GOCE DELCEV UNIVERSITY, STIP, NORTH MACEDONIA
FACULTY OF ELECTRICAL ENGINEERING

ETIMA 2025

THIRD INTERNATIONAL CONFERENCE

24-25 SEPTEMBER, 2025

TECHNICAL SCIENCES APPLIED IN ECONOMY, EDUCATION AND INDUSTRY

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FACULTY OF ELECTRICAL ENGINEERING

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PREFACE

The Third International Conference "Electrical Engineering, Technology, Informatics, Mechanical Engineering and Automation – Technical Sciences in the Service of the Economy, Education and Industry" (ETIMA'25), organized by the Faculty of Electrical Engineering at the "Goce Delchev" University – Shtip, represents a significant scientific event that enables interdisciplinary exchange of knowledge and experience among researchers, professors, and experts in the field of technical sciences. The conference was held in an online format and brought together 78 authors from five different countries.

The ETIMA conference aims to establish a forum for scientific communication, encouraging multidisciplinary collaboration and promoting technological innovations with direct impact on modern life. Through the presentation of scientific papers, participants shared the results of their research and development activities, contributing to the advancement of knowledge and practice in relevant fields.
The first ETIMA conference was organized four years ago, featuring 40 scientific papers. The second conference took place in 2023 and included over 30 papers. ETIMA'25 continued this scientific tradition, presenting more than 40 papers that reflect the latest achievements in electrical engineering, technology, informatics, mechanical engineering, and automation.

At ETIMA'25, papers were presented that addressed current topics in technical sciences, with particular emphasis on their application in industry, education, and the economy. The conference facilitated fruitful discussions among participants, encouraging new ideas and initiatives for future research and projects.

ETIMA'25 reaffirmed its role as an important platform for scientific exchange and international cooperation. The organizing committee extends sincere gratitude to all participants for their contribution to the successful realization of the conference and its scientific value.

We extend our sincerest gratitude to all colleagues who, through the presentation of their papers, ideas, and active engagement in discussions, contributed to the success and scientific significance of ETIMA'25.

The Organizing Committee of the Conference

ПРЕДГОВОР

Третата меѓународна конференција „Електротехника, Технологија, Информатика, Машинство и Автоматика – технички науки во служба на економијата, образованието и индустријата“ (ЕТИМА’25), организирана од Електротехничкиот факултет при Универзитетот „Гоце Делчев“ – Штип, претставува значаен научен настан кој овозможува интердисциплинарна размена на знаења и искуства меѓу истражувачи, професори и експерти од техничките науки. Конференцијата се одржа во онлајн формат и обедини 78 автори од пет различни земји.

Конференцијата ЕТИМА има за цел да создаде форум за научна комуникација, поттикнувајќи мултидисциплинарна соработка и промовирајќи технолошки иновации со директно влијание врз современото живеење. Преку презентација на научни трудови, учесниците ги споделуваат резултатите од своите истражувања и развојни активности, придонесувајќи кон унапредување на знаењето и практиката во релевантните области.

Првата конференција ЕТИМА беше организирана пред четири години, при што беа презентирани 40 научни трудови. Втората конференција се одржа во 2023 година и вклучи над 30 трудови. ЕТИМА’25 продолжи со истата научна традиција, презентирајќи повеќе од 40 трудови кои ги отсликуваат најновите достигнувања во областа на електротехниката, технологијата, информатиката, машинството и автоматиката.

На ЕТИМА’25 беа презентирани трудови кои обработуваат актуелни теми од техничките науки, со посебен акцент на нивната примена во индустријата, образованието и економијата. Конференцијата овозможи плодна дискусија меѓу учесниците, поттикнувајќи нови идеи и иницијативи за идни истражувања и проекти.

ЕТИМА’25 ја потврди својата улога како значајна платформа за научна размена и интернационална соработка. Организациониот одбор упатува искрена благодарност до сите учесници за нивниот придонес кон успешната реализација на конференцијата и нејзината научна вредност. Конференцијата се одржа онлајн и обедини седумдесет и осум автори од пет различни земји.

Изразуваме голема благодарност до сите колеги кои со презентирање на своите трудови, идеи и активна вклученост во дискусиите придонесоа за успехот на ЕТИМА’25 и нејзината научна вредност.

Организационен одбор на конференцијата

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A DATA-DRIVEN APPROACH TO REAL ESTATE PRICE ESTIMATION: THE CASE STUDY SLOVAKIA

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Abstract

Automated value model (AVM) is a computerized statistically based software that collects and uses Big Data in the real estate sector. It uses property information such as comparable and historical sales, property characteristics, price trends, and any other information relevant to the property in its algorithm. The effectiveness of using AVM depends on the amount and especially the quality of the data used, because only high-quality data can be considered reliable and representative. At the same time, it should be added that machine data collection and evaluation in the field of real estate would never be as accurate as manual valuation, where the appraiser can, based on his knowledge and experience, take into account factors that are not taken into account and documented in the collected data, through a physical inspection. Even if an appraiser uses certain specific methods to determine the price of a property, the appraiser's subjectivity factor always enters the valuation process, which can create a certain deviation in human-generated sales prices compared to the price generated by the software. The following contribution is devoted to the issue of creating an AVM model for evaluating real estate sales prices. The authors collaborated on the creation of such a model for practice in Slovak conditions, the main goal of which was to in-crease the efficiency and productivity of work in the field of real estate valuation.

Key words

Automated value model, Big Data, Real estate market, Real estate prices, Slovakia.

Introduction

Real estate prices on the real estate market are influenced by the demand for real estate and the supply of real estate. Supply and demand are affected by many factors [1]. Among the most important and most frequently mentioned factors in the literature, in addition to the demand and supply of real estate, they also include inflation [2]; household income; the amount of real estate rent; demographic development (demographic growth and development of the number and size of households) [3]; taxes (from sales / rent); state subsidies and subsidies; interest rates availability of loans, GDP development and others.

Real estate prices are not the subject of formal statistical surveys. The only official source of real estate prices is the National Bank of Slovakia (NBS), which analyses price developments based on data provided by the National Association of Real Estate Agencies (NARKS). However, prices are reported only at the regional level. For city-level research, therefore, the only possible source of prices is property for sale advertisements. Although the price of the apartment stated in the advertisement cannot be considered a transaction price, it is often used

as a proxy indicator of the real price [4]. Location is among the specifics that mainly and relatively significantly influence the price of real estate. By location, we mean the geographic location of the property, whether at the level of a city district, city, or at the regional level. Another specific feature of the property is its uniqueness and diversity. Uniqueness and diversity mean unique, unrepeatable characteristics, such as plot and location on the plot, age, orientation, area, height, style, etc. No two properties with all these same parameters can be found anywhere in the world, and this makes each property unique.
The aim of this contribution is to describe the creation of a real estate price estimate using the AVM model. The AVM model will ensure a quick and reliable valuation of residential real estate in the selected location.

1. Literature review

Automatic valuation model (AVM) have recently become an important and increasingly used tool in work related to the market valuation of real estate. In the past, appraisers, financial and insurance institutions, who needed to quickly determine the market estimate of a large number of primarily residential properties, mainly used them. Gradually, real estate agencies and companies that trade in the real estate market are starting to use these models more and more, which has made these tools available to a relatively wide range of ordinary users. Today, it is quite common for the average visitor to a real estate agency's website to get an estimate of their property free of charge and almost immediately. Whether it is a rough estimate of the market price of the property or an accurate estimate depends primarily on the AVM model itself.

There is no universal definition of AVM [5]. According to the European AVM Alliance [6], AVM is a real estate valuation system that provides the value of a specified property on a specified date using automated mathematical modelling techniques. According to Dimopoulos & Bakas [7], Automated Valuation Models (AVMs) are computational models used for the mass appraisal of real estate proper-ties. These models utilize machine-learning techniques to estimate property values based on various factors such as location, size, and condition.

Most AVMs compare values of similar properties at the same time. Authors Ecker, Isakson & Kennedy [5], define an AVM as a computer software programme that produces an estimate of market value, called an AVM valuation, together with statistics that assess the accuracy and precision of the AVM (called AVM performance metrics) for a single target property with respect to the address of the target property, as well as data on the sale of the property and the characteristics of the property. Lim and Bellotti [8], AVMs are generally developed based on a large number of characteristics of the property, their surroundings, and past property prices. It is useful for AVM to provide a valuation range so that the user can be confident in the estimate and use a conservative valuation price if necessary. Ideally, this range is within ±10% of the median price, but otherwise does not indicate how certain the user can be that the actual selling price will be within this range.

AVMs that produce predictions with a prediction confidence interval range equal to a value expressed in percentage means that this price prediction includes the actual price of the property with a confidence equal to this percentage prediction.

We include automatic valuation models among the statistical methods of real estate valuation. The main types of statistical valuation methods according to the European Standards for Statistical Valuation Methods for Residential Properties [6] include:

- House Price Indices,
- Single Parameter Valuations,

- Hedonic Models and
- Comparables Based AVMs.

Each of these types of statistical valuation method is characterized by the use of basic techniques, the rate of use of which increases from a mathematical and technical point of view. House Price Indices are a series of changes in property values that are applied to the previous value using simple multiplications. Single Parameter Valuations are provided as static numbers for a specific set of properties in a given area. The last two methods of statistical valuation are characterized by the deployment of real valuation models. Hedonic models typically describe the value of a property as a function of the attributes of the property itself and its location. Comparables Based AVMs consist of highly sophisticated automated processes and mathematical formulas requiring the deployment of complex bespoke technology and include elements of comparable valuation. This is an approach similar to that used by real estate valuation experts [6]. Automatic valuation models according to this classification are included in the group of hedonic models and Comparables Based AVMs. A more detailed schematic breakdown of the valuation methods and valuation models is shown in Figure 1.

Statistical valuation methods are completely objective in the sense that values are calculated based on measurable characteristics of the property and its location. For this reason, statistical valuation methods are well suited to be performed in an automated rather than manual manner. These real estate valuation methods can calculate market values for specific residential properties or track price trends in residential real estate markets in general. The accuracy of the results of the statistical valuation method depends on a number of factors, including the quality and detail of the available data and the sophistication of the modelling techniques used. Choosing the appropriate method should carefully consider the level of accuracy required. The higher the required level of accuracy, the more advanced the statistical evaluation method used should be [6].

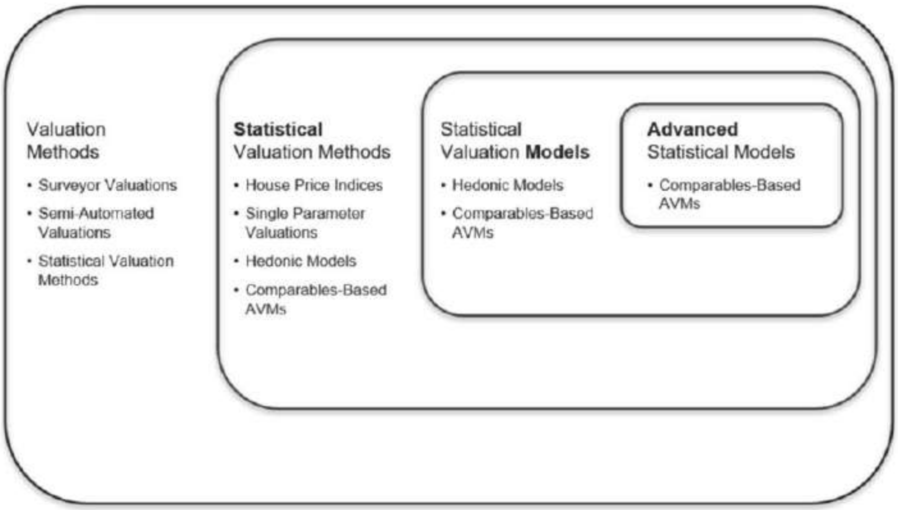

Fig. 1 Schematic breakdown of valuation methods and valuation models. Source: [6]

Statistical real estate valuation methods can be used to determine the current price of residential real estate through deterministic models. A deterministic model is understood as a model in which the quantities described do not change their state and are bound by fixed relationships. A state is not a random, but a deterministically determined quantity of relationships with initial and/or boundary conditions.

Automatic valuation models are not limited to residential properties. Filippova et al. [9] conducted a study on pricing office rents in Sydney CBD using AVMs. The study highlighted the use of AVMs in the commercial real estate market, where they in-form property valuation for lease purposes [9]. The use of AVMs extends beyond the real estate industry. Wang & Li [10] highlight the adoption of automated valuation methodologies in computer-assisted mass appraisal (CAMA) models. These models and standards incorporate AVMs to streamline the mass appraisal process [10]. An-other study that shows that AVMs are not limited to the real estate industry is from Hottat et al. [11], where they discussed the contingency approach to service automa-tion, which includes the use of AVMs [11].

2. Approaches to Real Estate Price Modelling

There are different approaches to modelling real estate prices. The most common approaches include:

Hedonic Models (hedonic regression)

One of the approaches through which they can be used in tools like AVM are hedon-ic models, which are based on the concept of hedonic prices. Rosen [12] defined hedonic prices as implicit prices of attributes, which are revealed to economic sub-jects from the observed prices of differentiated products and the specific amounts of characteristics associated with them. The hedonic pricing model is used to estimate how much each factor affects the market price of a property. In operating this type of model, if non-environmental factors are controlled (held constant), any remaining differences in price will represent differences in the external environment of the good [13].

This approach involves analyzing the property's characteristics (such as location, floor area size, number of rooms, etc.) and estimating the value of each individual characteristic. The sum of these values then provides an estimate of the total value of the property. These characteristics are used to create a model that estimates the property's value based on its attributes. Hedonic models were elaborated in detail in their monography [14].

Time-series Analysis

This approach involves analyzing property price trends over time to predict future property price movements. This can be done using statistical methods such as auto-regressive integrated moving average (ARIMA) models or machine learning algorithms.

Repeat Sales Analysis

This approach uses data on properties that have been sold more than once to estimate changes in property values over time. The point of this method is that by comparing the sales prices of the same property at different times, you can isolate the factors that cause changes in value.

Machine Learning

The machine learning approach involves the use of advanced algorithms to analyze large amounts of real estate data. Using data on a wide range of factors such as prop-erty characteristics, location, economic indicators, and more, machine-learning models can identify complex relationships and patterns in property prices.

Spatial Analysis

The spatial analysis approach involves analyzing the relationship between property prices and geographic variables such as distance to amenities, transportation, and other factors that can affect property values. It can help identify trends and patterns in property prices based on factors such as proximity to certain amenities, services, or neighborhood characteristics.

Comparative Market Analysis

This approach involves comparing the prices of similar properties that have sold in the same area in order to estimate the value of the property.

Cost Approach

The cost approach involves estimating the property's value based on the cost of building a similar property from scratch and then adding a reasonable profit margin, taking into account depreciation and other factors. This can be used as a basis for estimating the value of an existing property based on factors such as age, condition, and location.

Income Approach

This approach estimates the value of a property based on the income that the proper-ty generates, such as rental income or the potential value of resale.

This is just a sampling of a few examples of approaches used in real estate price modelling. The choice of the appropriate approach depends on the available data, the purpose of the analysis, and the characteristics of the investigated real estate market, and on the specific context.

3. Construction of the AVM

3.1 Creation and Construction of a General Model

First, we describe the creation of a general model. The theoretical concept of creating a general model can be simply described in the following steps, which logically follow each other (more Figure 2).

The purpose of the model recognizes what type of model it is and what theoretical problem the model solves. A theoretical problem means the verbal formulation of the problem and the solver's idea of its solution. The model type describes whether they are descriptive and predictive models or explanatory models. The first two are often quite complicated, focused on numerical accuracy, and the third type should be as simple as possible, focused on the description of principles. The first two focus only on numerically significant principles, and the third, on the contrary, ignores processes that are not fundamentally significant. The assumptions of descriptive and predictive models are quantitative and customized, while the assumptions of explanatory models are mainly qualitative and these models are applicable to relatively wide areas [15].

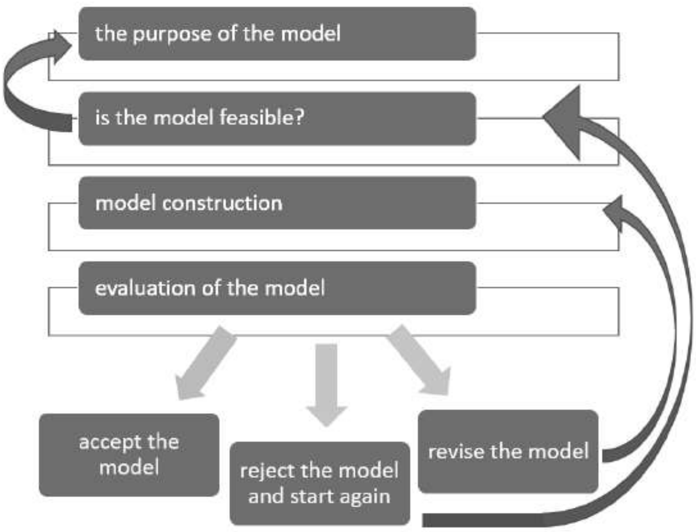

Fig. 2 Creation of the model Source: [15]

The feasibility of the model depends on several limiting factors. The most common include the time factor; data factor - availability, completeness and detail of data; and the tool factor (availability of a suitable tool).

The following is the general construction of the model itself, which includes four basic steps (more Figure 3).

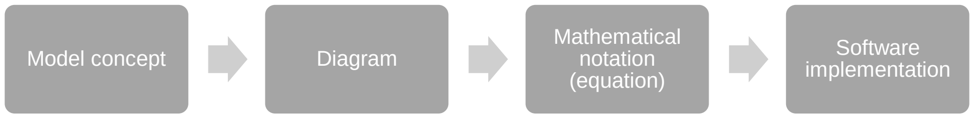

Fig. 3: Construction of the model, Source: [15]

The model concept describes which variables and parameters are essential for the model; division of these variables into state (determining the state of the described system) and exogenous (independent of the state of the system); to what extent the model will be detailed, and whether and how the quantities will be structured. The diagram shows the interrelationships between individual variables and parameters. By means of mathematical notation, equations sufficient to calculate all unknowns of the theoretical model are compiled, supplemented by boundaries placed on parameters and variables. At the same time, it is defined whether it is a static or dynamic model. The software implementation of the model is carried out through a suitably chosen software tool.
Evaluating the model is difficult for individual problems. In general, it depends on the purpose for which the model was created, on the possibilities of well-chosen variables and parameters, on the short-term or long-term of its prediction. No model ever becomes reality, it was created to be close to it, and it is only the decision of the solver how close enough it is to reality. If the model meets the requirements of the solver, it is accepted; if not, it is changed (repaired) or completely rejected.

3.2 Creation and construction of the AVM

Creating an AVM for residential real estate can be a complex and data-intensive process, but it can be divided into several general steps, which are broken down as follows:
1. Data collection and identification of variables
Collecting large amounts of data on residential real estate transactions, including characteristics of individual properties such as location, size, age, and other relevant factors that may affect property value. It is also recommended to collect other data such as market trends such as average sales prices, supply and demand trends, interest rates provided, and inflation information. After collecting the data, it is important to identify the relevant variables that will be used to construct the AVM. Some of the key variables include location, property size, age, number of bedrooms and bathrooms, and any other unique attributes such as a pool, patio, or garage.
2. Choosing a suitable modelling technique
Various modelling techniques and methods can be used for AVMs, including regression analysis, machine learning, and neural networks. The choice of a suitable technique and method depends, among other things, on the suitability of use for the given type of data set and objectives. Different approaches to property price modelling were mentioned in the previous post.

3. Data preparation
Next, we do the actual work with the database. Working with data includes cleaning, transforming and pre-processing the database so that the obtained data is consistent and ready

for modelling. This may include removing outliers, imputing missing values, and normalizing the data.

4. Building the model
Building a model means the application of a selected modelling technique to build an AVM for residential real estate. This usually involves using statistical methods to identify relationships between variables and property values. This may include splitting the collected and post-processed data into training and test sets, selecting relevant features, and fine-tuning model parameters.

5. Model verification
Model validation is most commonly performed using statistical metrics and cross-validation techniques to ensure that the model is accurate and reliable. Verification ensures that the model accurately predicts property values based on their properties. This can be done by comparing the model predictions with the actual sales prices of the properties. If necessary, the model can be modified.

6. Deployment of the model
After the model has been verified, it is deployed in a production environment where it can be used to automatically generate valuations for residential real estate. AVM deployment is implemented through a website or application that allows users to enter individual properties of a given property as input data to obtain its estimated value.

7. Monitoring and updating the model
AVM performance monitoring is performed during the specified time stage. We monitor the accuracy of his price estimates and compare them with the actual selling prices of properties with the same parameters at the same location. As needed, the model needs to be updated to ensure its continued accuracy and relevance.

Creating an AVM for residential real estate is a relatively complex and complex task that requires considerable professional, technical knowledge, and skills in the areas of statistical modelling and the real estate market. Activities during its creation often require cooperation with a team of data scientists (programmers) as well as real estate professionals, so that the resulting model is accurate, reliable, and useful.

4. Input data and their quality

Big data allows AVM models to incorporate machine-learning techniques to improve accuracy. By analyzing large data sets, machine-learning algorithms can identify patterns and correlations that would be difficult for humans to identify. This allows AVM models to adjust and improve their estimates over time as they receive more data and feedback. Big data has also enabled AVM models to expand their coverage beyond traditional real estate markets. AVM models can now estimate property values in emerging markets or areas with limited public record data. This is especially useful for investors or lenders who want to assess the value of properties in areas where traditional valuation methods may be less reliable.

In general, we can say that the quality and detail of the input data naturally affect the accuracy and quality of the result. The accuracy and reliability of an AVM de-pends largely on the quality and quantity of data used in the model. AVMs rely on a large amount of data to create property valuations, such as recent home sales, specific property characteristics, property location, and current market trends. If the data used in AVM are incomplete, inaccurate, or out of date, the resulting valuation of the property may be unreliable. In addition, if AVM does not take into account unique features or characteristics of a particular property, such as recent renovations or views, the appraisal may not accurately reflect the property's true value. Additionally, the AVM

algorithm used to analyze the data must be able to identify and account for any anomalies or outliers in the data, such as unusual property properties or sales transactions, which may bias the results.
However, high-quality inputs do not always necessarily guarantee high-accuracy results. Accuracy depends primarily on the valuation method and its sophistication. Through detailed and objective testing, we can reveal the accuracy of the selected valuation method or model.
Valuation methods that take into account the specific variables of each residential property (e.g. exact location or technical condition) can be considered more advanced and, as a result, more accurate. On the contrary, the incompleteness of the data or these variables often caused the unreliability of this method and led to inconsistency of the model, whereas this information should be taken into account in advance to calculate in advance with reduced accuracy. Therefore, it is important that AVM developers constantly update and validate the data used in their models to ensure their accuracy and reliability. Likewise, AVM users should carefully consider the quality and relevance of the data used in the model before relying on the result-ing property valuations.

5. Methodology and methods used in the creation of the AVM model under Slovak conditions: Case Study Bratislava

The very selection of the appropriate method to create the AVM model preceded and consisted of a long-term automated collection of big data (Big Data) regarding the offer prices of residential properties from the four largest real estate portals in Slovakia. In its initial phase, the creation of the model focused on the capital of the Slovak Republic, Bratislava. The offer prices of real estate were collected systematically, which are also considered transaction prices in the given location. This is a spatial projection of real estate prices in the given area, and therefore, the influence of the location is already taken into account in the final selling price. Bratislava was divided into 44 micro-localities, which had no basis in the territorial division of the city into districts. These micro-locations were chosen based on knowledge of the local real estate market.
A hedonic model (so-called hedonic regression) was chosen as an approach to modelling the prices of residential real estate (specifically, apartments in apartment buildings), which examines individual characteristics of apartments and their impact on the resulting price of the real estate. This approach was mentioned in more detail above.
When specifically determining the price of the selected property, the exact location (street and reference number) where the investigated property is located was entered. Through the database of offer price data from the portals (for the last available quarter), at least seven properties are subsequently selected, which are located in the closest distance to the searched location, while the search radius in the map projection was limited (in our case, we chose a radius with a limit of 300 meters from the searched point). Subsequently, of these seven closest searched apartments, two that had borderline prices (apartment with the highest and lowest price) were removed. Based on the price of the remaining five apartments, the price range (average price per square meter) in the given location. So far, this range was only a rough estimate of the price of the apartment searched in a specific location. However, this price did not take into account the unique specifics of the apartment, and subsequently we proceeded to maximize the accuracy of the data on this property. The latter enters the model through a specific point assessment of specific detailed physical parameters and characteristics of the property. These parameters and characteristics were scaled and defined into areas that formed the main criteria (C1, C2, and C3). Subsequently, these were divided into partial criteria (c1.1; c2; ...cn). Examples of the main and partial criteria, for better understanding, are presented in Table 1 below. Individual

partial criteria were subsequently assigned specific weights. The evaluation of points for a specific apartment in individual parameters (criteria) was subsequently multiplied by these weights. The subsequent sum of the partial criteria formed the resulting main criteria, which enter the final price of the estimated apartment.
The mathematical notation of the model described above is as follows:

$$P = f(\mu Price\ (5);\ C1,\ C2,\ C3;\ t) \quad (1)$$

Where:
P - is the sought price of the property;
µPrice (5) - price factor - average price (per m2) of at least five nearest apartments of similar size / the same number of rooms and technical condition, offered on the market at the same time. This component is used to determine a rough estimate of the property's value. This factor takes into account the site's market analysis.
C1, C2, C3 - are the main criteria, composed of partial criteria (c1.1, c1.2, ...cn), reflecting the specifics of the given property (apartment). A key part of the property price depends on the characteristics of the specific property.
t - Time factor - the time (time) of the property on the real estate market, as a factor that affects the decrease in the price of the property.
Table 1 shows the breakdown of the main and sub-criteria that enter the model as sub-characteristics of the property that affect the resulting price of the apartment.

Table 1. Main and partial criteria entering the AVM model.

Sign.	Main criterion	Weight of the main criterion	Sign.	Composition of partial criteria	Weight of the partial criterion
C1	apartment	0,45	c1.1	area	0,100
			c1.2	number of rooms	0,090
			c1.3	technical condition	0,070
			c1.4	disposition	0,060
			c1.5	floor	0,040
			c1.6	equipment	0,030
			c1.7	design	0,015
			c1.8	balcony/loggia/terrace/front yard	0,025
			c1.9	cellar/pantry/pantry	0,010
			c1.10	orientation	0,010
A weighted sum					0,450
C2	apartment house	0,25	c2.1	age of the building	0,050
			c2.2	technical condition	0,060
			c2.3	construction type	0,020
			c2.4	number of floors	0,020
			c2.5	technical equipment	0,030
			c2.6	parking options	0,070

A weighted sum					0,250
C3	external factors	0,3	c3.1	location	0,100
			c3.2	transport infrastructure	0,060
			c3.3	civic amenities	0,045
			c3.4	greenery	0,030
			c3.5	social composition of the population	0,010
			c3.6	crime	0,010
			c3.7	pollution	0,010
			c3.8	job opportunities	0,010
			c3.9	entertainment and recreation options	0,010
			c3.10	distance from the city center	0,015

The error rate is an important metric for evaluating the performance of a system, as it provides insight into the system's reliability and accuracy. High error rates can indicate problems with the system that need to be addressed, such as software bugs, incorrect data entry, or equipment failures.
The AVM error rate can vary depending on several factors, such as the type and quality of the data used, the level of sophistication of the model, and the complexity of the property being valued. AVMs are generally known to have a margin of error of around 5% to 10%, meaning that their estimates can vary by this percentage from the real market value of the property. However, it is important to note that this can vary widely depending on the particular AVM used and the conditions of the real estate market at the time of valuation. The following is the method to calculate the error rate for the mentioned AMV.

$$\textit{Model error} = P_{AVM} - P_S \quad (2)$$

Where:
P_{AVM} - AVM price of the property;
P_S - selling price of the property.

$$\textit{Percentage of model error} = (P_{AVM} - P_S) / P_S * 100\% \quad (3)$$

The result of the model evaluation is the percentage error. If this value is positive, then it is an overestimation of the price of the property; on the contrary, if this value is negative, it is an underestimation of the price of the investigated property. Multiple studies discuss the precision of AVM metrics; see [5], [16], or [17].

Conclusion

The creation of the aforementioned AVM model was based on the cooperation of a team of software analysts and real estate experts. The core of the entire AVM creation process was the collection and processing of Big Data regarding real estate, especially their selling prices, but also other characteristics such as location, size, and other partial specifics. With the increased availability of all of this data, AVM models can provide estimates that are more accurate, faster processing times, and greater coverage. One of the most significant impacts of big data on AVM models is the ability to include a wider range of data points. Traditional AVM models often relied on limited data sources that only provided insight into the real estate market. With big data, AVM models can incorporate data from a wider range of sources, such as transaction data from online real estate marketplaces, real estate data from government agencies, and consumer data from social media and other sources. Big data also allows AVM models to incorporate machine-learning techniques to improve accuracy. By analyzing large data sets, machine-learning algorithms can identify patterns and correlations that would be difficult for humans to identify. This allows AVM models to adjust and improve their estimates over time as they receive more data and feedback. Another way that big data has affected AVMs is by enabling them to be more customizable. With the ability to incorporate a wide range of data sources, AVMs can now be tailored to specific markets, property types, and user preferences. This makes AVMs more useful and relevant to a wider range of users, including lenders, appraisers, and real estate agents. Overall, the impact of big data on AVM models is significant, allowing for more accurate and comprehensive estimates of real estate values. As the amount of available data continues to grow, AVM models are likely to become even more accurate and reliable over time and have an even greater impact on the real estate industry.

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