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# Information system of economic and mathematical modelling of pricing in the residential sector of Ukraine

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**Abstract.** The article deals with the development of a web application on forecasting the dynamics of prices in the residential sector of Ukraine. The classification of economic forecasting methods according to which they are divided into formalized, extrapolated, intuitive methods of forecasting the financial state is presented. It has been established that forecasting methods should meet the following requirements: a combination of subjective value and objective significance of estimates; clear application of estimates, which does not allow different interpretations regarding the choice of methods; create the ability to accumulate statistical information and use it for forecasting. The model of standard square collocation for the real estate market is presented. A web-based application for forecasting the dynamics of prices in the Ukrainian housing sector was developed and tested.

## 1. Introduction

Today, there are a large number of statistics covering almost all areas of human activity. This also applies to real estate. On the Internet, you can find web portals for advertising real estate in Ukraine. General statistics, such as the average cost per square meter by a city or a region, are publicly available. Therefore, each user of the global network has the opportunity to view the dynamics of changes in real estate prices, to analyze it, and then to draw conclusions from the analysis.

However, looking only at the figures in the table or graph, it is difficult to say exactly how the price of real estate has changed over some time. There is also a more important, practical point of view, as to how the price will change in the future. A mathematical model of the real estate market should be developed to answer this question. With the adequacy of the model, it is easy to predict changes in real estate.

The average Internet user is more likely to be unable to interpret statistics correctly, and even more so to predict price changes in the future. Therefore, there is a need to develop a specialized web application where an average user who is not an expert in mathematics and economics, will be able to interpret the statistics correctly and understand how the real estate market can develop in the future.

## 2. Theoretical background

Economic and mathematical modeling has been studied by many scholars, in particular: Vakulenko



examines the conceptual principles of pricing in the real estate market [12], Voronin, Liantse & Mamchin investigates the real estate market in three aspects: problems, trends, forecasting [13], Mezentseva, Dmitrieva, Kuchevsky, Marynich & Stebletska conduct socio-geographical study of Ukrainian housing market [6], Potashev considers forecasting the price situation in the housing market in times of economic crisis [8].

Shapovalova investigates real estate price forecasting in the light of business cycle trends [10], Shaposhnikova analyzes time series of the primary residential real estate market in Kyiv [9].

Babeshko et al considers forecasting collocation model quantitative characteristics of the main financial instruments of the stock market [1] and forecasting of financial and economic indicators for heterogeneous data [2].

However, the economic and mathematical modeling of pricing in Ukrainian housing sector and the problem of developing an informative web application on forecasting price developments in Ukrainian housing sector have not been sufficiently investigated.

Therefore, the aim of the study is to develop an informative web application on forecasting price dynamics in the residential sector of Ukraine.

### 3. Results

Economic forecasting methods are a set of forecasting methods and techniques that allow, based on the analysis of retrospective data, external and internal factors of influence, as well as their quantitative changes, to make convincing predictions about the future development of the economy or society as a whole. For forecasting, statistical information on the processes of the recent years and expert assessment of trends in macroeconomic indicators is carried out. The objects of forecasting are the economy, its industries, regions, forms of ownership, etc. To choose the forecasting method, the aim and objectives of the forecast and the period for which it is formed should be determined. Moreover, the specifics of the forecasting object, types, completeness and probability of the input information, as well as some other factors should be considered [7].

#### 3.1. Formalized and extrapolated methods of forecasting financial condition

One of the groups of methods of forecasting the financial state of enterprises consists of formalized (quantitative) methods, which include stochastic, deterministic methods and methods of economic and mathematical modeling. A common characteristic of formalized methods is to evaluate the future state of projected objects and to quantify the projected indicators that characterize them, based on a retrospective study of their development [11].

Quantitative forecasting methods are extremely important in managing the enterprise financial resources and forecasting its financial condition. Although the application of these methods also has some limitations. First, any formalized forecasting method does not allow to take into account all the factors influencing the target parameter, but simply simplifies the correlation between the indicators ([8], [13]).

Secondly, for each forecast indicator, several variants of the forecast can be formed, each of which will have a high probability of realization, which does not allow making unambiguous conclusions about the dynamics of phenomena development, based solely on quantitative indicators.

The use of quantitative methods in the construction of forecasts for the short term when it is possible to reach fairly accurate estimates of changes in indicators is the most effective [3].

Formalized forecasting methods are based on stochastic methods, including methods for trend extrapolation, regression, and auto regression. Stochastic methods are based on the probabilistic nature of the relationship between variables, whose formalization accuracy increases with the increase of the input of empirical data [4].

Stochastic methods have many variations and can be adapted to almost any prediction need, making them the most common of the methods studied. The main disadvantage of using these methods is the possibility of obtaining significant errors in forecasting due to the influence of random fluctuations on the change of indicators.

Another method of short-term forecasting of economic phenomena is extrapolation.

The term “extrapolation” has several interpretations. Extrapolation is, in a broad sense, a method of scientific inquiry that consists of extending the conclusions drawn from observations of one part of the phenomenon to another part of it. In the narrow sense, it is a function of defining the function of other values outside the series by a series of data.

Extrapolations are the study of past and present sustainable tendencies of economic development and transfer them to the future.

The purpose of such a forecast is to show what results can be achieved in the future if we move at the same speed or acceleration as in the past [13].

The forecast determines the expected economic development assumptions based on the hypothesis that the main factors and trends of the previous period will be preserved for the forecast period or that the direction of their changes in the considered perspective can be justified and taken into account. A similar hypothesis is made based on the inertia of economic phenomena and processes.

In forecasting, extrapolation is used in the study of time series.

Extrapolation, in general, can be represented as a certain value of a function  $y_t^* = f(y_t, l, a_i)$ , where  $y_t$  – the predicted value of the level of several dynamics;  $i$  – bias period;  $y_i$  – the bias period taken as the extrapolation basis;  $l, a_i$  – parameters of the trend equation.

Depending on the peculiarities of changes in levels in the series of dynamics, extrapolation methods can be simple and complex.

Simple methods of extrapolation are based on the assumption of relative constancy in the future of absolute values of levels, an average level of a series, average absolute growth, average growth rate [2].

Consider the following methods of extrapolation.

Extrapolation based on the mean of the row-level uses the principle that the predicted level is equal to the average of the row levels in the past,  $y^* = \bar{y}$ .

In this case, the extrapolation gives a prognostic point estimate. The exact coincidence of these estimates with actual data is unlikely. Therefore, the forecast should be in the form of an interval of values. The confidence interval of the forecast for the mean with a small number of observations is according to the formula  $y^* = \bar{y} \pm t_\alpha \cdot \sigma \sqrt{1 + \frac{1}{n}}$ , where  $t_\alpha$  is the tabular value of the Student's  $t$ -test with  $n - 1$  degrees of freedom;  $\sigma$  is the root-mean-square deviation.

The mean square deviation for the sample, in turn, is:  $\sigma = \sqrt{\frac{\sum(y_i - \bar{y})^2}{n-1}}$ , where  $y_i$  is the initial level of the dynamics;  $n$  – the number of levels of several speakers.

The confidence interval obtained takes into account the uncertainty associated with the estimate of the mean, and its use for forecasting increases the degree of reliability of the forecast. However, the disadvantage of this approach is that the confidence interval is not related to the bias period.

Extrapolation by the average absolute increase can be carried out when we consider the general tendency of the development of the phenomenon linear.

To calculate the predictive value of the level, it is necessary to determine the average absolute increase  $l$ . Then, knowing the level of the dynamics taken as the basis of extrapolation  $y_n$ , write down the extrapolation formula:  $y^* = y_n + \bar{\Delta} \cdot l$

Extrapolation of the average growth rate can be carried out when there is reason to believe that the general trend of several dynamics is characterized by a show curve. The predicted level of the series, in this case, is determined by the formula  $y^* = y_n \cdot \overline{TP}$ , where  $\overline{TP}$  – the average growth rate, which is calculated by the formula of the geometric mean.

The confidence interval of the average growth rate forecast can only be determined if the average growth rate is calculated by statistically estimating the exponential curve parameters.

All three considered methods of trend extrapolation are the simplest, but also the closest.

Complex extrapolation methods involve the identification of a major trend, that is, the use of statistical formulas to describe a trend. The methods of this group can be divided into two main types: analytical (growth curves) and adaptive.

The basis of analytical methods of forecasting (growth curves) is based on the principle of obtaining, by the method of least squares, the estimation of the determined component, which characterizes the main trend.

Adaptive forecasting methods are based on the fact that the process of their implementation is to calculate sequential values of the predicted indicator over time, considering the degree of influence of the previous levels. These include the methods of the current and exponential averages, the method of harmonic weights, and the method of auto-regression.

The method of analytical trend equalization (the least squares method) can only be applied if the development of the phenomenon is well described by the constructed model and the conditions that determine the trend of development in the past will not change significantly in the future. When these requirements are met, the forecasting is done by substituting in the trend equation the values of the independent variable  $J$ , which corresponds to the magnitude of the bias period [12].

The procedure for developing a forecast for the use of analytical trend equalization undergoes the following steps:

- 1) selection of the curve shape that reflects the trend;
- 2) identifying indicators that quantify trends in change;
- 3) estimation of the probability of predicted calculations.

You can choose the shape of the curve based on the graph, the general appearance of which usually indicates:

- 1) whether the dynamic range of the indicator has a clear trend;
- 2) if the trend is smooth;
- 3) what the nature of the trend is.

When answering these questions, it must be remembered that the external simplicity of the graph is wrong. Any dynamic task is much more complicated than a static one, and every point in the curve is the result of a change in the phenomenon, both in space and in time.

In this regard, to improve the validity and likelihood of alignment to more accurately identify the current trend, it is necessary to carry out a variant calculation for several analytical functions and to determine the best form of communication-based on expert and statistical estimates [8].

In the second step, it is necessary to determine the parameters of the equation of communication. To do that we use the method of least squares. In this case, the equalization function will occupy a position among the actual values of the indicators, in which the total deviation of points from the function will be minimal.

A reliable and reasonable estimation of the obtained results can be given using such statistics as average growth rate, total and residual variance, correlation coefficient, correlation index, the correlation coefficient of the original series and the number of deviations determined by the difference of actual and equivocal data.

To test the hypothesis of the presence or absence of autocorrelation, use tables with critical values of the autocorrelation coefficient at different levels of significance. If the table value of the autocorrelation coefficient is higher than the actual one, then it can be argued that the autocorrelation is missed or eliminated, and therefore formulas can be used to probabilistically estimate the values predicted by these points.

For this reason, it is necessary to develop a multifunctional web application that allows the user to correctly interpret statistics on the dynamics of real estate prices within Ukraine and make forecasts based on fluctuations in prices in the real estate market.

Therefore, to implement this web application, we need to:

- develop website design;
- create a database and populate it with data provided by <http://domik.ua/nedvizhimost/dinamika-cen.html>;
- output statistics in tables and graphs by date and every month;
- realize the ability to save data in json and xml formats;
- enable site visitors to register and authorize:

- to implement a model of standard square collocation for forecasting housing prices in Ukraine;
- enable users to make an adequate forecast of price movements for 1-12 months.

### 3.2. *Technical specification*

#### 3.2.1. *Goal and aim of creating an informative web application*

The web application should provide statistics on the sale of apartments in Ukraine and make a forecast based on these data.

The main goals of creating an information web application: provide the user with quick access to real estate statistics within Ukraine with a user-friendly interface, the ability to save the received data in the form of files of different formats and to make a forecast on the model of the average square collocation.

In the target audience of the web application, you can select groups such as Guests, Users, and Administrators.

#### 3.2.2. *Requirements for an information web application*

##### 1. Requirements for the structure and operation of the information web application.

The web application should be an information structure accessible on the Internet. Moreover, it should include interconnected sections with clearly separated features.

##### 2. Requirements for storing and updating information.

The web application information management system should view database records and the registered users. The procedure for updating statistics in the database should be carried out automatically and only when the data have not been updated for three days.

##### 3. Demarcation requirements.

The information hosted on the information web application is publicly available.

Web application users are divided into three groups according to their access rights:

- 1) visitors have access to the public part of the web application only. In addition, they can view statistics as a table, graph, and view and save data in json format;
- 2) registered users are provided with the access to additional features of the site, namely to view and save statistics in xml markup;
- 3) administrators have access to the administrative part, can view information about the registered users of the site as well as data on the sample stored in the database.

##### 4. Information web application structure.

The web application consists of the following sections:

- dynamics of changes in real estate prices and its forecasting (main page);
- database entries are available (administrative part);
- information about its registered users (administrative part);

The web application interface provides an intuitive view of the structure of the information contained therein. Navigational elements contribute to better understanding of the content: links to pages should be provided with headings, the conventions should be generally accepted.

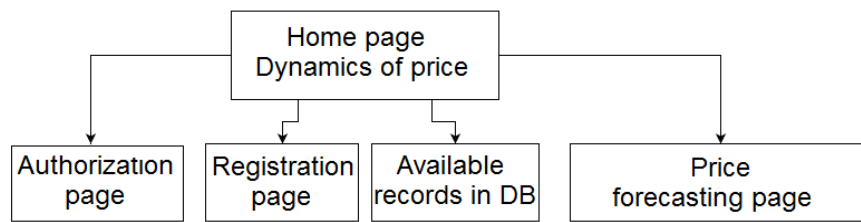
The system provides navigation to all available user functions and displays relevant information. A content menu system is used for navigation. The menu is a text block at the top of the page.

When selecting any of the menu items by the user, there is a smooth transition to the block with relevant information (statistical information, pricing, available records in the database, information about registered users).

The filling of the database of the statistical web application should be done automatically (the necessary information is taken from the following pages on the Internet <http://domik.ua/nedvizhimost/dinamika-cen.html>) [5]. Only the site administrator can view the available records in the database.

#### 3.2.3. *Navigation system (map of a web application)*

The relationship between sections of the web application is presented in figure 1.



**Figure 1.** Map of web application.

Content management system (administrative part) views database records and registered users’ data. The content management system has an interface that meets the following requirements:

- uniform design style;
- intuitive assignment of interface elements;
- displays only those features that are available to the user;
- provides the necessary data only to solve the current application problem information.

### 3.3. The functionality of sections

The following information is displayed on the main page:

- graphical user interface elements for input;
- statistical and forecast data in the form of tables and graphs;
- links to the pages “Authorization”, “Registration”, “Administrative part”, “Price forecasting”.

In the section “Authorization” the form of authorization includes email; password; password recovery links; registration form link.

The “Registration” section is displayed in the registration form, which includes: login; email; password; repeat the password option.

The “Records in the database” section should show all records in the database with a detailed description of each record.

#### 3.3.1. General design requirements

The style of the site is contemporary with a clean, minimalistic design in light blue and orange. The site design uses the concepts of material design. Fonts are tails in order not to strain the user's eyes.

The site header includes the logo centred and the main menu located at the top of the window (to the right of the logo) that contains links to all sections of the first level.

The basement has site information, links to additional resources, developer information, and contact information.

The header and navigation menu of the site are located at the top of the main page. In the area of the main page (figure 2) there is an input selection form, a table and a graph in which statistics are displayed.

### 3.4. RMS (root-mean-square) model for the real estate market

Using the root-mean-square collocation model, values with different physical, economic or mathematical nature can be observed and predicted ([10], [9]), that is, the dynamics of changes in housing prices in the coming months can be predicted. The collocation prediction model retains the main advantages of classical regression models and can be used not only to construct an optimal prediction of homogeneous data but also to evaluate any characteristics based on heterogeneous source information.

Description of the algorithm of the collocation method.

1. Enter the input data:

- $Y$  – time-series of real estate prices with an interval of a month;
- $n$  – the number of points in the time series;

- $m$  – is a parameter that shows how many months to forecast.
- 2. Centre the time series  $Y$ .
- 3. We calculate the auto-covariance function  $S$ .
- 4. We calculate the approximating function  $V$  by the method of significant parameters.
  - A parameter  $k$  is an index of the first number in an array  $S$  that is less than the value, where  $\sigma$  is the mean square deviation of the sample  $Y$ .
  - The parameter  $j$  is the index of the first negative number in the array  $S$ .
- 5. Calculate the auto-covariance matrix.
- 6. Calculate the forecast for  $m$  months.

The screenshot shows a web interface for data analysis. At the top, there are two main input sections. The first section contains a 'Region' dropdown menu set to 'Kyiv' and a 'Select' dropdown menu also set to 'Region'. The second section contains a 'Parameter' dropdown menu set to 'Middle price', a 'Currency' dropdown menu set to '\$', and an 'Approximation' dropdown menu set to 'Hi'. Below these is a 'receive statistics' button. Underneath, there is a summary row with 'Region Kyiv', 'Select Region', and 'Parameter Middle price'. Below that, 'Currency \$' and 'Approximation no' are displayed. A navigation bar includes 'Table', 'Graph', and 'Save file' buttons. The main content area features a table with the following data:

Date	By region
21.09.19	2600
24.09.19	2484
27.09.19	2523
01.10.19	2567

To the right of the table is a large empty box with a diagonal cross and the text '291 x 211'. At the bottom of the interface are two buttons labeled 'Json' and 'XML'.

**Figure 2.** Home page of the site.

The block diagram of the collocation method algorithm is shown in figure 3. The flowchart shows the additional functions used in the calculation:

- mean (arr) is a function that returns the average of an array of arr numbers
- reverse (arr) is a function that returns an array of arr with elements in reverse order;
- slice (arr, start, end) is the function that returns an array that is a cross-section of the arr array, starting from the start position and ending with the end position.

**3.5. Web application architecture design**

According to the terms of reference, the MVC model and the Laravel PHP framework should be used in the development of a web-based information application for real estate pricing.

The implementation of the MVC model for the development application is presented in figure 4.

Figure 4 shows a simplified MVC principle in Laravel. First, the user enters the URL he needs. The corresponding controller class method is then executed according to the URL.

Moreover, the query methods are explicitly listed here. It means that only “get” and “post” page requests/forecasting trigger the forecasting () method of the ForecastingController class.

Controller classes usually spell out the logic behind the application. It involves working with the database through model classes. Each controller class returns a representation, in which case it returns a blade template compiled into PHP.



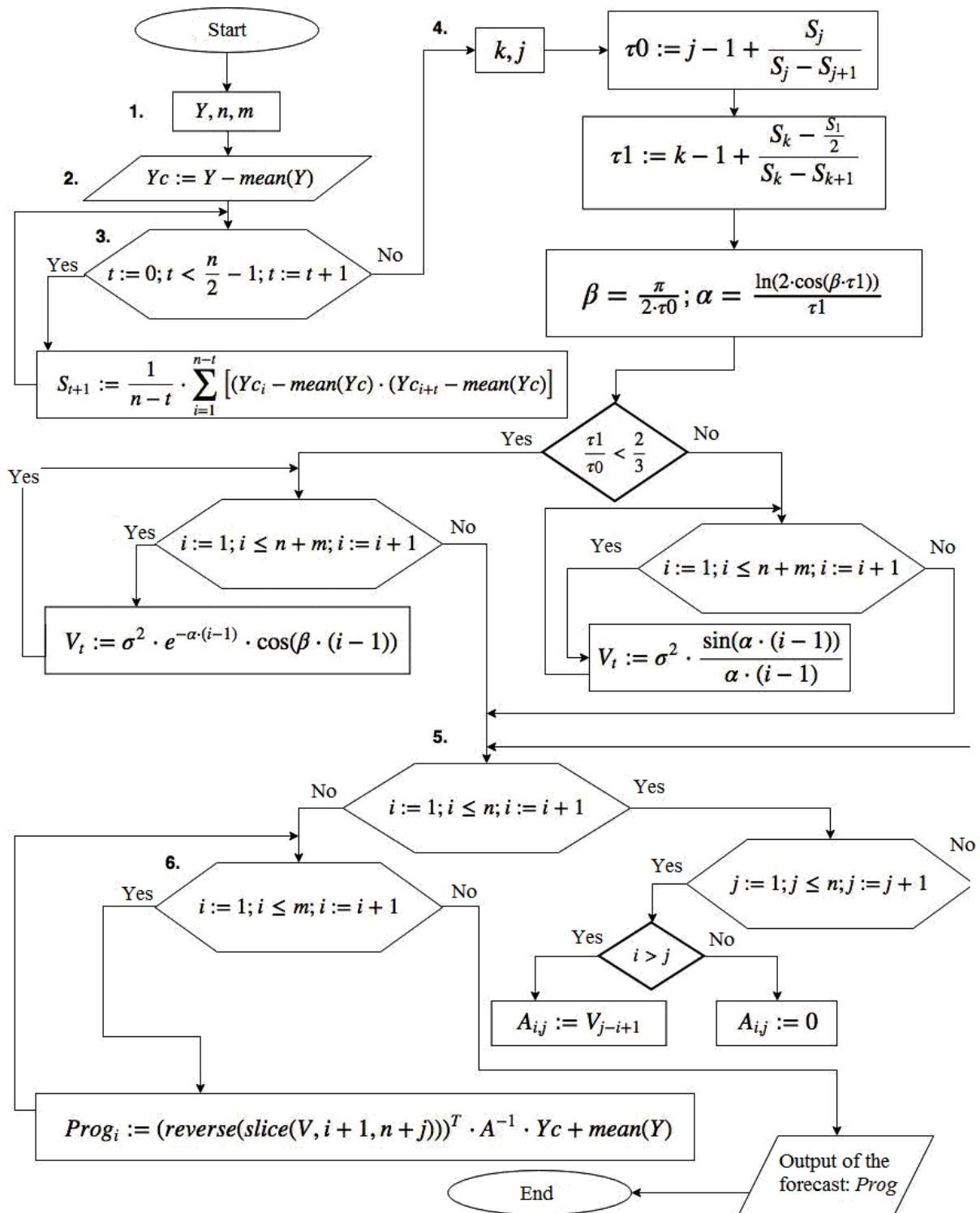
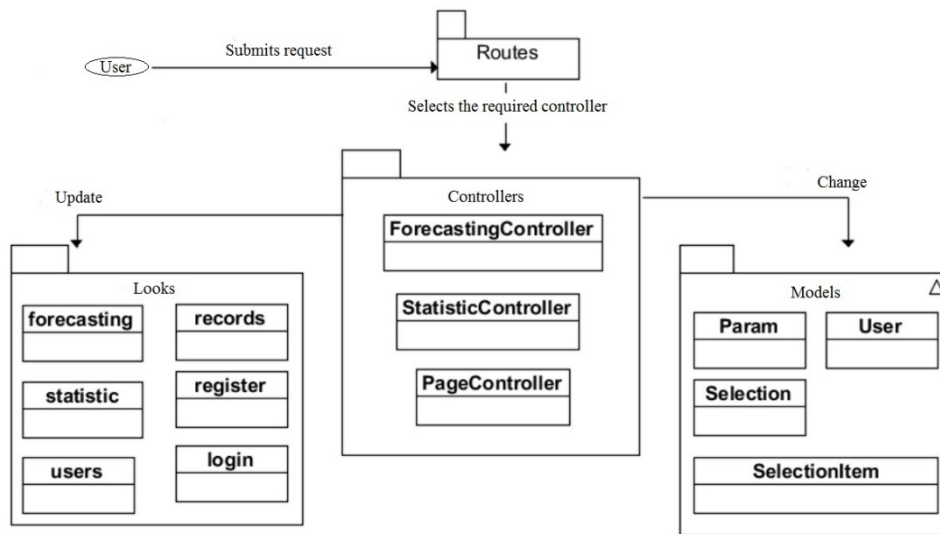


Figure 3. Flowchart of the collocation method algorithm.

ForecastingController is responsible for forecasting statistics and returning the finished forecast page (forecasting results are presented as a table and graph).

StatisticController is responsible for processing statistics and storing them in a database.

StatisticController deals with methods for working with the administrative page of the site.



**Figure 4.** Model MVC web application on Laravel.

User implies a model for handling user data registered on the site.

Param is a class model for working with the Params table, which stores additional parameters for forecasting processing.

Selection is a class model for working with a Selections table that stores statistics in JSON format.

SelectionItems is a model class for working with a SelectionItems table that contains additional information about a sample (for example, a specific area or type of house).

Forecasting view is a blade template that displays the results of the forecast in tables and graphs.

Statistic view is a blade template that displays price statistics in a specific region of Ukraine in the form of tables and graphs.

“Users” view displays information about all registered users in the administrative part of the site.

“Records” view displays detailed information about available statistics samples in the administrative part of the site.

Register view displays the registration form for new users.

Login view displays the authorization form.

### 3.6. Software testing

One of the available statistical data sets has been selected to test the implementation of the RMS method and the operation of the information web system as a whole [5].

Source statistics set information:

- region: Kyiv;
- sampling: by district (Darnytskyi);
- currency: dollar;
- approximation: moving average (5 points);
- parameter: average price per square meter. m.

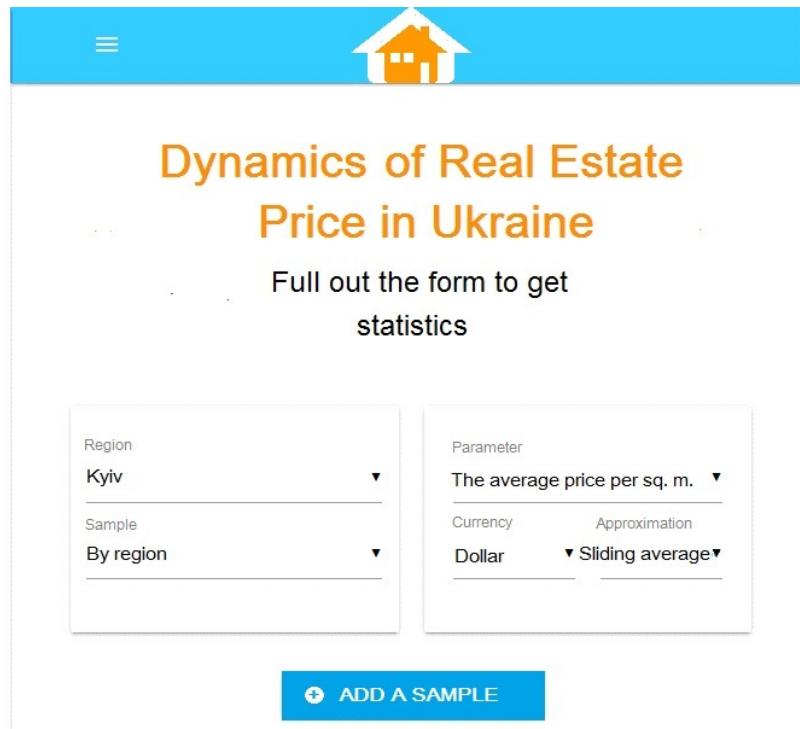
The forecasting period is 6 months.

The layout of the main forecasting page is presented in figure 5.

The result of the simulation is to predict the dynamics of changes in real estate prices in the form of a table (figure 6) and a graph (figure 7). In figure 6 Months are highlighted in bold, for which projected values of housing prices per square meter are constructed (from March 2020 to August 2020). The same information is given in figure 7 in the form of a graph (predictive values are plotted in the right half of the graph).

To ensure the adequacy of the built-in collocation model for online predictions of average prices per

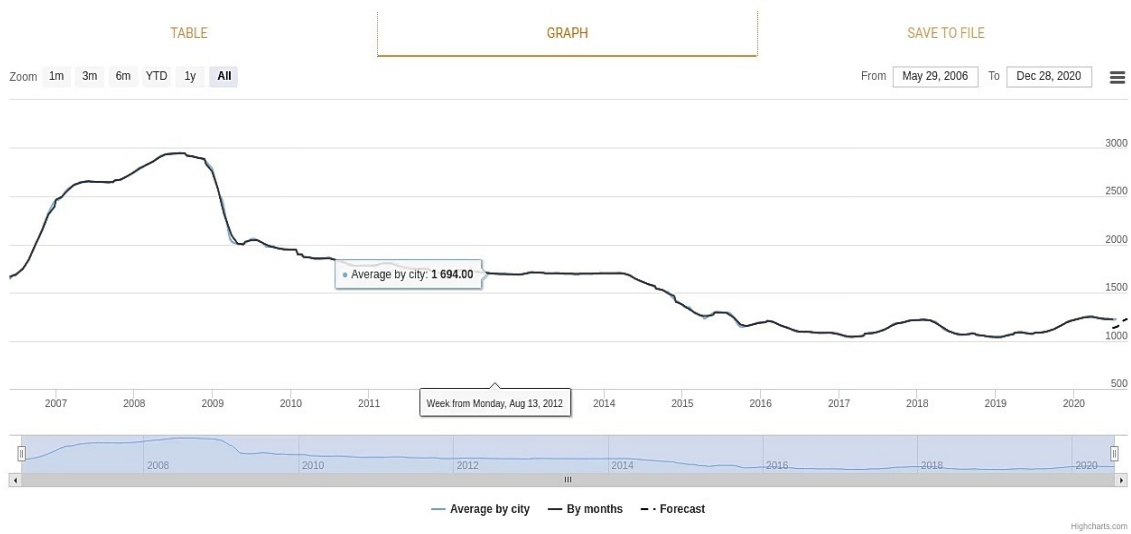
square meter in the housing market of Ukraine it is necessary to compare the forecast values for three months with the actual values for this period. Table1 shows the calculated average sales price of 1 sq. km. area of the constructed collocation model and the actual average sales data of 1 sq. m. of residential real estate in Kyiv for the specified period.



**Figure 5.** The result of the information web application implementation.

TABLE		GRAPH	SAVE TO FILE
BY DATE		BY MONTHS	
Months	Price - Average by city		
December 2020	1222,62		
November 2020	1213,27		
October 2020	1199,03		
September 2020	1180,23		
August 2020	1157,45		
July 2020	1131,49		
June 2020	1224,25		
May 2020	1226,80		
April 2020	1242,25		
March 2020	1252,25		

**Figure 6.** Results of the housing prices forecast in Kyiv.



**Figure 7.** Results of housing price forecasting in Kyiv.

The estimation of the adequacy of the obtained model proves its high accuracy (table 1), namely, the average error of approximation is rather small (up to 10%):

$\hat{A} = \frac{\sum_{t=1}^m \left| \frac{e_t}{Y_t} \right|}{m} \cdot 100\% = 2.2 \%$ , where  $e_t$  – the difference between actual and predicted values;  $Y_t$  – actual housing price;  $m$  – the number of time cycles of the forecast.

$R^2 = 1 - \frac{\sum_{t=1}^m (e_t)^2}{3\sigma^2} = 0.885$ , where  $\sigma = 29.63$ .

**Table 1.** Adequacy of the collocation model assessment.

Period	Factual price, \$ per sq. m	Estimated average selling price, \$ per sq. m	The error of approximation, %
July 2020	1223.3	1131.5	7.5
June 2020	1221.0	1224.3	0.3
May 2020	1224.4	1226.8	0.2
April 2020	1238.8	1242.3	0.3
March 2020	1253.8	1252.3	0.1
February 2020	1242.4	1173.4	5.6
January 2020	1224.8	1208.9	1.3
December 2019	1212.0	1178.6	2.8
November 2019	1177.6	1143.6	2.9
October 2019	1142.0	1114.0	2.4
September 2019	1108.4	1084.7	2.1
August 2019	1086.3	1071.2	1.4

Thus, it makes possible to use the RMS model to forecast real estate prices in the short (up to one year) and in the medium (from one to three years).

#### 4. Conclusions

The article deals with the development of an informative web application for forecasting the dynamics of prices in the residential sector of Ukraine. The classification of economic forecasting methods according to which they are divided into formalized, extrapolated, intuitive methods of forecasting the financial state is presented. A web-based application for forecasting the dynamics of prices in Ukrainian housing sector has been developed and tested.

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