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Development of a methodology for property valuation using the retrospective method of correlation–regression dependence

The conducted research is based on information databases of real estate objects, where an important problem is that while there is a large amount of data, on the one hand, they are used for market research and mass valuation of real estate, but on the other hand, due to the lack of sufficient information or tools, do not allow to reflect the market situation fully.
The paper shows the analysis of the use of data collection and processing of real estate data in different countries, research results and opportunities in the use and implementation of real estate data depending on the pricing factors.
This paper considers economic and mathematical methods of evaluating the data set in the assessment of real estate objects, including the use of artificial intelligence. The reasonable confirmation of the hypothesis that the use of retrospective information of the most similar and comparable objects of analogues on price-forming factors for the assessed real estate object allows to determine the current market value using the retrospective method of correlation-regression dependence is carried out. The substantiation is given on the example of calculation of the market value of an arbitrarily selected real estate object. The conducted research partially displays the change in the value of the property object from the time factor based on the processing of the data set. As one of the price-forming factors are real indices of change in prices of real estate objects on the basis of several data sources. The conclusion summarizes the results of the study and the advantages of the method for the valuation of real estate objects, including the determination of cadastral value by the mass valuation method.
Keywords: *real estate classification, information systems, digital platforms, open data, data aggregators, cadastral valuation, real estate valuation, database, real estate objects, information bases*

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INTRODUCTION

In the property offer and rental market in Russia and in other countries there are many different databases, advertisement archives, printed publications and many other sources of advertisements. When assessing commercial and residential real estate, a number of pricing factors, availability of property classification with GIS distribution by information layers and other important information are also important. The analysis of information databases, aggregators of the market of real estate objects showed that there is a sufficient amount of information, including a large amount of data. For example, from global, such as the impact of the crises of 2008, 2014, changes in prices for the main segments of real estate during the pandemic COVID-19 in 2020, the degree of impact of foreign policy factors such as “special military operation” and imposed sanctions, and local and regional factors: the construction of public gardens, parks, infrastructure development, and others. In this case, it is necessary to process the array of data, and not just processing, but with certain criteria to be systematic and interconnected with each other on prices, offers of real estate objects. To process the data set many authors have developed and presented various methods of market analysis in many segments of real estate, where the most common are the method of correlation and regression analysis, the method of discrete-spatial parametric modelling, the method of geocoding. For example, the problem of cartographic support of land and property geoservices and Rosreestr geoportal, especially in the territory of smal.rural settlements, unfortunately, was not solved. However, in Russia there is an experience of works, where the possibilities of using commercial databases are disclosed [1]. Acceleration of information processing at the stage of recognition and identification allowed to revalue real estate objects in real time mode [2]. If property valuation is based on the availability and quality of information, information technology is the most concrete and fruitful prospect in valuation studies [3].

The use of economic and mathematical methods in the process of analyzing the real estate market allows making managerial decisions aimed at increasing the affordability of housing and taking into account the interests of the majority of the population living on the territory in question [4].

The purpose of this study is to confirm the author's hypothesis about using retrospective information of the most similar and comparable analogue objects in terms of price-forming factors for the appraised property, which will allow determining the current market value using the retrospective correlation-regression method. The essence of the method of correlation and regression analysis is the acceptable formalization of the relationship between changes in the prices of real estate objects and changes in any of its characteristics [5]. This method does not require absolutely reliable object-analogues [6].

Thus, the hypothesis is based on the fact that regardless of the chosen period of data analysis up to the valuation date, it is possible to determine the current market value of the valuation object.

RESEARCH METHODOLOGY

The objectives of the study are:

- research of data array techniques in the assessment of real estate objects, including with the use of artificial intelligence;
- calculation of the market value of a randomly selected property using the retrospective correlation-regression method.

RESULTS OF THE STUDY OF METHODOLOGIES

The hypothesis was based on a retrospective correlation-regression method, where the key difference is the use of historical information on properties. The basis for this particular historical information and the development of this method was also provided by the research of a scientist from the Czech Republic [7].

An analysis of a database for property valuation in the UK is presented where data is extracted, filtered and combined through a three-stage process from various publicly available sources [8]. In Italy, an AVM model with machine learning capabilities is presented, where the most important tool to achieve this goal was the use of a structured real estate database [9]. Researchers from Germany proposed that a non-linear modelling method can be used in property valuation to value properties in an inactive market [10]. Researchers from Bosnia and Herzegovina adapted a market value estimation model where one of the input parameters is the age and expected life of the structure [11]. Mamdani output system based on expert knowledge has many advantages in property valuation, has a high level of subjective factors based on human perception (according to researchers from Turkey) [12]. A number of scientists from Moscow propose to provide for the creation of an information subsystem of mass assessment of all real estate objects owned by the city of Moscow and located on the territory of the city [13]. Researchers from Perm proposed the concept of neural network modelling of the processes of mass valuation and scenario forecasting of the market value of residential real estate objects [14]. Domestic researchers in their articles presented the concept of online notary with the use of Rosreestr and registration of transactions [15], IT-platform of real estate property management [16], the project "System City" on services in the sphere of commercial and residential property [17], a number of recommendations for innovative start-ups in construction and real estate related objects [18].

Developed by S.G. Sternikmethodology of static interpolation spatial-parametric forecasting based on DSPM allows to fill in the missing data in unrepresentative clusters and in clusters with missing sample [19]. With the help of TechnoCad-Online software complex it is possible to obtain general data of SPC (State Property Cadastre) about cadastral block, to find out necessary information about land plots on the basis of thematic maps [20]. For example, scientists A.N. Kochurko, A.Y. Khoronzhevskaya developed the programme "Comparative method of assessment" allows to store, add, change, delete normative and reference information, information about objects-analogues. The obtained result is saved in a file with the extension xls, designed to work in Microsoft Office Excel [21].

To test the hypothesis, the author studied the experience of using MS Excel to solve the problem of cost estimation using the method of correlation and regression dependence on the basis of a linear multifactor model [22].

CALCULATION OF THE MARKET VALUE OF AN ARBITRARILY SELECTED PROPERTY USING THE RETROSPECTIVE CORRELATION-REGRESSION METHOD

The retrospective correlation-regression method was performed in the following sequence:

1. Determination of the segment of the selected appraisal object.
2. Selection of objects-analogues that are most comparable in terms of price-forming factors.
3. Selection of the type of regression model $f(x)$.
4. Estimation of model parameters.
5. Regression model construction.
6. Checking the adequacy of the model.
7. Calculation of the market value of the appraised object as of the date of collection of object-analogues.
8. Calculation of indices of change in prices of real estate objects from the date of offer of objects-analogues as of September 1, 2022.
9. Calculation of the market value of the assessed object as of September 1, 2022.

Step 1. A randomly selected property at the address: 33/1 Pravo-Bulachnaya St., Kazan, Republic of Tatarstan, where the main price-forming factors are: location, location relative to the traffic artery, total area, number of floors, state of finishing. Each price-forming factor is assigned a coefficient of significance, except for the total area, as the above mentioned coefficients are qualitative attributes. Table 1 presents the adopted significance coefficients for the pricing factors.

Step 2. For the price-forming factor, such as location, the coefficients are also not entered, as the objects-analogues in the comparable central district of the city and location relative to the transport main are selected as the objects-analogues. According to the data of database sampling as of two dates (analogues as of January 1, 2018 and as of February 28, 2021, valuation date: September 1, 2022), the selected objects-analogues differ in the date of offer, area, floor area and state of finishing. Characteristics of the appraised object and the objects-analogues by price-forming factors (materials of the author).

Table 1. Significance coefficients of price-forming factors of the objects-analogues

Pricing factor	Factor characterization	Significance factor
Number of storeys	1 storey and above	2
	1 storey and above + basement (ground floor)	1
Location in relation to the motorway	1 line	2
	Neighbourhood	1
Finishing condition	High-quality renovation	3
	Standard finish	2
	Unfinished	1

Source: compiled by the author.

Step 3. A multiple linear regression equation was chosen as the type of regression model for the function $f(x)$:

$$y = (a_0 + a_1x_1 + a_2x_2 + \ldots + a_nx_n) \cdot b, \quad (1)$$

where y is the value of the resultant trait obtained by substituting the corresponding values of the factor traits into the regression equation;

$x_1, x_2, \ldots, x_n$ are factor attributes;

$a_0, a_1, \ldots, a_n$ — model parameters (model coefficients);

b — price change index from the bid date to the valuation date.

Step 4. Table 1 presents the pricing factors and assigns significance coefficients based on the principle that if the object-analogue is better in any pricing factor, a higher coefficient is assigned. Based on the above-mentioned qualitative characteristics, a score table of price-forming factors of the appraised object and objects-analogues was drawn up (author's materials). Since the objects-analogues were used as market analysis, which are actually offers, a 10 % discount for bargaining was applied to all offer prices of objects-analogues. In this case, the dependent variable is the value of the market value of 1 sq. m of the area of the objects-analogues, the other characteristics are qualitative.

Step 5. Multiple linear regression was constructed using the "data analysis/regression" add-in in excel, where the input interval for *Y* were the values of the area according to the objects-analogues, and for *X* the input interval were the values of price-forming factors (total area, number of floors, location in relation to the motorway and state of finishing).

Step 6. The criterion that characterizes the adequacy of the regression model is called the coefficient of determination — *R2* (Table 2), it indicates the percentage of variance of known market data that can be explained by the regression relationship. If the coefficient of determination is close to one, the model explains almost all variability of the relevant variables. In practice, if *R2* values reach values of 0.9

Table 2. Regression statistics and analysis of variance

Data	Model data as of 01.01.2018	Model data as of 02.28.2021
Regression statistics	–	–
R-squared (determined from data from the "data analysis/regression" add-in in excel)	0.80	0.94
Analysis of variance	–	–
F-observed (determined using data from the "data analysis/regression" add-in in excel)	6.02	19.11
F-critical (determined using excel function = FRASPOBR (probability; degree of freedom 1; degree of freedom 2))	= FRASPOBR(0.05; 4; 6) = 4.53, where 0.05 is the probability; 4 is the number of factors in the regression model constructed; 6 is the number of observations minus the number of factors minus one	= FRASPOBR(0.05; 4; 5) = 5.19, where 0.05 is the probability; 4 is the number of factors in the regression model constructed; 5 is the number of observations minus the number of factors minus one

Source: compiled by the author.

Table 3. Calculation of the market value of the object as of 01.01.2018

–	Coefficients	Significance coefficients of the assessed object	Obtained values by formula for each variable $a_0; a_1x_1; a_2x_2 \ldots + a_nx_n$	Sum of all values, rub. sq. m by the formula for each variable $y = (a_0 + a_1x_1 + a_2x_2 + \ldots + a_nx_n)$, rub. sq. m	Area of the assessed object, sq. m	Market value of the appraised object, rub.
Y-intersection	8,041.40	–	8,041.40	71,878.24	3,209.80	230,714,768
Variable x_1	2.11	3,209.80	6,783.31			
Variable x_2	5,075.93	1.00	5,075.93			
Variable x_3	0.00	2.00	0.00			
Variable x_4	25,988.80	2.00	51,977.60			

Source: compiled by the author.

Table 4. Calculation of the market value of the object as of 02.28.2021

–	Coefficients	Significance coefficients of the assessed object	Obtained values by formula for each variable $a_0; a_1x_1; a_2x_2 \ldots + a_nx_n$	Sum of all values, rub. sq. m by formula for each variable $y = (a_0 + a_1x_1 + a_2x_2 + \ldots + a_nx_n)$, rub. sq. m	Area of the assessed object, sq. m	Market value of the appraised object, rub.
Y-intersection	21,225.70	–	21,225.70	70,423.30	3,209.80	226,044,716
Variable x_1	–3.57	3,209.80	–11,443.66			
Variable x_2	12,209.80	1.00	12,209.80			
Variable x_3	0.00	2.00	0.00			
Variable x_4	24,215.73	2.00	48,431.46			

Source: compiled by the author.

Table 5. Calculation of the average value of price change indices from 01.01.2018 to 09.01.2022, from 02.28.2021 to 09.01.2022

Number	Date	Average value of retail and office property in Kazan	Value of the price change coefficient as of 09.01.2022
1	09.01.2017	70	1.6607
2	09.01.2022	116.25	
3	–	–	1.051
–	Average value	–	1.3558
1	09.01.2020	69.5	1.6727
2	09.01.2022	116.25	
3	–	–	1.041
–	Average value	–	1.3566

Source: compiled by the author according to the data[1, 2, 3, 4].

Table 6. Calculation of the final value of the assessed object using information as of 01.01.2018 and as of 02.28.2021

Number	Date of evaluation/ proposal	Market value as of the valuation date, rub.	Value of price change coefficient as of 09.01.2022 relative to the valuation date	Market value as of the valuation date — 09.01.2022	Deviation of results
1	01.01.2018	230,714,768	1.3558	312,807,086	5.32 %
2	02.28.2021	226,044,716	1.3566	306,648,178	
Number	–	Offer price of the appraised object without adjustment for bargaining, roubles	–	Offer price of the appraised object taking into account haggling adjustment (10 %), rub.	
3	09.01.2022–10.05.2022	330,000,000	1.0000	297,000,000	

Source: compiled by the author.

and above, the model is considered very high, and sufficient at values corresponding to the interval 0.70–0.89. According to the Chaddock scale, the obtained values of the coefficient of determination are 0.80 and 0.94, which indicates a strong direct correlation.

The Fisher coefficient is used to indicate the probability of erroneously concluding that there is a strong interdependence. If the *F*-observed is greater than the *F*-critical, then there is a relationship between the variables. The observed values of Fisher's coefficient (Table 2) are greater than the critical values, accordingly, the regression equations obtained are correct for calculating the value of the building being valued.

Step 7. Having obtained the regression dependence coefficients, it is possible to calculate the market value of the appraised object according to formula (1) by substituting the values of the ballistic characteristics of the appraised object as of the relevant dates of the market analysis (Table 3, 4). The final market value is determined as the product of the total area by the received value of 1 sq. m. rub. of the object on the relevant dates.

Step 8. Price change indices from the bid dates to the valuation date (09.01.2022) were calculated using data from several sources, where the average value was determined (Table 5).

Step 9. The final value of the appraised property as on 09.01.2022 using data as on 01.01.2018 and 02.28.2021 was calculated by multiplying the market value calculated in Step No. 7 by the average of the change in price indices calculated in Step 8 (Table 6).

DISCUSSION OF RESULTS

Table 6 presents the results of the calculation of the market value of the property using the objects-analogues as of January 1, 2018 and as of February 28, 2021, as well as provides information on the actual supply on the market of the object of study[5]. As can be seen, in the column market value on the date of assessment September 1, 2022 is within the acceptable range of prices in the amount of 5.32 %, which is calculated as the maximum value divided by the minimum, minus one unit multiplied by 100 %. In practice, the maximum allowable range, according to the survey data, is (+/–) 17–20 %, and may reach 30 % in an inactive market.

Accordingly, the conducted research and the result of the discrepancy between the variants of calculations using the objects-analogues on different dates of offer speaks about the confirmation of the hypothesis, where the use of retrospective information of the most similar and comparable objects-analogues on

1 Information portal of real estate (database of objects, statistics, market analysis). Statistics of the property market. URL: tatistika-rynka (date of reference: 01.17.2024).

2 Monitoring of prices of real estate objects, land plots, rental rates in the Republic of Tatarstan as of 09.01.2017. 2017. Pp. 1–22. URL: appraisers-rt.rf/results-of-monitoring/ (date of reference: 01.17.2024).

3 Monitoring of prices of real estate objects, land plots, rental rates in the Republic of Tatarstan as of 09.01.2022 2022. Pp. 1–45. URL: appraisers-rt.rf/results-of-monitoring/ (date of reference: 01.17.2024).

4 Monitoring of prices of real estate objects, land plots, rental rates in the Republic of Tatarstan as of 09.01.2020. 2020. Pp. 1–62. URL: appraisers-rt.rf/results-of-monitoring/ (date of reference: 01.17.2024).

5 Information about the object offer "Sell non-residential building, 3,300 m²". 2022. URL: https://tatarstan.move.ru/objects/6875901981/# (date of reference: 01.17.2024).

price-forming factors for the assessed property allows to determine the current market value using the retrospective method of correlation-regression dependence.

CONCLUSION

Availability of current and retrospective information databases of real estate objects is one of the great advantages today for analyzing information and determining the market value of real estate. The presented retrospective method of correlation-regression dependence with the use of price index coefficients justifies the possibility of using information databases for the current date. Accordingly, the essence of this method is that regardless of the date of selected objects-analogues to the valuation date for the object under study, the result will be the market value at the current date within the acceptable range.

This method can be applied for mass valuation of real estate, including the determination of cadastral value with the addition of various variants of price-forming factors, as part of the development of the methodology of valuation and management of real estate objects of various functional purposes. The advantage of this method, when building the model, is the possibility to use objects-analogues, where price-forming factors can be maximally comparable, i.e. correction factors are close to the minimum value. An additional bonus when using this method is the availability of market information in passive markets with undeveloped economy, where there are 2–3 offers per year.

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Развитие методологии оценки объектов недвижимости с использованием ретроспективного метода корреляционно-регрессионной зависимости

Проведенное исследование базируется на информационных базах данных объектов недвижимости, где важной проблемой является, что при наличии большого количества данных, они, с одной стороны, используются для исследования рынка и массовой оценки недвижимости, однако с другой, в связи с отсутствием достаточного количества информации или инструментов, не позволяют в полной мере отображать конъюнктуру рынка.

Статья отображает анализ использования данных сбора и обработки информации объектов недвижимости в различ-

ных странах, результаты исследований и возможности при использовании и внедрении данных об объектах недвижимости в зависимости от ценообразующих факторов.

В данной статье рассмотрены экономико-математические методы оценки массива данных при оценке объектов недвижимости, в том числе с использованием искусственного интеллекта. Проведено обоснованное подтверждение гипотезы о том, что использование ретроспективной информации наиболее аналогичных и сопоставимых объектов аналогов по ценообразующим факторам для оцениваемого объекта недвижимости позволяет определить текущую рыночную стоимость с использованием ретроспективного метода корреляционно-регрессионной зависимости. Обоснование приведено на примере расчета рыночной стоимости произвольно выбранного объекта недвижимости. Проведенное исследование частично отображает изменение стоимости объекта недвижимости от фактора времени на основе обработки массива данных. В качестве одного из ценообразующих факторов выступают реальные индексы изменения цен объектов недвижимости на основе нескольких источников данных. В заключении приведены итоги проведенного исследования и преимущества метода для оценки объектов недвижимости, в том числе для определения кадастровой стоимости методом массовой оценки.

Ключевые слова: *классификация недвижимости, информационные системы, цифровые платформы, открытые данные, агрегаторы данных, кадастровая оценка, оценка недвижимости, база данных, объекты недвижимости, информационные базы*

СПИСОК ИСТОЧНИКОВ

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