288	0.127	0.127	0.173	0.035	0.360	0.210	0.215	0.034	0.077	0.126	0.057	0.160	0.601**
Area	0.325	0.401	0.180	0.288	0.380	0.021	0.313	0.035	0.211	0.348	0.390	0.059	0.410	0.327	0.104	0.233	0.721**
CR	0.032	0.033	0.000	0.000	0.000	0.033	0.008	0.000	0.021	0.260	0.008	0.016	0.003	0.016	0.008		
Educ.	0.013	0.009	0.005	0.009	0.007	0.023	0.045	0.096	0.017	0.022	0.008	0.033	0.004	0.004	0.073	0.026	0.138*
Shop	0.042	0.006	0.029	0.062	0.017	0.101	0.014	0.162	0.037	0.057	0.029	0.099	0.015	0.012	0.042	0.050	0.327**
Sanc.	0.013	0.004	0.004	0.007	0.004	0.039	0.009	0.013	0.006	0.019	0.006	0.017	0.003	0.007	0.028	0.012	0.067
Health	0.014	0.004	0.016	0.013	0.003	0.013	0.065	0.023	0.026	0.006	0.020	0.023	0.007	0.005	0.026	0.019	0.076
Green	0.035	0.029	0.010	0.030	0.010	0.060	0.111	0.041	0.009	0.043	0.013	0.062	0.009	0.023	0.176	0.047	−0.019
Trans.	0.187	0.035	0.063	0.046	0.036	0.213	0.040	0.229	0.108	0.039	0.067	0.222	0.043	0.049	0.246	0.119	0.226**
Cent.	0.081	0.020	0.037	0.094	0.030	0.150	0.025	0.070	0.057	0.075	0.051	0.177	0.026	0.040	0.133	0.074	0.114
CR	0.038	0.062	0.063	0.045	0.049	0.054	0.084	0.057	0.093	0.236	0.042	0.046	0.135	0.046	0.070		
Corner	0.014	0.049	0.066	0.035	0.147	0.033	0.027	0.116	0.024	0.018	0.028	0.116	0.058	0.185	0.019	0.066	0.340**
Break	0.007	0.016	0.033	0.018	0.049	0.017	0.009	0.058	0.012	0.009	0.014	0.058	0.029	0.037	0.009	0.026	
CR	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000		
5–10 m	0.001	0.007	0.008	0.002	0.002	0.006	0.002	0.004	0.002	0.003	0.002	0.003	0.005	0.004	0.003	0.003	0.431**
11–15 m	0.002	0.011	0.011	0.002	0.004	0.010	0.004	0.006	0.003	0.005	0.002	0.004	0.009	0.007	0.005	0.005	
16–20 m	0.003	0.018	0.019	0.005	0.006	0.015	0.005	0.009	0.007	0.007	0.003	0.006	0.016	0.016	0.007	0.009	
21–30 m	0.007	0.030	0.033	0.009	0.010	0.025	0.010	0.014	0.011	0.016	0.007	0.012	0.031	0.031	0.013	0.016	
31–40 m	0.012	0.046	0.051	0.014	0.017	0.038	0.018	0.033	0.016	0.034	0.011	0.022	0.046	0.047	0.019	0.026	
41–abv	0.015	0.082	0.076	0.021	0.027	0.057	0.034	0.022	0.031	0.016	0.017	0.040	0.068	0.007	0.009	0.034	
CR	0.056	0.012	0.018	0.042	0.009	0.016	0.046	0.020	0.035	0.025	0.029	0.044	0.044	0.034	0.097	Total = 1	

Note: ** Correlation is significant at the 0.01 level (2-tailed); * Correlation is significant at the 0.05 level (2-tailed).

Table 9. Descriptive statistics of the dataset

Criteria	Units of measurement	Mean	Standard deviation	Minimum	Maximum
Market value	₺	455,112	387,217.62	50,000	2,000,000
BAC	Ratio	0.26	0.02	0.20	0.30
FAC	Ratio	0.78	0.25	0.40	1.75
Area	Square meter	1,628.64	1,336.23	465.46	7,696.46
Corner/break	Text	0.80	0.25	0.50	1.00
Road status	Meter	16.62	11.98	3	100
Education	Meter	270.10	135.79	61	690
Shopping	Meter	219.03	110.17	62	608
Sanctuary	Meter	313.58	143.17	74	745
Healthcare	Meter	1,246.95	515.91	139	2,382
Green areas	Meter	157.92	69.68	37	368
Transportation	Meter	633.57	265.34	161	1,367
Center	Meter	5,513.95	870.35	4,002	7,252

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 Selcuklu 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:

$$AHP\,Output = 4.805 \cdot AHP\ point - 1.017. \tag{10}$$

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 10. Summary of the MRA model

Model	R	R square	Adjusted R square	Std. error of the estimate	Durbin-Watson
1	0.939	0.882	0.876	0.29016	1.485

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

Table 11. Coefficients of the MRA model

Coefficients[a]							
Model		Unstandardized coefficients		t	Sig.	Collinearity statistics	
		B	Std. Error			Tolerance	VIF
1	(Constant)	–3.991	0.273	–14.626	0.000		
	BAC	–1.797	1.421	–1.265	0.207	0.376	2.661
	FAC	1.885	0.109	17.335	0.000	0.445	2.246
	Area	3.047	0.127	23.935	0.000	0.692	1.444
	Parcel status	8.241	2.381	3.462	0.001	0.851	1.175
	Road status	–1.479	2.383	–0.621	0.535	0.786	1.273
	Education	–0.154	0.152	–1.014	0.312	0.790	1.266
	Shopping	0.242	0.148	1.629	0.105	0.840	1.190
	Sanctuary	0.052	0.162	0.324	0.746	0.893	1.119
	Healthcare	–1.287	0.448	–2.871	0.004	0.709	1.410
	Green areas	0.087	0.101	0.860	0.391	0.910	1.099
	Transportation	2.928	0.382	7.660	0.000	0.800	1.250
	Center	75.810	19.200	3.948	0.000	0.399	2.508

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

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 R^2 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

Heteroscedasticity test: Breusch-Pagan-Godfrey		
F-statistic	1.514	0.120
nR^2	17.750	Chi-Square (12)

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).

$$Ln\left(MRA\,Output\right) = -3.991 - 1.797 \cdot BAC + 1.885 \cdot FAC + 3.047 \cdot Area + 8.241 \cdot Parcel\,Status - 1.479 \cdot Road\,Status - 0.154 \cdot Education + 0.242 \cdot Shopping + 0.052 \cdot Sanctuary - 1.287 \cdot Healthcare + 0.087 \cdot Green\,Areas + 2.928 \cdot Transportation + 75.810 \cdot Center. \quad (11)$$

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 R^2 (Equation 12), Mean Absolute Percentage Error (MAPE) (Equation 13), and the Root Mean Square Error (RMSE) (Equation 14) were analyzed for performance analysis.

$$R^2 = 1 - \frac{\sum_{i=1}^{n}\left(x_p - x_i\right)^2}{\sum_{i=1}^{n}\left(x_i - \overline{x}\right)^2}; \quad (12)$$

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

$$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}\left(x_p - x_i\right)^2}\,. \quad (14)$$

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; $\overline{x}$ 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. R^2 is the power measurement of the dependent variable of the equation obtained from the regression analysis.

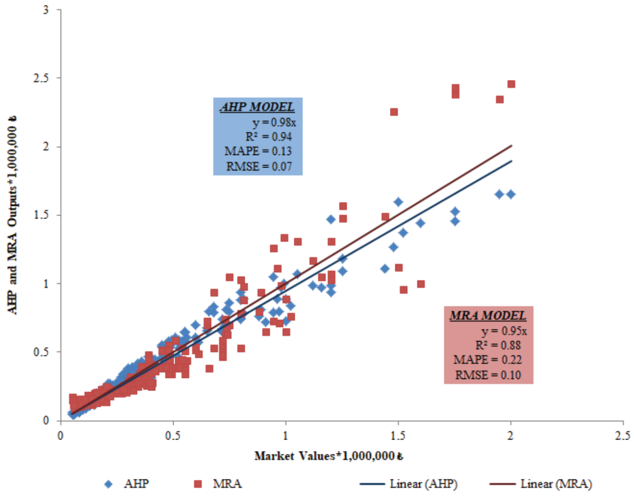

Figure 5. Model approximation of AHP and MRA models

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 (Yomralıoglu, 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).

Figure 6. Prediction maps of (a) market value, (b) AHP, and (c) MRA outputs

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 13×250 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 calculated using the residuals of the MRA model, heteroscedasticity is present in the residuals. In the literature, heteroscedasticity is a problem that is generally encountered in regression models that predict real estate values. A disadvantage of MRA is the need to repeat the processes due to heteroscedasticity and there are many control tests. In the study, most of control tests were confirmed, but MRA was applied two times because of heteroscedasticity. Firstly, it was made with normally criteria; secondly to remove heteroscedasticity it was performed by taking into accountant natural logarithmic of market value and 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.

References

Abidoye, R. B., & Chan, A. P. C. (2017). Valuers' receptiveness to the application of artificial intelligence in property valuation. *Pacific Rim Property Research Journal*, *23*(2), 175-193. https://doi.org/10.1080/14445921.2017.1299453

Absar, N., Pathak, A., & Uddin, M. A. (2016). Multi-Criteria analysis for the best location selection in Chittagong city area, Bangladesh. *International Journal of Computer Applications*, *143*(8), 10-18. https://doi.org/10.5120/ijca2016910030

Albayrak, A. S. (2008). Weighted regression analysis alternative to the least squares technique in the presence of none constant variance and an application. *Afyon Kocatepe University, Journal of Economics and Administrative Sciences*, *X*(II), 111-134.

Alonso, J. A., & Lamata, M. T. (2006). Consistency in the analytic hierarchy process: a new approach. *International Journal of Uncertainty, Fuzziness and Knowledge-Based Systems*, *14*(4), 445-459. https://doi.org/10.1142/S0218488506004114

Antipov, E. A., & Pokryshevskaya, E. B. (2012). Mass appraisal of residential apartments: an application of random forest for valuation and a CART-based approach for model diagnostics. *Expert Systems with Applications*, *39*, 1772-1778. https://doi.org/10.1016/j.eswa.2011.08.077

Aragonés-Beltrán, P., García-Melón, M., Aznar, J., & Guijarro, F. (2009). Asset appraisal method based on the analytic network process. In *XIII International Conference on Engineering Projects*. Badajoz.

ArcGIS. (2016). *Environmental Systems Research Institute (ESRI) Inc.* (version 10.4.1). Trademark, Redlands, California, USA.

Arribas, I., García, F., Guijarro, F., Oliver, J., & Tamošiūnienė, R. (2016). Mass appraisal of residential real estate using multilevel modelling. *International Journal of Strategic Property Management*, *20*(1), 77-87. https://doi.org/10.3846/1648715X.2015.1134702

Aznar, J., Guijarro, F., & Moreno-Jiménez, J. M. (2011). Mixed valuation methods: a combined AHP-GP procedure for individual and group multicriteria agricultural valuation. *Annals of Operations Research*, *190*, 221-238. https://doi.org/10.1007/s10479-009-0527-2

Ball, J., & Srinivasan, V. C. (1994). Using the analytic hierarchy process in house selection. *Journal of Real Estate Finance and Economics*, *9*, 69-85. https://doi.org/10.1007/BF01153589

Barańska, A. (2013). Real estate mass appraisal in selected countries–functioning systems and proposed solutions. *Real Estate Management and Valuation*, *21*(3), 35-42. https://doi.org/10.2478/remav-2013-0024

Bellver, J. A., & Mellado, V. C. (2005). An application of the analytic hierarchy process method in farmland appraisal. *Spanish Journal of Agricultural Research*, *3*(1), 17-24. https://doi.org/10.5424/sjar/2005031-120

Bender, A., Din, A., Favarger, P., Hoesli, M., & Laakso, J. (1997). An analysis of perceptions concerning the environmental quality of housing in Geneva. *Urban Studies*, *34*(3), 503-513. https://doi.org/10.1080/0042098976104

Bender, A., Din, A., Hoesli, M., & Laakso, J. (1999). Environmental quality perceptions of urban commercial real estate. *Journal of Property Investment & Finance*, *17*(3), 280-296. https://doi.org/10.1108/14635789910270521

Bender, A., Din, A., Hoesli, M., & Brocher, S. (2000). Environmental preferences of home-owners: further evidence using the AHP method. *Journal of Property Investment and Finance*, *18*(4), 445-455. https://doi.org/10.1108/14635780010345391

Bisello, A., Marella, G., & Grilli, G. (2016). SINFONIA project mass appraisal: beyond the value of energy performance in buildings. *Procedia-Social and Behavioral Sciences*, *223*, 37-44. https://doi.org/10.1016/j.sbspro.2016.05.285

Brondino, N. C. M., & Silva, A. N. R. (1999). Combining artificial neural networks and GIS for land valuation purposes. In *Computers in Urban Planning and Manegement*. Venice, Italy.

Cagsir, H. (2005). *GIS based multiple criteria decision support system for urban planning problems in Gaziantep* (Ms Thesis). Gaziantep University, Industrial Engineering, Gaziantep, Turkey.

Cay, T., & Uyan, M. (2014). Evaluation of reallocation criteria in land consolidation studies using the analytic hierarchy process (AHP). *Land Use Policy*, *30*, 541-548. https://doi.org/10.1016/j.landusepol.2012.04.023

Chasco, C., Gallo, J. L., & López, F. A. (2018). A scan test for spatial groupwise heteroscedasticity in cross-sectional models with an application on houses prices in Madrid. *Regional Science and Urban Economics*, *68*, 226-238. https://doi.org/10.1016/j.regsciurbeco.2017.10.015

Cingoz, A. R. A. A. (2010). Analysis of residential house prices of gated communities in Istanbul. *Journal of Social Sciences*, *2*, 129-139.

Cowen, D. J. (1988). GIS versus CAD versus DBMS: what are the differences? *Photogrammetric Engineering and Remote Sensing*, *54*(11), 1551-1555.

D'Amato, M. (2010). A location value response surface model for mass appraising: an "Iterative" location adjustment factor in Bari, Italy. *International Journal of Strategic Property Management*, *14*(3), 231-244. https://doi.org/10.3846/ijspm.2010.17

Damigos, D., & Anyfantis, F. (2011). The value of view through the eyes of real estate experts: a fuzzy delphi approach. *Landscape and Urban Planning*, *101*, 171-178. https://doi.org/10.1016/j.landurbplan.2011.02.009

Dey, P. K., & Ramcharan, E. K. (2008). Analytic hierarchy process helps select site for limestone quarry expansion in Barbados. *Journal of Environmental Management*, *88*, 1384-1395. https://doi.org/10.1016/j.jenvman.2007.07.011

Dimopoulos, T., & Moulas, A. (2016). A proposal of a mass appraisal system in Greece with CAMA system: evaluating GWR and MRA techniques in Thessaloniki Municipality. *Open Geosciences*, *8*, 675-693. https://doi.org/10.1515/geo-2016-0064

Ferreira, F. A. F., Spahr, R. W., & Sunderman, M. A. (2016). Using multiple criteria decision analysis (MCDA) to assist in estimating residential housing values. *International Journal of Strategic Property Management*, *20*(4), 354-370. https://doi.org/10.3846/1648715X.2015.1122668

Fletcher, M., Gallimore, P., & Mangan, J. (2000). Heteroscedasticity in hedonic house price models. *Journal of Property Research*, *17*(2), 93-108. https://doi.org/10.1080/095999100367930

Garcia, N., Gamez, M., & Alfaro, E. (2008). ANN+GIS: an automated system for property valuation. *Neurocomputing*, *71*, 733-742. https://doi.org/10.1016/j.neucom.2007.07.031

García-Melón, M., Ferrís-Oñate, J., Aznar-Bellver, J., Aragonés-Beltrán, P., & Poveda-Bautista, R. (2008). Farmland appraisal based on the analytic network process. *Journal of Global Optimization*, *42*, 143-155. https://doi.org/10.1007/s10898-007-9235-0

Ge, X. J., & Runeson, G. (2004). Modeling property prices using neural network model for Hong Kong. *International Real Estate Review*, *7*(1), 121-138.

Ghasemi, K., Hamzenejad, M., & Meshkini, A. (2018). The spatial analysis of the livability of 22 districts of Tehran Metropolis using multi-criteria decision making approaches. *Sustainable Cities and Society*, *38*, 382-404. https://doi.org/10.1016/j.scs.2018.01.018

Gomes, L. F. A. M., & Rangel, L. A. D. (2009). An application of the TODIM method to the multicriteria rental evaluation of residential properties. *European Journal of Operational Research*, *193*(1), 204-211. https://doi.org/10.1016/j.ejor.2007.10.046

Halvorsen, R., & Palmquist, R. (1980). The interpretation of dummy variables in semilogrithmic regressions. *American Economic Review*, *70*, 474-475.

Kaklauskas, A., Zavadskas, E. K., & Trinkunas, V. (2007). A multiple criteria decision support on-line system for construction. *Engineering Applications of Artificial Intelligence*, *20*, 163-175. https://doi.org/10.1016/j.engappai.2006.06.009

Karimov, A. (2010). *Office rent variation in CBD: An application of mamdani and TSK-type fuzzy rule based system* (Ms Thesis). Middle East Technical University, Financial Mathematics, Ankara, Turkey.

Kauko, T. (2002). *Modelling the locational determinants of house prices: neural network and value tree approaches* (PhD Thesis). Utrecht University, Netherlands. https://doi.org/10.1108/14635780310481676

Kauko, T. (2003). Residential property value and locational externalities: on the complementarity and substitutability of approaches. *Journal of Property Investment & Finance*, *21*(3), 250-270. https://doi.org/10.1108/14635780310481676

Kauko, T. (2004). Towards infusing institutions and agency into house price analysis. *Urban Studies*, *41*(8), 1507-1519. https://doi.org/10.1080/0042098042000226975

Kavas, S. (2014). *Multi-criteria decision support model for appraising residential real estates* (Ms Thesis). Istanbul Technical University, Industrial Engineering Department, Istanbul, Turkey.

Kisilevich, S., Keim, D., & Rokach, L. (2013). A GIS-based decision support system for hotel room rate estimation and temporal price prediction: the hotel brokers' context. *Decision Support Systems*, *54*, 1119-1133. https://doi.org/10.1016/j.dss.2012.10.038

Kontrimas, V., & Verikas, A. (2011). The mass appraisal of the real estate by computational intelligence. *Applied Soft Computing*, *11*, 443-448. https://doi.org/10.1016/j.asoc.2009.12.003

Kryvobokov, M. (2005). Estimating the weights of location attributes with the Analytic Hierarchy Process in Donetsk, Ukraine. *Nordic Journal of Surveying and Real Estate Research*, *2*(2), 7-31.

Lam, K. C., Yu, C. Y., & Lam, C. K. (2009). Support vector machine and entropy based decision support system for property valuation. *Journal of Property Research*, *26*(3), 213-233. https://doi.org/10.1080/09599911003669674

Limsombunchai, V. (2004). House price prediction: hedonic price model vs. artificial neural network. In *New Zealand Agricultural and Resource Economics Society (NZARES) Conference*. Blenheim, New Zealand.

Lin, C. C. (2010). *Critical analysis and effectiveness of key parameters in residential property valuations* (PhD Thesis). State University of New York, Department of Civil, Structural, and Environmental Engineering, New York.

Liu, X., Deng, Z., & Wang, T. (2011). Real estate appraisal system based on GIS and BP neural network. *Transactions of Nonferrous Metals Society of China*, *21*, 626-630. https://doi.org/10.1016/S1003-6326(12)61652-5

Lokshina, I. V., Hammerslag, M. D., & Insinga, R. C. (2003). Applications of artificial intelligence methods for real estate valuation and decision support. In *Hawaii International Conference on Business*. Honolulu, Hawaii, USA.

Lughofer, E., Trawinski, B., Trawinski, K., Kempa, O., & Lasota, T. (2011). On employing fuzzy modeling algorithms for the valuation of residential premises. *Information Sciences*, *181*, 5123-5142. https://doi.org/10.1016/j.ins.2011.07.012

Malczewski, J. (1999). *GIS and multicriteria decision analysis*. New York: John Wiley and Sons.

Malczewski, J. (2006). GIS-based multicriteria decision analysis: a survey of the literature. *International Journal of Geographical Information Science*, *20*(7), 703-726. https://doi.org/10.1080/13658810600661508

Maliene, V. (2011). Specialised property valuation: multiple criteria decision analysis. *Journal of Retail & Leisure Property*, *9*, 443-450. https://doi.org/10.1057/rlp.2011.7

Masri, M. H. M., Nawawi, A. H., & Sipan, I. (2016). Review of building, locational, neighbourhood qualities affecting house prices in Malaysia. *Procedia – Social and Behavioral Sciences*, *234*, 452-460. https://doi.org/10.1016/j.sbspro.2016.10.263

Mora-Esperanza, J. G. (2004). Artificial intelligence applied to real estate valuation. *CT-CATASTRO*, 255-265.

Mulliner, E., Smallbone, K., & Maliene, V. (2013). An assessment of sustainable housing affordability using a multiple criteria decision making method. *Omega*, *41*, 270-279. https://doi.org/10.1016/j.omega.2012.05.002

Nas, B. B. (2011). *Development of an approach for real-estate valuation by the methods ANN and AVM* (Ms Thesis). Selcuk University, Electronic and Computer Systems Education Department, Konya, Turkey.

NetCAD. (2008). *National CAD and GIS Solutions Inc.* (version 5.1). Trademark, Ankara, Turkey.

Nguyen, N., & Cripps, A. (2001). Predicting housing value: a comparison of multiple regression analysis and artificial neural networks. *Journal of Real Estate Research*, *22*(3), 313-336.

Ong, S. E., & Chew, T. I. (1996). Singapore residential market: an expert judgemental forecast incorporating the analytical hierarchy process. *Journal of Property Valuation and Investment*, *14*(1), 50-66. https://doi.org/10.1108/14635789610107499

Ozer, M. (2010). *Financial and numerical techniques used in real estate valuation: an application with TOPSIS and new multiple criteria models* (Ms Thesis). Dokuz Eylul University, Department of Economics Money and Banking, Izmir, Turkey.

Ozkan, G., Yalpir, S., & Uygunol, O. (2007). An investigation on the price estimation of residable real-estates by using ANN and regression methods. In *The 12th International Conference on Applied Stochastic Models and Data Analysis*. Chania.

Ozturk, D., & Batuk, F. (2011). Technique for order preference by similarity to ideal solution (TOPSIS) for spatial decision problems. In *Proceedings ISPRS*. Retrieved from http://www.isprs.org/proceedings/2011/Gi4DM/PDF/PP12.pdf

Rikalovic, A., Cosic, I., & Lazarevic, D. (2014). GIS based multicriteria analysis for industrial site selection. *Procedia Engineering*, *69*, 1054-1063. https://doi.org/10.1016/j.proeng.2014.03.090

Saaty, T. L. (1980). *The analytic hierarchy process*. New York: McGraw-Hill.

Saaty, T. L. (2008). Decision making with the analytic hierarchy process. *International Journal of Services Sciences*, *1*, 1. https://doi.org/10.1504/IJSSCI.2008.017590

Safian, E. E. M., Nawawi, A. H., & Sipan, I. A. (2014). *Building and locational characteristics' quality of purpose-built office and their relationship with rentals* (MPRA Paper No. 64908). Retrieved from https://mpra.ub.uni-muenchen.de/id/eprint/64908

Sarac, E. (2012). *Real estate appraisal with artificial neural networks method* (Ms Thesis). Istanbul Kultur University, Civil Engineering, Istanbul, Turkey.

Selim, H. (2009). Determinants of house prices in Turkey: hedonic regression versus artificial neural network. *Expert Systems with Applications*, *36*, 2843-2852. https://doi.org/10.1016/j.eswa.2008.01.044

Shyjith, K., Ilangkumaran, M., & Kumanan, S. (2008). Multi-criteria decision-making approach to evaluate optimum maintenance strategy in textile industry. *Journal of Quality in Maintenance Engineering*, *14*(4), 375-386. https://doi.org/10.1108/13552510810909975

SPSS. (2011). *International Business Machines (IBM) Corp., Statistics* (version 20). Trademark, Armonk, New York, USA.

Supciller, A. A., & Capraz, O. (2011). Application of the supplier selection based on AHP-TOPSIS methods. *Econometrics and Statistics Journal*, *13*, 1-22.

Sykes, A. O. (1992). *An introduction to regression analysis*. The Inaugural Coase Lecture.

Tastan, H. (2012). *Heteroscedasticity*. Yıldız Technical University, Department of Economics, lesson notes from Introductory Econometrics: a Modern Approach (2nd ed.), J. Wooldridge.

Tepe, S. (2009). *Examination of expropriation and property relations* (Ms Thesis). Selcuk University, Department of Map Engineering, Konya, Turkey.

Tezcan, O. (2010). *Using of analytic hierarchy process method for evaluating investment projects in the construction* (Ms Thesis). Eskisehir Osmangazi University, Civil Engineering, Eskisehir, Turkey.

Unel, F. B., & Yalpir, S. (2013). Positional determination of real estates with analytic hierarchy process. In *Proceedings of the Fourth International Conference on Mathematical and Computational Applications* (pp. 326-336). Manisa, Turkey.

Vahidnia, M. H., Alesheikh, A. A., & Alimohammadi, A. (2009). Hospital site selection using fuzzy AHP and its derivatives. *Journal of Environmental Management*, *90*, 3048-3056. https://doi.org/10.1016/j.jenvman.2009.04.010

Wilkowski, W., & Budzynski, T. (2006). Application of artificial neural networks for real estate valuation. In *XXIII FIG Congress*. Munich, Germany.

Wong, K. W., & Wu, M. (2002). Priority setting of preferential parameters for home purchase in Chongqing-an analytic hierarchy process approach. In M. Anson, J. M. Ko, & E. S. S. Lam (Eds.), *Proceedings of the International Conference on Advances in Building Technology 4–6 December.* Hong Kong, China. https://doi.org/10.1016/B978-008044100-9/50053-X

Worzala, E., Lenk, M., & Silva, A. (1995). An exploration of neural networks and its application to real estate valuation. *Journal of Real Estate Research*, *10*(2), 185-201.

Yalpir, S., & Tezel, G. (2013). Comparison of SVM and MRA methods for real estate valuation. In *6th Symposium of Engineering and Technology, Çankaya University*. Ankara.

Yalpir, S., & Unel, F. B. (2016). Investigation and reduction of criteria affecting the value of land plot in Turkey and International Standards by Factor Analysis. *AKU Journal of Sciences and Engineering*, *16*(025502), 303-322. https://doi.org/10.5578/fmbd.28134

Yilmaz, A. (2010). *Real estate valuation by using multicriteria decision support system (analytic hierarchy process) and ratio study* (Ms Thesis). Yildiz Tecnical University, Geomatic Engineering, Istanbul, Turkey.

Yilmaz, A., & Demir, H. (2011). Real estate valuation by using multicriteria decision support system and ratio study. In *13 Scientific and Technical Congress of Map in Turkey*. Ankara, Turkey.

Yomralıoglu, T. (2002). *Geographical information systems: the basic concepts and applications* (2nd ed.). Turkey: Academy Bookstore.

Zhang, R., Du, Q., Geng, J., Liu, B., & Huang, Y. (2015). An improved spatial error model for the mass appraisal of commercial real estate based on spatial analysis: Shenzhen as a case study. *Habitat International*, *46*, 196-205. https://doi.org/10.1016/j.habitatint.2014.12.001

Zurada, J., Levitan, A. S., & Guan, J. (2011). A comparison of regression and artificial intelligence methods in a mass appraisal context. *Journal of Real Estate Research*, *33*(3), 349-387.