

## РОЗДІЛ 10

# МАТЕМАТИЧНІ МЕТОДИ, МОДЕЛІ ТА ІНФОРМАЦІЙНІ ТЕХНОЛОГІЇ В ЕКОНОМІЦІ

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### MODELING OF THE REAL ESTATE MARKET REFLECTION WITH THE USING OF DATA MINING

The features of reflection on the real estate market are analyzed. It is investigated the causes of information reflection in the market. It is determined the factors that cause reflection on the information market still second property, and the relationship between them. It is built cognitive model of economic reflection information agent for the real estate market. The cognitive model for real estate market is suggested. It is done overview of data mining methods used for the study of financial markets, including real estate market. It is analyzed the features of the property market, which require the using of methods of data mining. It is suggested the algorithm of real estate market data mining. On the basis of consideration coherent market hypothesis for the real estate market in Ukraine a method for identifying the corresponding phase is given.

**Keywords:** reflection, real estate, the uncertainty, decision making, cognitive model, data mining.

**Introduction.** In the 21st century, in the formation and development of the information society, it's particularly important the institutionalized economy while taking any economic decisions are not just objective forms of information circulating in the economic space (such as legal documents, statistics, analytical research) but also subjective opinions, interpretations, opinions about events happening today and projected in the future. This is special characteristic of financial markets, which one of the main objectives is getting increasing profits, including the real estate market. If the real estate market is well-developed, and all economic agents that act on it will be able to combine all the information on investment objects, dynamics of other agents price behavior including all the rules and regulations established in the market, an institutional process and creation of capital is catalyzing. This is one of the manifestations of reflection information, which increases the relevance of this study.

**Literature review.** The issue of reflection research and modeling is analyzed in the famous domestic and foreign scholars works of Davison, Cramer [1], Lepa [2], Soros [3] etc. These writings explored the essence of the concept of "reflection" of the level, the possibilities and the need for reflective management, and simulation problems using reflection not only of classical (Boolean logic, graph theory), but also modern (fuzzy mathematics, cognitive modeling) modeling techniques. In particular [4] it is analyzed the reflection features in various sectors of the economy: in industry, insurance companies, in banking, in the tourist business, etc., but informative reflection of financial markets, including the real estate market, is not investigated.

Existing studies allow concluding that the financial market reflection is closely linked to its current state, which in turn is determined by the group sentiments. That is the real processes in the financial market – the result of a nonlinear relationship communication environment with the internal organization and action group consciousness. This statement meets coherent market hypothesis, according to which, as a rule, the market is in one of its four states: random walk, unstable transition, chaos and coherence. Let's note also

that coherent market hypothesis usually explains the empirical data, the amount of which is insufficient to affirmatively say relatively fractal. These problems of the financial markets properties and prediction are studied through the use of dedicated scientific works of Yanovsky, Filatov, Cheverda, Maksyshko.

The basis of information reflection developing for real estate market is suggested in [4; 5]. In particular, it is analyzed the real estate market features, characterized Ukraine's economy at the present stage of its development, the aims of his research. The study [6] presents the preconditions for the application of cognitive modeling for analyzing the real estate market, and develops a model that realizes the interaction of the real estate market. However, modeling reflection information directly in the market to this time is failed.

*The aim of this paper* is to study the characteristics of the reflection process in real estate market, and information modeling reflection of the economic agent in the market.

**Results.** To date, the reflection is present in all spheres of society, so there are many options for interpretation of the essence of the concept. In a general sense, *the* concept of "reflection" understand the complex and conscious psychological *process*, which is based assigned understanding and analysis of their individual actions and form their own ideas, values and stereotypes influenced internal factors [7]. The concept of "reflection" is a psychological term, as this process begins in the mental activity of man under the influence of various environmental factors. This reflection is a reaction to the economic agent events occurring in objective reality, creating his subjective judgment. Only after realizing the processes and phenomena individual acting in the market leads to certain economic results [1]. So there are certain relationships between the individual and reality (reality), that is, between subject and object of reflection, respectively, which are intermediate stage – the formation of subjective perception.

The economy of reflection is an essential factor in the enterprise, region, and country development; while the highest manifestation of consciousness (*reflection*) observed in free markets, including the real estate market in the system of private

property. If the state tries to control the processes that occur in the real estate market more, the less found self-awareness of economic agents because their responsibility for their own actions. Decisions what are made by economic agents (individuals, households, firms, government agencies) based on the subjective perception of reality is not always rational. So much research *information* requires *reflection* [2] of the financial market as a direct analysis process not only possible potential results of their actions, but the actions of other real estate market (buyers, sellers, brokers, etc.).

According to [8], the real estate market is considered as one of the segments of the financial market that is analyzed with the points of view of coherent market [9], according to which in the dynamics of the real estate market there next phase: random walk, unstable transition, chaotic market, coherence. This phase coherence, in particular, corresponds to the situation when there is a combination of extremely strong expressions of social consciousness and basic assumptions, which causes structural changes as a result of price trend.

Research allow argue that reflection as address economic agents focus on ourselves [2], in any area in particular, and real estate market, increasing with the onset of crisis events. The crisis in the real estate market as a particular case of phase coherence (because of significant impact of the fundamental factors [9]), is in the field of real estate market information [5], that is the object of analysis and reflection result real estate agents concerning the processes taking place in the real estate market.

In *reflection of real estate information* factors affect both the environment in which the decision and the individual are inherent characteristics that form the subject of a specific outlook reflection. These characteristics should include religion and education goals experience, knowledge and competence in specific fields, confident of life values, education, social status, and general social norms and rules, other psychological aspects of the subject of reflection. In addition, the importance of acquiring the circumstances that have not yet occurred, but may occur: certain developments in the legal field (for example, the adoption of laws and other legal acts, change of government, rallies, protests, etc.) in the economy (growth or falling prices, in exchange rates, etc.) and more. Thus, the triad formed the subject of reflection, "I know – I understand – I want to know" on which emerging objective effect on the real estate market.

Despite the deemed sufficiency objective information that occurs on the market, the occurrence of reflection effects include:

- spontaneous actions of economic agents (transient situation on the real estate market);
- knowledge of the lack of transparency in the information base property;
- knowledge of asymmetric information on the real estate market (some entities have access to complete information, others are deprived of such opportunities);
- inability unambiguous assessment of events occurring in the real estate market;
- limited authority in deciding certain economic agents.

It should be noted that the asymmetry of information on the real estate market is growing with the approach to phase coherence. At this time there is a combination of extremely strong expressions

of social consciousness and the fundamental assumptions that results in structural changes of price trend.

In contrast, phase coherence spontaneous action of economic agents is in the phase of a random walk that substantially corresponds to a situation where all (including representatives of various groups), investors confused, random decision, despite the collective opinion. This situation usually occurs directly during the recession processes immediately after a sharp decline.

When you exit from this state of the market is beginning to public rational thought, leading count to phase unstable transition that leads to the impossibility of an unambiguous assessment of events taking place at the real estate market. Then, the bundle market occurs; its distribution to groups and investors has different horizons (phase chaotic market).

Given the information presented factors reflection real estate market is an important determinant of cultivation of intellectual and moral institutions (for awareness about economic agents increase the quality of decisions made in the real estate market, improving the habits and morals).

In order to predict the outcome of reflection of information on the real estate market is not sufficient merely highlight features that are inherent to this phenomenon. It is necessary to go through a long and complicated process – the development and implementation of reflection information models. There is a need for reflection modeling information to identify impacts and relationships between them followed by their quantitative assessment. Among the methods that should be used for information modeling reflection, there is the cognitive modeling methodology that allow analyzing the influence of subjective factors and psychological characteristics of economic agents on objective indicators, including the dynamics of prices on the real estate market. Constructing informative reflection cognitive model for property market includes three components: an inner contour real estate market, contour perception of the economic agent, real estate external circuit (Fig. 1).

Note that the speaker volume of transactions in the real estate market is directly dependent on risk appetite because the more economic agents prefer risk (including the risk of investment), the more transactions conclude on the market. The efficiency of decision-making in the market real estate is directly proportional to the highest level of education affect economic agents transparency of information in the country and the quality of the legal framework. Accordingly, the better is degree of market transparency and higher quality information and legal environment in the country, the higher is the decisions efficiency in the market.

There is also an inverse relationship between the efficiency of decision-making in real estate and risk appetite economic agent, so the more economic agents prefer risk, and the less effective decisions they take.

Factors that belong to the external circuit (the state of the economy, transparency of information in the country, the quality of the legal framework) are directly related, and reinforce its influence each other.

The inner contour real estate market (to which factors are dynamic price and volume of transactions, quality of infrastructure, real estate and efficiency of decision-making on it) is stabilizing, as the correlation factors that belonged to it, there is

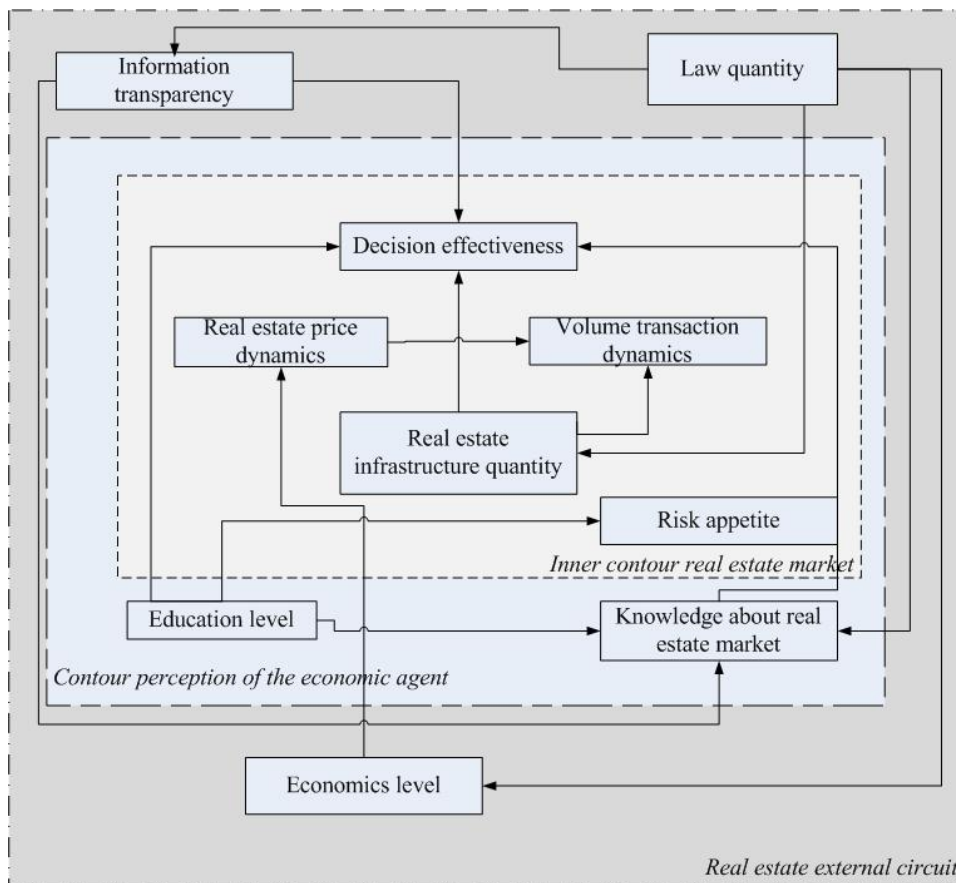


Fig. 1. Cognitive model of economic agent reflections information on real estate market

a positive (especially between quality infrastructure and efficiency solutions) and negative (between the dynamics of transactions volume and the effectiveness of decisions).

The obvious thing is that the dynamics of real estate prices none of these factors carries decisive influence, and can only adjust the current trend dynamics of real estate prices. To confirm this thesis will explore the characteristics of the column where vertices (variables cognitive model); and arcs (relationship between the variables of cognitive model) are making the cognitive model as cognitive map (Fig. 2).

Graf, which is presented in Fig. 2, is incomplete logical oriented non flat heterogeneous. Heterogeneity (heterogeneity) column indicates that cognitive model variables exert different effects on the dynamics of property prices. Characteristics of vertices (variables cognitive model) are presented in table 1.

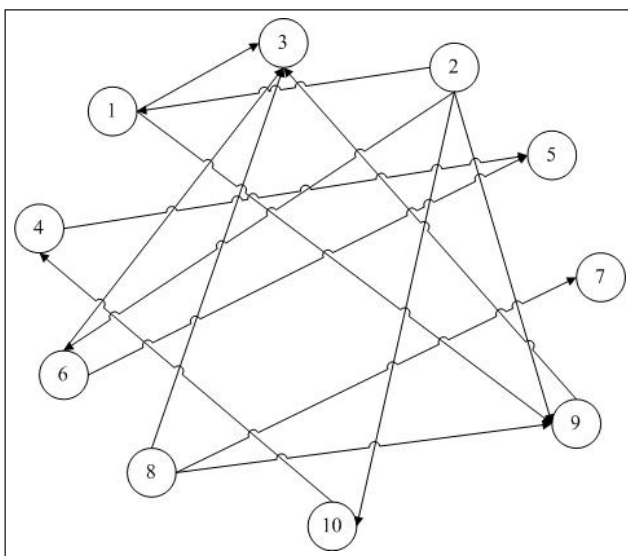


Fig. 2. Cognitive map of the economic information agent reflection for real estate market

Table 1  
Characteristics of vertices (cognitive map)

Characteristic Number	The Vertices Essence	Characteristic Level
1	Transparency of information in the country	2
2	The quality of the legal framework	4
3	Efficiency solutions	0
4	Dynamics of prices on real estate	1
5	Dynamics of transactions in the real estate market	0
6	The quality of infrastructure, real estate market	2
7	The tendency to take risks (economic agent)	0
8	Education level (economic agent)	3
9	Knowledge in the field of real estate market (economic agent)	1
10	State of the economy	1

Definition and summarizing the main characteristics of the column (cognitive maps) are presented in the table 2.

Table 2  
Main graph (cognitive map) characteristics

Characteristics Count	The Value of Properties	The Characteristic Essence
Radius Count	1	The presence of direct influence between the variables of cognitive models
The diameter of the column	Unable to determine the (lack of opportunities to get some other peaks)	The lack of relationships between some variables models
chromatic number	4	Number of the most significant variables of the model (variables that have the greatest degree)
Peripheral top (hanging)	Top 7	In sailing variable, which corresponds to the peak, appears during phase coherent situational market
Count Density	3	Expressions of direct influence between variable models

For reflection, a special type of knowledge, there are several consequences of the process of development of the situation. Each set of characteristics derives from the individual that participates in the reflection and phase of the real estate market. For example, phase coherent approach to market reinforces the reflection of economic agents, so that there are structural changes in the dynamics of prices and volume of transactions. During the phase of a random walk and unstable transition investors confuse, so make decisions are more spontaneous than intentionally.

Also significant fact is the content and tasks facing the person who decides on the real estate market. First of all, identify existing interdependencies, causal relationships in it, associations, unique, values time factors and circumstances, events and phenomena. In addition, a comprehensive study of the financial market usually provides its classification (or clustering) of objects and classes. While analyzing the real estate market is important to have an idea of the number of real estate types for various characteristics, and the number of states that market. It is also necessary to predict the course of events processes and trends of such complex dynamic economic system as the real estate market. To this end, appropriate use of the economic and mathematical tools that would take into account all the peculiarities of a given system and successfully cope with the task. In addition, it is essential to be able to extract information from the weakly-formalized data that exist in the system and beyond. This systematic approach is inherent data mining.

A significant contribution to the development of methods of data mining have made foreign and domestic scientists, particularly Zadeh, Dubois, Prado, Kofman. Improving methods of decision-making in the economy based on the methods of data mining carry Matviichuk, Nedosekin, Orlovsky, Shtovba. Comprehensive analysis of the real estate market includes the following components:

1) the collection, storage and processing of the information available. During this phase, all data contained in the system and outside it is necessary to collect and analyze the presence of "emissions" and the original errors, to alter information that you can analyze known, including, and new methods;

2) direct analysis, which includes operational and intellectual;

3) preparation of the analysis of received information in an acceptable form for the adequate perception of potential consumers for adoption on the basis of effective solutions.

In the real estate market information collection is mainly through private (such that real estate agents) and government agencies (including Bureau of Technical Inventory (BTI) – Municipal property company which carries out technical inventory of real estate and property evaluation and accounting. A real estate agency receives information about:

1) the amount of demand and supply of real property;

2) corridors prices of supply and demand;

3) the volume and prices of real estate transactions;

4) the "quality" of real estate, i.e. information about residential and commercial properties, the state of each of the separate properties (the presence of these appliances, balconies and prestige areas, etc.).

Based on the data available real estate agencies by using a sufficiently powerful mathematical tool can be concluded about the structure of the real estate market, namely the value of commercial and residential real estate; trends in the volume of transactions and property prices, changes in purchasing power, business activity in the country and the region and so on. Furthermore, comparing similar data in different regions may receive the classification of regional property markets, identify their characteristics.

The information contained in databases BTI is more quantitative. In particular, it contains information on the scope and structure of residential and commercial real estate funds of their owners (in terms of public and private sector). The information from data warehouses singled Bureau of Technical Inventory can be used to classify the market. In addition, comparing data from BTI and real estate agencies may perform factor analysis, namely, analysis of factors (events, events, etc.) that affect the structure of the market.

Solving the tasks on the basis of the information available it is advisable through data mining tools, which include all known development of mathematical modeling and information technologies. Directly it is used statistical (including correlation and regression analysis), methods of fuzzy logic, neural networks, genetic algorithms, decision trees, graph theory, and others. Indirectly involve methods of linear algebra, mathematical analysis and classical discrete mathematics and others. In addition, data mining must include information technologies, such as operational data analysis (On – Line Analytical Processing, or OLAP) and operations with databases. At present there is no clear classification methods in terms of their membership of a predictive analysis, because in fact they believe any methods to obtain valuable to review information about the economic system that will take effective decisions on management. Therefore, the present methods mathematical modeling and information technologies that relate to data mining and research are important for the real estate market (table 3).

Thus, analysis of table 3 gives an opportunity to develop an algorithm of data mining real estate market (table 4). In the first stage of the algorithm there is analysis of available data and clearing them of errors, including those committed by a



Table 3

Features techniques of data mining real estate market

Number	Methods of data mining	Features (including flaws) methods	Distressed properties on the real estate market research	Research Objectives real estate market, which can be solved by using this method
1	Statistical, regression-correlation analysis	Used only formalized data	Uncertainty (fuzzy factors affecting the dynamics of prices)	The analysis of interdependencies, causation, associations, unique, values time factors and circumstances, events and phenomena
2	Decision Tree		Nonlinearity (indirect the impact of certain factors on the dynamics of property prices)	Classification, clustering, data visualization
3	Methods of Fuzzy Logic	Can be used in the presence of qualitative data	The uncertainty (imperfect information, ambiguity in the findings and assessments of experts)	Classification, clustering, association analysis, unique, values time factors and circumstances, events and phenomena, data visualization
4	Neural networks	Require significant time and effort of individual settings	Asymmetry (difference in the reactions of market participants in the events market in strength and reaction time lag)	Classification, clustering, forecasting the dynamics of the property market, data visualization
5	Genetic algorithms		Instability (dynamic conditions and objectives of internal and external environment)	Forecasting the dynamics of the property market
6	Databases (data warehouse)	The structure of the method largely depends on the person who makes the decision; largely dependent on technical support (hardware)	Massiveness (presence of a significant volume of disparate data)	Data storage
7	OLAP – technology			Storage and operational analysis

Table 4

Data mining algorithm for the real estate market

Number	Step algorithm	The method used at this stage	The information used at this stage	Result phase
1	Data collection and their primary processing	Statistical, regression-correlation analysis	Data from real estate agencies, BTI, the State Committee of Statistics of Ukraine, other statistical information	Clearing raw data from the "emissions" and technical errors; interdependencies, causation, associations, unique, values time factors and circumstances, events and phenomena
2	Storing the required information and simple operation with them (statistical analysis, respond to inquiries, etc.)	Databases and OLAP – technology	Pure information after this stage	The database with the necessary statistical information
3	The classification / clustering property market	The decision making trees, fuzzy logic and neural nets methods	Information obtained in the previous step	Classification of real estate by type (residential, commercial); kind (primary, secondary); state of the object (for the middle class, luxury, etc.); regional clustering feature on the real estate market and other regional markets
4	Analysis of the current state of the property market as a whole and each of the classes (clusters) separately	Fuzzy logic methods	Data from real estate agencies, BTI, the State Statistics Committee of Ukraine, other statistical information	The definition phase of the real estate market on the basis of coherent market hypothesis
5	Predicting the dynamics of the real estate market	Genetic algorithms, the hybrid approach	Information obtained in the previous step and retrospective statistical information	A forecast of the real estate market (including the volume of transactions, the price of real estate, infrastructure, real estate volume, etc.)
6	Decision-making in the property market	The decision making trees, fuzzy logic and neural nets methods	Information obtained in step 3–5	Strategy on the behavior of the real estate market (the decision to purchase – selling real estate, etc.)

person while creating information databases (data transformed into information). At the second phase it is important to create a database that would allow quick and easy access to available information. The results of the classification or clustering further stages are getting the classes for the real estate market by type (residential, commercial); kind (primary, secondary); state of the object (for the middle class, luxury, etc.); regional clustering feature on the real estate market and other regional markets;

current state of the property market as a whole and each of the classes (clusters) separately with regard to coherent market hypothesis, dynamics of the real estate market; and so on. As for regional clustering data mining is especially important, because active development of the real estate market is a prerequisite for economy's sustainable development in general and region development in particular. It is known that Ukraine real estate market is regionally stratified. Proof of this is proactive in recent

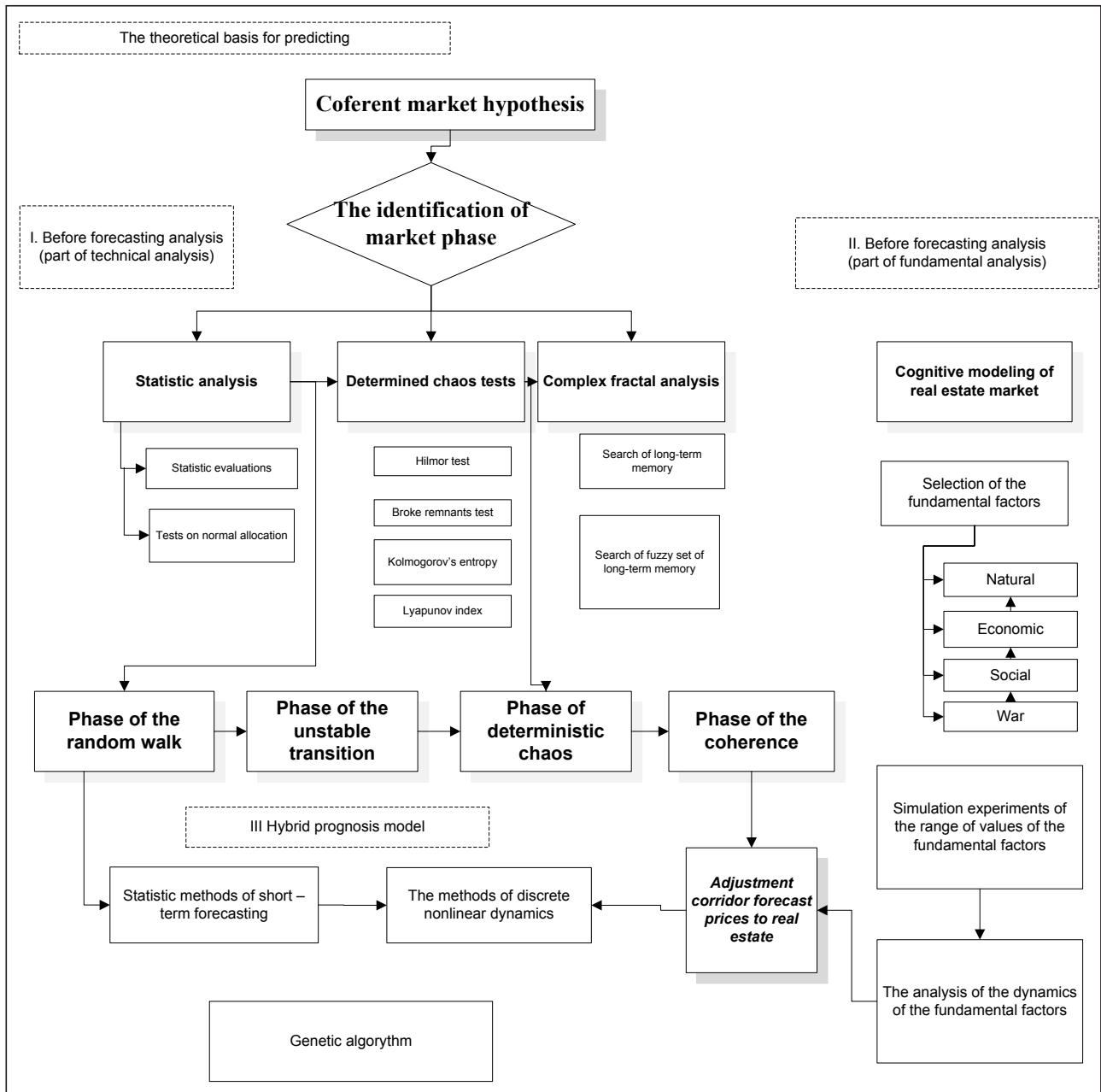


Fig. 3. General scheme of an innovative approach to forecast the dynamics of the price of the real estate market

years the growth rate of housing prices compared to the rate of income growth and the volume of housing in some cities and stagnant real estate market in others. Consequence of the uneven development of the real estate market across the country is the difficulty of obtaining an accurate prediction of the dynamics for ineffectiveness of decisions made in the real estate market (both social and investment). Therefore the before forecasting analysis of the real estate character dynamics is necessary for quality prediction of price behaviour in regional aspects.

We consider the state of real estate market as a full event space  $T = \{Eq\}$ , where  $E_1$  – phase random walk,  $E_2$  – unstable phase transition,  $E_3$  – phase chaotic market,  $E_4$  – phase coherence. Consider them more:

1) random walk phase corresponds to the situation when individual investors make decisions under the influence of some random factors regardless of the other investors, that there is no collective decision. This may occur during recession processes, in particular after the acute recession;

2) phase transition corresponds to an unstable situation, when deciding gradually begins to form (or break down) public is expected to rational thought;

3) during the chaotic phase (or fractal) market oriented investor sentiment group found that match their preferences regarding investment horizon;

4) in the coherence phase there is a combination of group awareness and a strong manifestation of the fundamental factors causing the observed significant change of trend of price changes.

For example, let's propose a system for forecasting the overall scheme is shown in Fig. 3 and implementing innovative approach to forecasting the price of the real estate market. Forecasting system consists of three blocks of tools:

**I block** – implements of beforeforecasting analysis, which is the study of nature (stochastic, deterministic, fractal or chaotic) dynamics and retrospective identification of the current state of the market (considered as a component of technical analysis in terms of time series analysis);

**II block** – implements of beforeforecasting analysis, which is to study the factors influencing the type of speakers in retrospect and identify their current status (considered as a fundamental component analysis);

**III block** – is a set of forecasting methods, elected according to the type of identifiable phase of the market.

In **block I** we explore the nature of time series based on statistical analysis (calculation of the estimates of statistical characteristics levels of the time series as a random variable, the analysis of species distribution density function), tests for deterministic chaos (Gilmore test, the Broc test of remains, the Kolmogorov entropy calculation and Lyapunov characteristic) and complex fractal analysis, which contains methods normalized magnitude Herst (*R/S-analysis*) and method of sequential *R/S-analysis* (determining whether long-term memory and characteristics of fuzzy set long-term memory).

As for improving the accuracy of forecasting in the forecasting systems includes **block II**, the result of which is the study of quantitative and qualitative impact of fundamental factors on the dynamics of market prices of real estate.

**Block III** forecasting system directly represents a set of forecasting methods which are chosen depending on the type of identifiable phase of the market. As noted above, for the first two phases is appropriate to use and inclusion of known statistical extrapolation methods. For fractal market phase based on discrete data type of forecasting is a necessary tool model discrete nonlinear dynamics. To take into account the conditions of instability, nonlinearity and uncertainty that are characteristic of modern markets, forecast models are built in block III, based on a hybrid approach. Hybrid approach is one of the leading destinations currently in the construction of intelligent systems. Hybridization is an integration of methods and techniques at a deep level, where different

blocks of implementing a single method of solving intellectual problems and interact. The deep level of association involves the creation of new methods that use the basic concepts incompatible methods.

So as a result it was found that data mining allows you to apply a systematic approach to research real estate market. A further focus of research may be the creation of information technology, which would be combined topical issues of improvement of the register of real estate, predicting the dynamics of real estate prices, and technology of the decision making support.

**Conclusion.** Thus, the result of reflection can be measured quantitatively. It is the dynamics of prices and volume of transactions (a consequence of the presence of group sentiment and fundamental market shift), i.e. the difference between the price dynamics during the phase random walk, unstable transition and phase coherent market. It is significant shifts in market dynamics that occur due to the formation of group consciousness, can be considered a manifestation of reflection of the market.

So, in the study of information reflection property market found that the process of reflection associated with the phases of the real estate market by market hypothesis coherent. It was built cognitive model based on the cognitive map – count information reflection real estate market, which includes the following, as the dynamics of prices for real estate, volume of transactions in the real estate market, the quality of market infrastructure, the effectiveness of decision-making in the real estate market, the tendency of market risk, the level of education of economic agents, transparency of information in the country, knowledge of the market in real estate, the state of the economy and the quality of the legal framework. They were the main characteristics of the column (cognitive maps). Areas for future research can be a complex analysis of information graph reflection and analysis of real estate market based on it.

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## МОДЕЛЮВАННЯ РЕФЛЕКСІЇ РИНКУ НЕРУХОМОСТІ З ВИКОРИСТАННЯМ ЗАСОБІВ ІНТЕЛЕКТУАЛЬНОГО АНАЛІЗУ ДАНИХ

### Резюме

Аналізуються особливості відображення на ринку нерухомості. Досліджено причини відображення інформації на ринку. Визначено чинники, що викликають інформаційну рефлексію на ринку нерухомості, а також взаємозв'язок між ними. Побудовано когнітивну модель інформаційної рефлексії на ринку нерухомості. Запропоновано когнітивну модель ринку нерухомості. Зроблено огляд методів пошуку даних, що використовуються для вивчення фінансових ринків, включаючи ринок нерухомості. Проаналізовано особливості ринку нерухомості, які вимагають використання методів інтелектуального аналізу даних.

Запропоновано алгоритм інтелектуального аналізу даних ринку нерухомості. На основі розгляду узгодженої ринкової гіпотези ринку нерухомості в Україні наведено метод визначення відповідної фази.

**Ключові слова:** рефлексія, нерухомість, невизначеність, прийняття рішень, когнітивна модель, інтелектуальний аналіз даних.

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## МОДЕЛИРОВАНИЕ РЕФЛЕКСИИ РЫНКА НЕДВИЖИМОСТИ С ИСПОЛЬЗОВАНИЕМ СРЕДСТВ ИНТЕЛЛЕКТУАЛЬНОГО АНАЛИЗА ДАННЫХ

### Резюме

Анализируются особенности отражения на рынке недвижимости. Исследованы причины отображения информации на рынке. Определены факторы, вызывающие информационную рефлексию на рынке недвижимости, а также взаимосвязь между ними. Построена когнитивная модель информационной рефлексии на рынке недвижимости. Предложена когнитивная модель рынка недвижимости. Сделан обзор методов поиска данных, используемых для изучения финансовых рынков, включая рынок недвижимости. Проанализированы особенности рынка недвижимости, которые требуют использования методов интеллектуального анализа данных. Предложен алгоритм интеллектуального анализа данных рынка недвижимости. На основе рассмотрения согласованной рыночной гипотезы рынка недвижимости в Украине приведен метод определения соответствующей фазы.

**Ключевые слова:** рефлексия, недвижимость, неопределенность, принятие решений, когнитивная модель, интеллектуальный анализ данных.

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## УСТОЙЧИВОСТЬ ОЛИГОПОЛИСТИЧЕСКОГО РЫНКА

Исследована модель олигополистического рынка с произвольным количеством фирм – участниц рыночного взаимодействия. Выполнен анализ структурной устойчивости модели. Приведены примеры с одношаговым сосредоточенным отставанием и распределенным в геометрической прогрессии запаздыванием. Соответствующие результаты проиллюстрированы графиками переходных процессов объемов выпуска продукции для различного количества фирм на рынке.

**Ключевые слова:** олигополия, распределенное запаздывание, устойчивость, экономическая динамика, положение равновесия.

**Постановка проблемы.** По своей природе олигополия является достаточно распространенной формой рыночной организации. Олигополистическими отраслями можно считать металлургию, нефтехимию, автомобильную промышленность, производство компьютерной техники и средств связи и т. д. Функционирование олигополистической фирмы подразумевает процедуры принятия решений об объеме производства, ценовой политике и стратегии инвестирования в условиях конкуренции. Соответствующие экономические расчеты имеют комплексный характер. Это означает, что управленческие действия каждой фирмы ориентированы на поведение своих конкурентов. Все это, в свою очередь, определяет сложную структуру взаимодействия всех участников олигополистического рынка как динамический процесс, протекающий во времени.

**Анализ последних исследований и публикаций.** В работах [1–5] рассмотрены традиционные подходы, ориентированные на максимизацию прибыли каждой из фирм – участниц рынка с учетом одношагового запаздывания во времени. Необходимо отметить ограниченность указанной методологии, существенно влияющей на устойчивость переходных процессов в исследуемых системах экономической динамики.

**Цель статьи** заключается в анализе устойчивости математической модели олигополи-

стического рынка с учетом эффекта последействия, обусловленного наличием распределенных запаздываний различного типа.

**Изложение основного материала исследования.** Базовый принцип построения математической модели состоит в нахождении такого объема выпуска продукции для каждой фирмы, который обеспечивал бы максимальную прибыль. Допустим, что на олигополистическом рынке присутствуют  $m$  фирм с соответствующими объемами  $q_1, q_2, \dots, q_i, \dots, q_m$ . При этом доход каждой фирмы  $R_i$  равен цене товара  $P_i$ , умноженной на объем реализованной продукции:  $R_i = P_i \cdot q_i$ . Существующие издержки производства у каждой из фирм  $C_i$  также являются функциями от объема выпуска  $q_i$ , то есть  $C_i = C_i(q_i)$ ,  $i = \overline{1, m}$ . Прибыль фирмы  $\pi_i$  есть разница между доходом и издержками:  $\pi_i = R_i - C_i$ ,  $i = \overline{1, m}$ .

Предположим, что цена  $P_i = A - \sum_{i=1}^m q_i$ , где  $A = const$  и затраты  $C_i = B \cdot q_i$  для всех фирм одинаковы. Здесь  $B = const$  – постоянная величина предельных издержек. Такие допущения могут иметь место в положении равновесия (статика) олигополистического рынка.

Выражение для прибыли  $\pi_i$  имеет вид:

$$\pi_i = \left( A - \sum_{i=1}^m q_i \right) \cdot q_i - B \cdot q_i, \quad i = \overline{1, m}. \quad (1)$$