Creating A Valuation Map In GIS Through Artificial Neural Network Methodology: A Case Study

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The present study compared models and market values by creating a model for valuation estimations with artificial neural networks (ANN), which is one of the most advanced methods in immovable valuation and making applications by using Multiple Regression Analysis (MRA). Estimation results obtained from the models with the help of geographical information systems (GIS) were analyzed for spatial analysis. Data sets consisted of the criteria as the values of 300 residential real estates in Bosna Hersek Neighborhood in Konya /Selçuklu Region, the ages that affect those values, the number of stories, the frontage of the apartments, the number of rooms, and the distance to social infrastructures.

GIS based value maps, which were integrated to ArcGIS10.0 software, were produced in order to create an algorithm via ANN, which is one of the modern immovable valuation methods, and MRA, which is used to determine the immovable valuations according to those results. Spatial information about parcel and buildings was transferred to the database of ArcGIS 10.0 software and then was associated with oral data. Value maps were obtained through integrating the values of immovable properties in market conditions and estimation values of ANN and MRA to the map of the studied area. The performances were calculated and the produced value maps were compared in order to ensure the success of the models.

Key words*: artificial neural networks ANN, Multiple Regression Analysis MRA, geographical information system GIS, immovable valuation*

Introduction

Immovable valuation is an estimation that considers the rights and limitations on real estate properties like fields, land, residential real estate, and the economic, social and technical conditions in a certain period of time. The valuation in immovable valuation process is carried out by an expert and to do this constructional, legal, economic, social and technical information about immovable(s) should be obtained.

Attaining an exact value is difficult to do in immovable valuation due to many factors that affect the value. Sales comparisons, incomes, and cost-replacement approaches which are called classical valuation systems in total (mass) valuation of immovable properties (Pagourtzi et al., 2003) are insufficient since on a regional basis, the organization of much spatial data is required. Until quite recently, the values of immovable properties have been determined by the instincts and experiences by people who determine immovable valuation. However, securitization of immovable properties has become widespread, which requires the use of scientific, objective, quantitative, and liable methods in the determination of the values of immovable properties (Yomralıoğlu, 1993; Tanaka and Shibasaki, 2001). Today, thanks to computer technologies that are able to copy human brains, finding more accurate results is possible. The method group that can make value estimations using those technologies is an advanced system, which includes Artificial Neural Networks, Spatial Analysis, and Fuzzy Logic among regional or mass immovable valuation processes (Yomralıoğlu, 1993; Pagourtzi et al., 2003).

Artificial neural networks are an advanced method used in value estimations of immovable properties. Artificial neural networks are a type of artificial intelligence technique, which has been studied for many years in order to find the solutions to problems with unknown or complex internal relations. According to the observation in the literature studies: the closed MRA performs better than the more ANN when small samples are used, but if appropriate parameters are found, the ANN performs better(Kauko, 2004; Nguyen and Cripps, 2001). Whether appropriate parameters are found, in turn, depends on the amount and structure of the input; thus the usefulness of the ANN is dependent on large homogenous data sets to be able to perform successfully in mass appraisal – Tulkki (1998),

Since literature includes studies proving the accuracy of ANN, more successful results were observed in performance analyses of ANN and comparisons with ANN model (Lin 2010; Nas, 2011; Saraç, 2012; Khalafallah, 2008; Ozkan et al., 2007; Selim, 2009; Kontrimas and Verikas, 2011).

Recently developed computer technologies and information systems have made great contributions to immovable valuations. While the past use of spatial statistics were limited, currently developing information technology, calculation methods, the development in algorithms, and space based information system software have made spatial statistic applications an ordinary application (Pace et al., 1998). Producing immovable value

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maps through integrating GIS and Decision-Support systems is now possible. Therefore, the demands of users can quickly be answered and appropriate terrestrial analysis, the determination of purchase-sale regions and spatial analysis of immovable properties can easily be done (Zeng and Zhou, 2001).

Due to the requirements of developments and easy-to-use properties, GIS has become a tool in the production of valuation maps. The integration of ANN and MRA methods to GIS enables the production of value maps to be quicker, cheaper, and healthier (Xiao-sheng et al., 2011).

Models that can estimate the value of residential real estate in ANN and MRA were created using data sets obtained from this implementation. Statistical and performance results of the created model were examined, and thematic maps of MRA models and market values were compared using ArcGIS 10.0 software.

Method

Immovable valuation methods are listed as three main titles, traditional, statistical and advanced (modern). Traditional methods are the comparisons, incomes, and cost methods that are commonly accepted. Traditional valuation methods can be used when one or more than one immovable valuation process is done. However, traditional methods are insufficient in the valuation process of all real estate in a neighborhood or province. In this state, hedonic, nominal or regression methods, which are among the statistical methods accepted in the studies in the literature, can be used. However, current developments in computer technologies have resulted in the discovery of more advanced techniques. These techniques, which do not have validity in the use of immovable valuation yet, are used and tested in implementations. Those methods called advanced valuation methods include applications like artificial neural networks, fuzzy logic, genetic algorithm, expert systems, and rough sets theorem. Every passing day brings the production of new algorithms, whose appropriateness to study area is tested. Conducted studies used MRA method in the analysis and comparison of the application with sufficient performance. MRA method can be used for testing conducted studies, as it can be seen in the literature.

Artificial NEURAL NETWORKS

Artificial neural network is a method that was transferred to computer technology inspired by the neural network structure in the human brain. In addition, "artificial neural network is a processor that consists of simple processing units, and that work in a very dense, parallel and distributed order." It has features to store experimental information and then is able to bring the information it has gathered into use.

Artificial neural networks have been proposed as an alternative tool to valuation because of their ability in domains with non-linear relationships or initially unknown models. Nevertheless, the major drawback of neural networks is the explanation of its predictions. ANN generally are called of "black boxes" because of the lack of a simple and explicit model mapping the relationships among inputs and outputs, which is important in some applications, such as taxation or insurance (González, 2008) .

Neural networks are systems of massively distributed parallel processing. Initially inspired by the human brain, they use learning mechanisms for knowledge acquisition and save this knowledge in weighted connections (Rumelhart and McClelland, 1995; Haykin, 1999). An artificial neural network is composed of a set of neurons (nodes) and a number of weighted connections among them. The neurons have two parts: an initial sum of the weighted inputs and an activation function (generally non-linear), which give the neuron's output (Fig. 1).

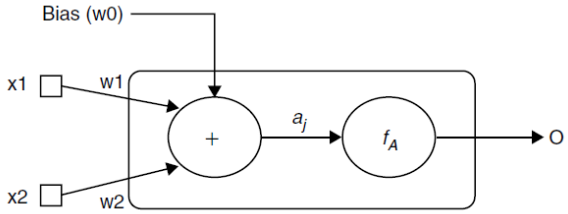


Fig. 1. The process structure of ANN .

The network structure of ANN is applied in two ways as feed-forward neural structure and feedback neural structure.

- Feed-forward neural structure proceeds forward as data input, nodal point process, and output process.
- Feedback neural structure is the repetition of processes in one part while process flow is continuing like feed-forward.

In real life, many problems are non-linear structures. MLP or Multilayer Perceptron is an ANN model most often used to solve non-linear problems. More successful results were obtained through MLP model in

implementations in different study areas (Saraç, 2012; Khalafallah, 2008; Kontrimas and Verikas, 2011; Garcı´a et al., 2008).

There are many learning algorithms that are used. These learning algorithms have more than a hundred types of variety according to the architecture of Artificial Neural Networks and the characteristics of the encountered problem, and the most popular network structure for MLP is the Back Propagation network (Elmas, 2003). Appropriate activation functions should be determined in a process called ANN black box. Tab. 1 shows some of activation functions.

Tab. 1. Activation Functions (Canan, 2006; Nas B., 2011).

Sigmoid *Logsig(x)*	$f_a(x) = \dfrac{1}{1+e^{-x}}$
Linear *Lin(x)*	$f_a(x) = x$
Tangent Hyperbolic *Tansig(x)*	$f_a(x) = \dfrac{1-e^{-2x}}{1+e^{2x}}$
Saturation Function *Sat(x)*	$f_a(x) = \begin{cases} +1 & x \geq 1 \\ x & -1 \leq x \leq +1 \\ -1 & x \leq -1 \end{cases}$
Hard Limiter *Signum(x)*	$f_a(x) = \begin{cases} +1 & x \geq 0 \\ -1 & x \leq 0 \end{cases}$

The present study used feedback from neural structures and sigmoid activation functions.

Geographical Information Systems

In many developed countries, the determination of immovable values and their taxation depend on a legal basis. Today, information technologies, especially GIS technologies, and their implementation areas have developed extensively. These developments revealed the use of GIS technology in immovable valuations. In immovable valuation methods, creating a database, where spatial information is predominant, regarding immovable valuations increased the role of GIS in immovable valuations.

The real estate appraisal is a very complex process. The accuracy of the appraisal is influenced by the accuracy of the obtained real estate information, the technology of appraisal staff, and the size of errors caused by various factors in the process of appraisal (Bing-hua,2006; Bing, 2008; Ping-heng, 2007). GIS has a large database technology, super computer graphic processing, and spatial analysis capability and provides a comprehensive and accurate information technology platform for the real estate appraisal industry (Da-zhi, 2002; Xin-cai, 2002; Da-seng et al., 2006), and then neural network has the dynamic processing ability in nonlinear problem (Yuan-bing et al.,2007; Ping-fan et al., 2005; Li-qun, 2002).

GIS uses digital technology, which combines hardware and software to meet user needs in handling spatial data to produce graphical output. GIS-based automated appraisal systems – on desktop computers and on the Internet will inevitably and profoundly change the appraisal industry (Castle, 1998). GIS in Real Estate: Integrating, Analyzing and Presenting Locational Information. Illinois: Appraisal Institute)

Geographical Information Systems help make spatial examinations and analysis, and can be used as a tool in the production of value maps and in the disciplinary implementations of other professions.

Application And Results

Study Area

Bosna Hersek Neighborhood, which is the biggest neighborhood of Turkey and located in Konya/Selçuklu District. It has a population of 100.000 people and was chosen as the study area. Bosna Hersek Neighborhood is in the north of the Konya Province and 20 km away from the city center and located on Konya-Afyon, which is the main road. It is across from the Alaeddin Keykubat Campus of Selcuk University; therefore it may be considered a residential area for students. It has many social infrastructure areas like primary and elementary schools, education centers for women, youth centers, public gardens, shopping centers etc. It has a high number

of residential real estate offered for sale or for rent and has no adjacent neighborhood, which are all important factors in the neighborhood to be chosen (Fig. 2).

In order to collect accurate, complete, and current data about the immovable properties to be valued, an application was created; a matrix with 10x300 size data set of residential real estate was created using current market values of purchase-sale immovable properties from the study area. Fig. 3 shows the general structure of the work flow diagram of the study.

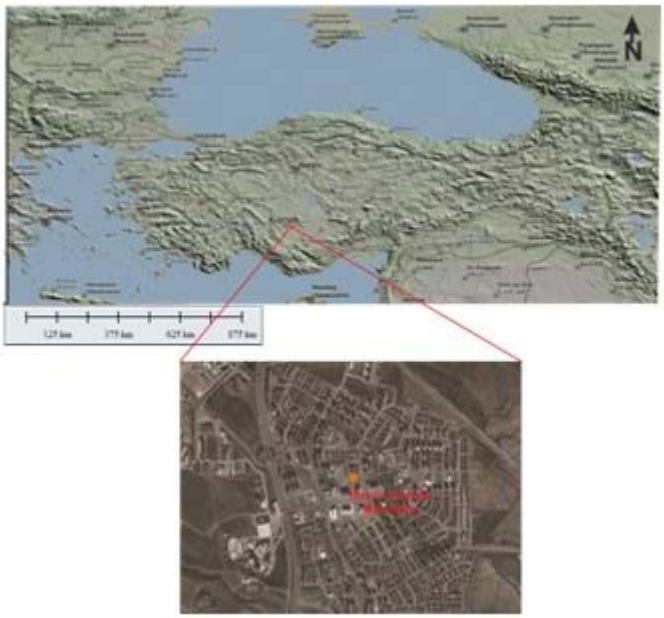


*Fig. 2. The location of **the** Bosna Hersek Neighborhood.*

The market values of 300 residential properties that were subjected to purchase-sale and their features of 2012 were collected. Data sets were created through examining the features of those residential real estates in market conditions, their distance to social infrastructures, and sale prices. The criteria and features in data set are as follows:

- **The number of rooms:** The number of rooms in the apartments ranges between 2+1 and 3+1. It was considered as 3+1=4 and 2+1=3 while organizing the data set. The number of rooms defines the usage area of residential real estate, as well.
- **The number of stories:** It is the total stories of the building. The higher the number of stories the building has indicates the presence of most preferred heating system; in which case, the apartments in higher stories have more value.
- **The storey of the residential real estate:** There is a low demand for apartments on the ground floor, penthouses, and the apartments under the roof. The preference of intermediate stories due to heating increases the values of immovable properties in this state.
- **Age:** The age of the buildings were examined and it is the difference between construction year and valuation year.
- **Frontier:** It is the position of the buildings according to its direction. Due to the predominance of continental climate in the study area, the apartments with south frontier are more preferred in Konya due to heating. Digitalization of this criterion has the values as Southeast: 4, Southwest: 3, Northeast: 2, Northwest: 1.
- **Distance to transportation network:** It is the distance of the residential real estate to the route of mass transportation vehicles by walking distance in meters. The proximity of the residential real estate is important for individuals with no vehicle is important, which increases the value of the residential real estate.
- **Distance to green areas:** It is the distance of residential real estates to green areas like forests, public gardens, etc. Individuals use these places both for resting and entertainment. In addition, the view of these kinds of areas from residential real estates increases their value.
- **Distance to trade centers:** It is the walking distance of residential real estates to markets, marketplaces, or any trade area. The proximity of the aforementioned areas increases the value since people residing in those areas require this as one of their needs.

- **Distance to University:** The distance of the residential real estates to the Alaeddin Keykubat Campus of Selçuk University was determined. The residential properties that were subjected to purchase-sale in the study area are generally preferred for investment; therefore obtaining income from rent is a predominant idea. Tenants are generally university students or university workers; therefore the distance to university is important in the valuation of residential real estates.
- **Sale price of the residential real estate:** It is the value of residential properties that were subjected to purchase-sale of 2012 in TL currency unit, which was obtained from real estate agencies. The highest residential property price is 88.000 TL and the lowest price was 50.000TL.

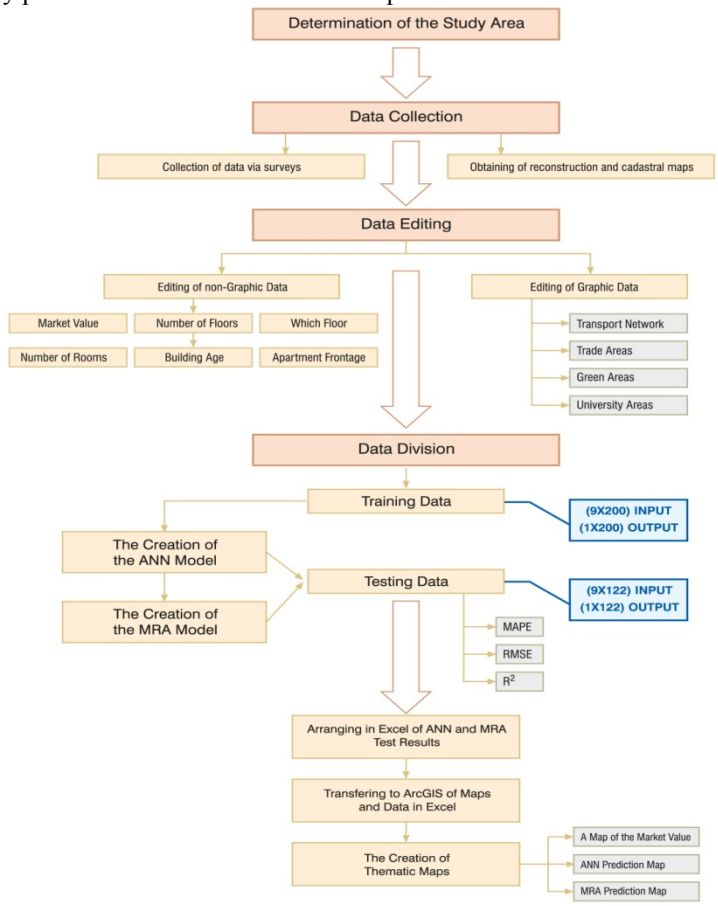


Fig. 3. Work Flow Diagram.

In the data set, the sale price of the residential properties is output and other criteria are input. Approximately 70 % (10x200 matrix) of the data set was spared for education and the remainder of the 30 % (100x100 matrix) was spared for testing (Fig. 4).

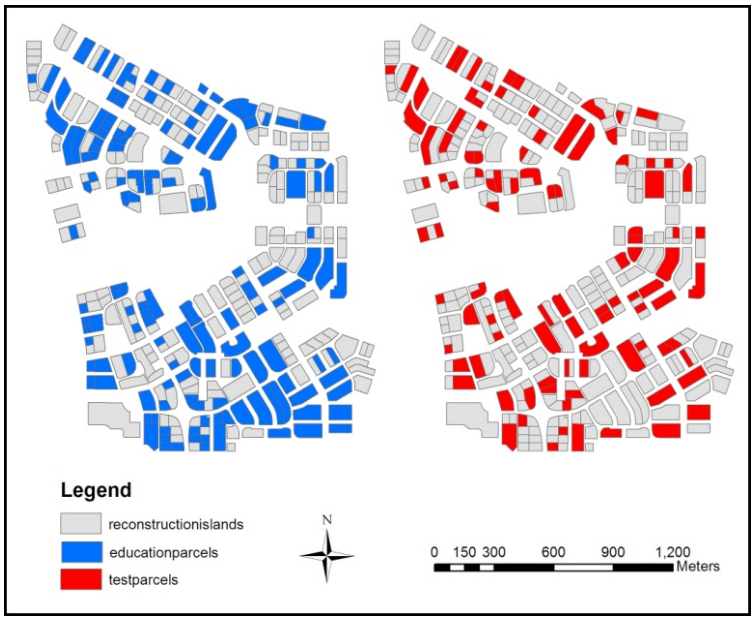


Fig. 4. The distribution of education and test data in the study area .

While creating the education and test data set, their homogeneous distribution was especially ensured with the help of the map since the most important parameters affecting value were the spatial ones. Therefore, distribution was made attentively due to the belief that it was important while creating the model and adapting it to GIS. Matlab R2010b software was used in creating ANN model and SPSS20 software was used in creating MRA model. The Educational data set was used for creating models in both methods, and test data were used for comparison.

ANN Application

This ANN structure was created by normalizing the data set organized for the study area the in 0-1 interval (Fig. 5).

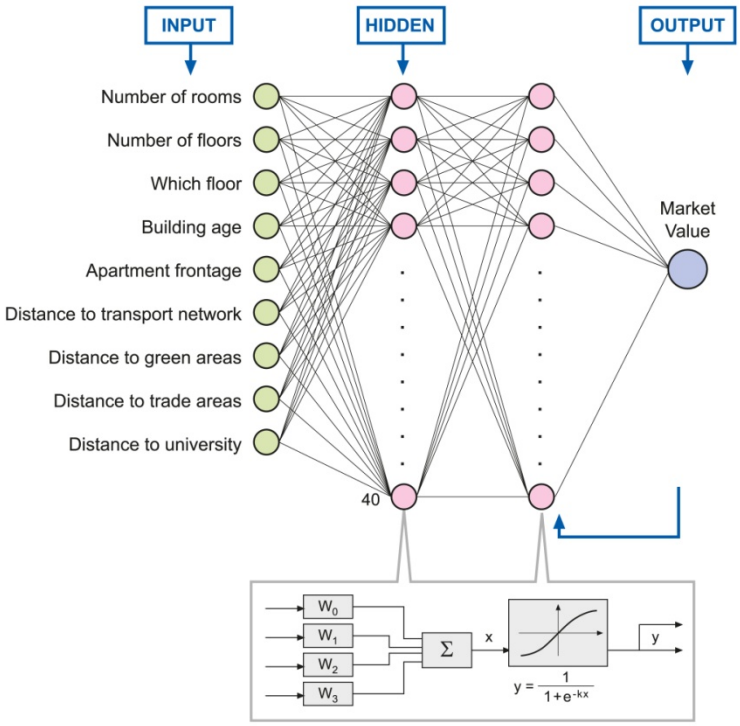
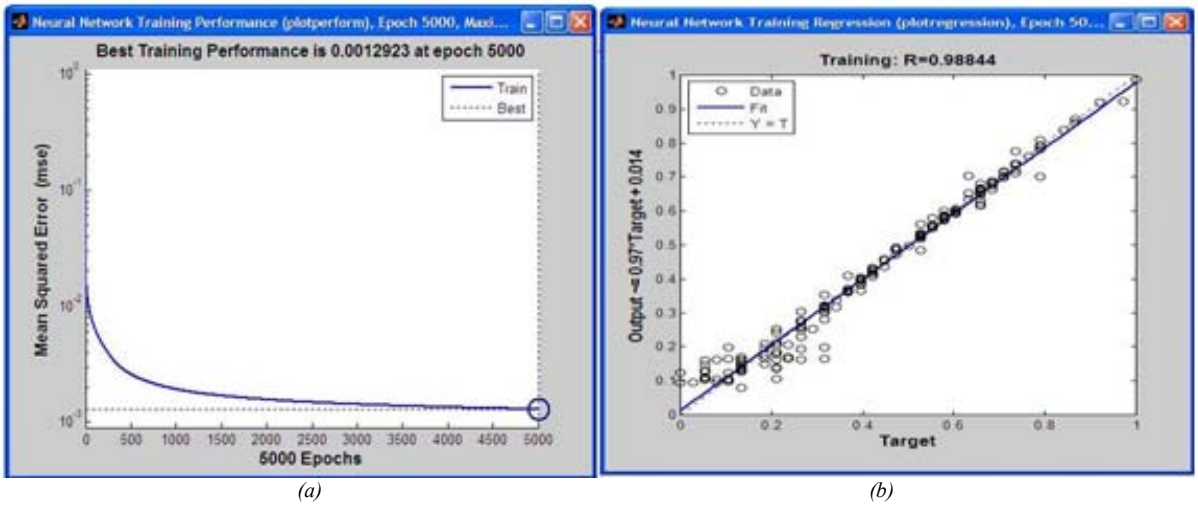


Fig. 5. The structure of ANN.

The best results with the application of ANN algorithm were obtained with 5000 epoch. Education error was found to be 2.23 and test error was found to be 9.81 in ANN model and the education performance graphic was created (Fig. 6a). Point dispersion created with the estimation of values obtained from ANN model and education data output variable is linear (Fig. 6b).



(a) *(b)*

Fig. 6. Education performance of ANN (a) and error distribution of education set (b)

MRA Application

The 200 data was used to form the mathematical model in the regression in order to determine value of the real estate. 100 data were used in testing mathematical data. The built model and the coefficients can be seen in the following Equation (1)

Y=4,280+0,418***The number of rooms** +0,177* **The number of stories**+0,006* **The floor of the residential real estate**-0,019* **Age**+0,076* **Frontier** -0,016* **Distance to transportation network** +0,041* **Distance to green areas** +0,014* **Distance to trade centers** -0,037* **Distance to university** (1)

In the order of significance regarding the effects of the criteria on the value according to MRA model, total number of rooms is the independent variable with the highest effect. It is also clear from the equation that number of floors of the building is the second most important variable. Age of the structure, distance to transportation network, and distance to the University are seen to be the criteria having negative effect on the value. According to Equation 1, the effect of the floor of the residential real estate is so low that can be ignored.

Performance Analyses

In order to determine the models' performances comparatively, the coefficient of determination (R^2 in equation 2), the mean average percentage error (MAPE 3), and the root mean square error (RMSE in equation 4) were calculated.

$$R^2 = 1 - \frac{\sum (x_p - x_i)^2}{\sum_i^n (x_i - \bar{x})^2} \qquad (2)$$

$$\text{MAPE} = \frac{\sum_{i=1}^{n} \left(\frac{|x_p - x_i|}{x_p} \right)}{n} * 100 \qquad (3)$$

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n} (x_p - x_i)^2}{n}} \qquad (4)$$

Where, x_p is Market value, x_i is Value of the model, i: {1,2,3….n}n is the total number of the residential real-estates in the data set.

ANN estimation results were denormalized in order to compare the estimation results of ANN model of test data and the results of residential real estate values in market conditions. Point distributions and the trend line between residential real estate prices in test data and estimation values of ANN and MRA models were examined. According to R^2 values of test data, ANN had 87% accuracy and MRA had 81% accuracy. Point distribution of ANN, MRA and market values were linear, however ANN model was found to give closer results to market values and the best trend line for distribution was reached by ANN model which is the closest to 1, the coefficient of x (Fig. 7).

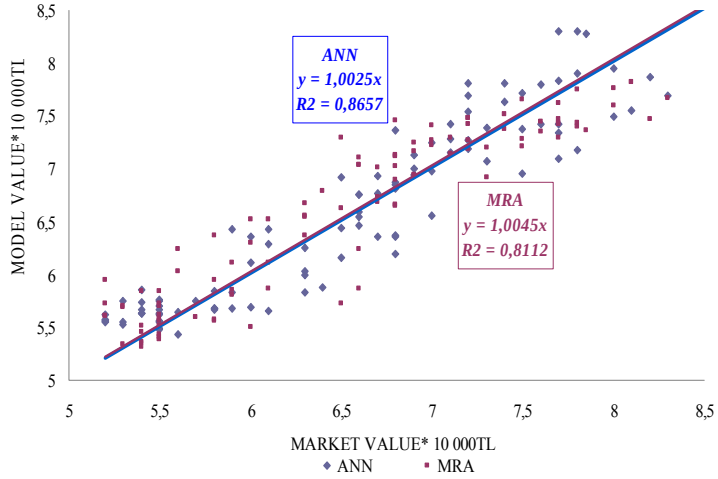


Fig. 7. Models and the distribution between market values.

Tab. 2 examined the mean absolute percentage error (MAPE) and root mean square deviation (RMSE) results of both models and ANN model estimation was found to be better than MRA model.

Tab. 2. Model performance analyses

Model	MAPE [%]	RMSE	R^2	Y=a*x
ANN	3,93	0,0975	0,8657	1,0028
MRA	4,26	0,1184	0,8112	1,0045

The Integration Of Real Estate Values With ArcGIS

Layers were created in order to integrate the map of the study area to ArcGIS 10 software. Organized data sets were associated with a map and under the light of information in data sets; analyses regarding the number of stories, age, the density of social infrastructure (Transportation- Shopping- Green areas and university campus area) were made (Fig. 8).

Thematic maps of market values of residential properties and their estimation values made by ANN and MRA were compared with the help of geostatistics.

In ArcGIS 10 software, the values were interpolarized using 'Inverse Distance Weighting' (IDW) interpolarization method in 'Geostatistical Analyst' module and value maps of residential real estates in the study area were created.

Similar results were obtained upon examining the value distributions in thematic map of residential property prices obtained from market and the thematic map created from estimations of ANN and MRA model (Fig. 9). According to these maps, the closeness to the university campus area and the transportation network increase the value more than other infrastructure criteria and the buildings closer to university have more stories than the buildings in other regions, which increased their value.

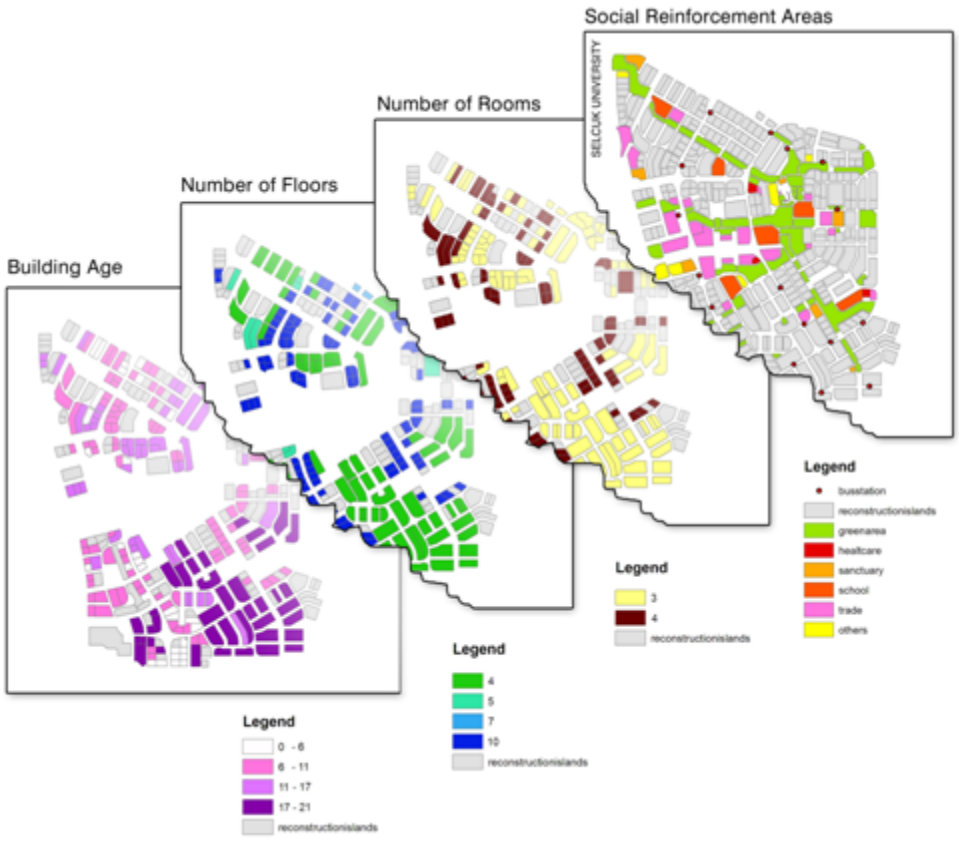


Fig. 8. The distribution of the age (a), total stories (b), the number of the rooms (c) and the social infrastructures (d) of the residential real estates in the study area.

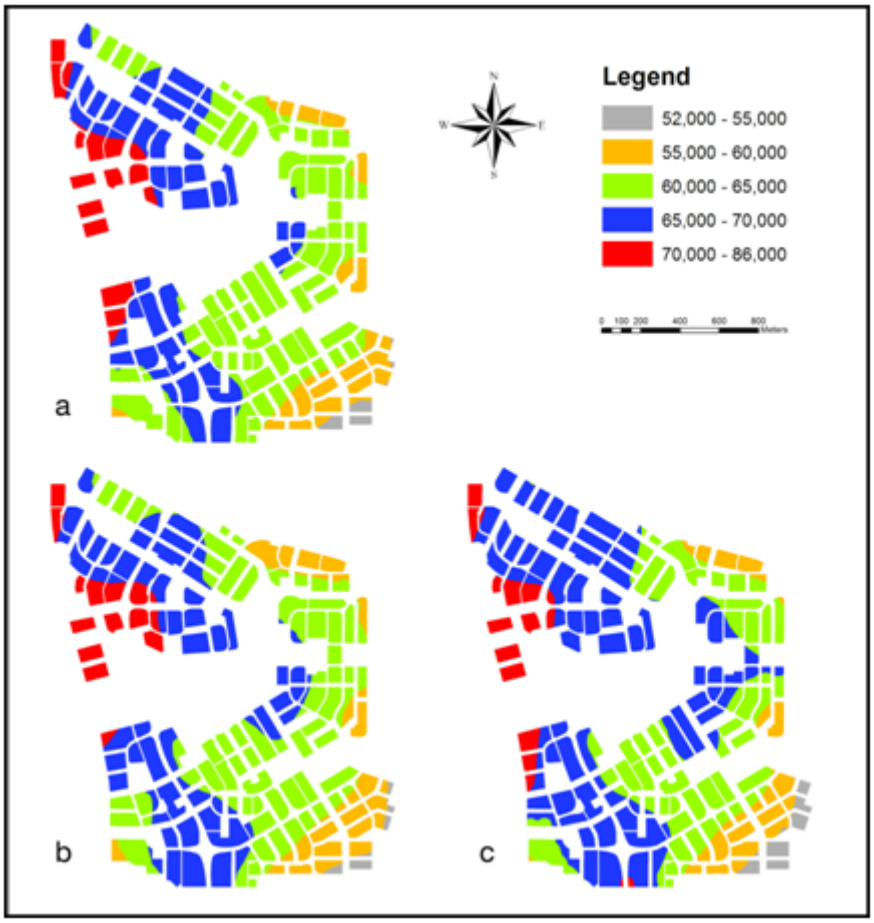


Fig. 9. Thematic maps obtained from residential real estate prices (a), ANN values (b) and MRA (c).

Suggestions

The present study created ANN and MRA models in order to make value estimations for immovable properties with unknown values through choosing their features and value of property in Bosna Hersek Neighborhood. Analyses and error calculations were made for model comparisons and ANN model was found to be more successful in making more accurate value estimations. The estimations of the values of immovable properties can be made with an average of a 4% absolute error in MAPE proportions in both models. Considering the fact that a difference at 15 to 20% rate for real estate in market conditions is normal, those models are observed to be usable. RMSE calculation results show that closer estimations can be made through ANN model compared to MRA model. Similarly, ANN performance is observed to be better compared to MRA in R^2 and trend line equations.

Among developed information technologies, GIS is the best tool to examine spatial distributions. Therefore, GIS helped create a basis to be used in having information about the approximate value of residential real estates with unknown values in market conditions. Therefore, having information about the value distribution of the whole region is not possible without the help of information systems in method development studies for value estimations. In the present study, ANN produced closer results to the map of market values among the value maps produced with geostatistical analyses for ANN and MRA models.

ANN model can be used as a base of processes regarding residential real estate appraisal in many areas like taxation, socialization, expropriation, and credit facilities in other regions where valuation maps are to be produced. According to the results of the study, ANN model produces closer results to market prices in value estimations and is more suitable. for valuations due to its structure. With the help of this model, values can be produced for other regions. In addition, its integration to GIS can be a basis for application requiring valuation.

The combination of ANN and GIS has proved to be a very powerful and useful tool for the task of house valuation and these results could surely be extended to any problem dealing with spatial data.

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