Business Intelligence Models

INFORMATIONAL SUPPORT OF MANAGERIAL DECISIONS AS A NEW KIND OF BUSINESS INTELLIGENT SYSTEMS

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Abstract*:* The paper considers main aspects of developing a combined system for informational support of operative managerial decisions. Such Managerial Decisions Informational Support System (MDISS) should contain data and models storage and the following three main components: subsystem for current analysis and visualization of operational management information; subsystem for modelling and forecasting of processes involved; subsystem for integral evaluation of interdependent indicators of a complex system state. Functional capabilities and features of the subsystems are presented.

A new type of sorting-out GMDH algorithm based on the principle of backward successive selection (BSS) of the most informative variables was used to perform modeling and prediction of economic indicators of Ukraine. Multiple dynamic autoregression models were built in form of systems of multidimensional difference equations of interdependent indicators. Construction of the models was based on statistical data of Ukraine economy for 13 years (1996 to 2008). Such models were built for 4 demographic and 5 investment indicators demonstrating good accuracy on validation part of the sample as well as on prediction period of 2009 and 2010 years.

An example of informational support task solution in the field of economic safety by the developed MDIS System is presented using the built predictive model for the area of Ukraine investment activity. Estimations of future evolution of the activity are based on predictions of this model as useful information for decision making.

Keywords*: business intelligence, decision making, informational support, GMDH, dynamic models, investment activity, demographic indicators.*

ACM Classification Keywords*: H.3.4 Systems and Software – Information networks; H.4.2 Types of Systems – Decision support (e.g., MIS); J.1 Administrative Data Processing – Government; I.6.5 Model Development.*

Introduction

Efficiency and quality of managerial or administrative decisions essentially depends on the timely supply of management process by necessary reliable information which describes these processes and phenomena that occur at a particular management object. Taking this into consideration, the informational support of managerial decisions is a vital problem. To solve this problem, it is proposed to develop appropriate tools based on inductive algorithms for analysis, modeling and prediction of complex processes.

To enhance the effectiveness of administrative decision making support, for instance, in the state economic safety field, it is necessary to monitor the main safety indicators statistics, to quantitatively evaluate the safety level, predict the indicators taking into account its dynamic interdependence and to visualize all the monitored and predicted information in the human-transparent form being easy-to-use by decision-makers. This approach leads to the necessity to analyze and solve the problem of construction a system for informational support of managerial decisions in the area.

Also the informational support concept refers to the new type of decision-making process organization that takes into account not only the traditional tasks of data storage, processing and visualization, but also providing full support for this process based on solving the analysis, modeling and forecasting tasks, presenting the results in informational and advisory form under conditions of constant changing the managerial situation.

Managerial Decisions Informational Support System as a kind of information system used to support managerial decisions

A Managerial Decisions Informational Support System (MDISS) being introduced here is a kind of Information Systems (IS) of a general type and at the same time it has some number of properties inherent to Executive Information Systems (EIS) and Decision Support Systems (DSS).

In general, an information system can be defined as an automated man-machine system that provides information to users from different organizations [DeSanctis, 1987].

Current DSSs that have arisen by the merger of management information systems and database management systems are the systems most adapted to solve problems of daily management activities and are tools that aim to help persons and/or authorities to make decision [Little, 1970]. Choice-making in complex problems, including those based on many criteria, may be carried out by DSS features [Power, 2000].

According to Turben [Turban, 1995], DSS has the following four main features: 1) uses data as well as models, 2) is designed to assist managers in making decisions for slightly structured and unstructured tasks, 3) supports, rather than replaces, decision made by managers 4) is designed to improve decisions.

An Executive Information System (EIS) or Information System for Managers is a specialized DSS that helps implementers to analyze important information and use appropriate tools to guide it in forming strategic decisions within a specific organization [Edwards, 1992].

We consider Managerial Decisions Informational Support Systems (MDISS) [Samoilenko, 2008] as systems that combine main characteristics of EIS and DSS. However, in contrast to DSS, they have no means of generating and actual making decision. In other words, tools for generating possible solutions and choosing the optimal one of them are not present in MDISS; user generates and makes decision with help of appropriate system features. But inherent for EIS means for data handling as well as visual representation and analysis are widely used here. This provides great opportunities for a user or decision maker to orient oneself in the current state of a problem and find the most appropriate course of action to resolve it. Modeling methods and forecasting tools aimed to help increase decision making effectiveness should be presented in MDISS as well.

General structure of the MDIS System

To solve the stated problem, the task of developing a software system should be considered. Such a system should contain data and models storage and the following three main blocks/components (Fig. 1):

- subsystem for current analysis and visualization of operational management information;

- subsystem for modelling and forecasting of processes involved;
- subsystem for integral evaluation of interdependent indicators of a complex system state.

Subsystem for current analysis and visualization of operative management statistics

This component provides support to the following functional tasks:

- collecting and storage of primary statistical data;
- pre-processing the row initial data;
- checking the correlation dependences of the primary indicators;
- tracking the status of every indicator;
- evaluating the integral state of a system;
- visualization and documentation of all the results.

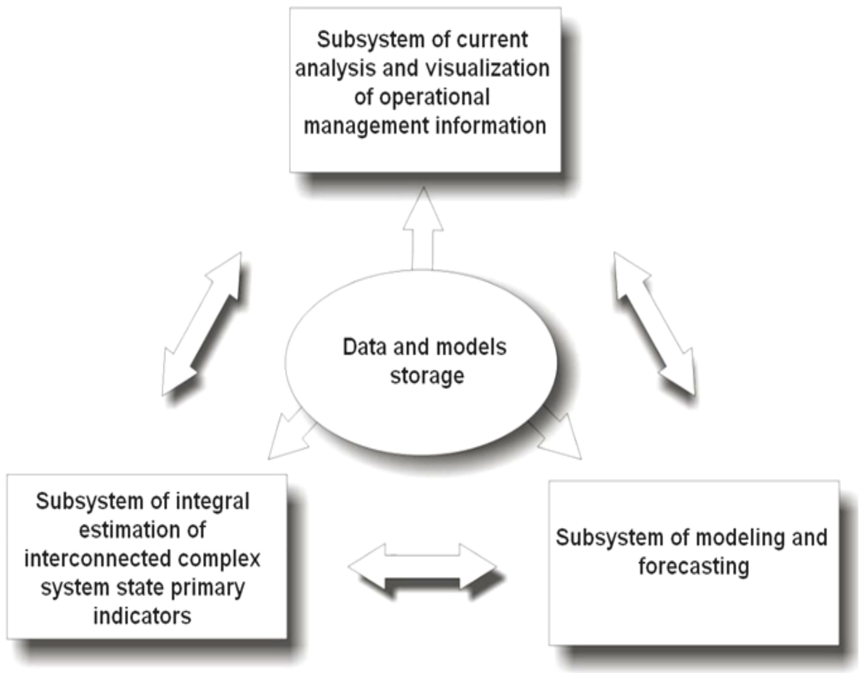

Fig. 1. Main components of Managerial Decisions Informational Support System MDISS

Subsystem for modeling and forecasting

It is based on the inductive approach to building a system model of a controlled multidimensional process. Methodology of this approach is based on maximum "extraction" of all necessary information from the data sample and focused on the inclusion to the model only the most significant/informative factors under specific conditions, rather than all factors which may affect the target value [Ivakhnenko, 1985]. The main functional characteristics of this subsystem:

- building models (manual and automatic modes);
- selecting the optimal model for information support;

– determining significance of each indicator (factor);
– visualization and documentation of the results.

Modeling and forecasting subsystem is intended to build models of optimal complexity using inductive modeling algorithms. Visual analytical tools are implemented for models analyzing to help users to choose best models. Based on the obtained models, approximations and predictions may be calculated here and for other system components. There are tools to analyze significance level of indicators regarding their influence on the final result.

Sorting-out GMDH algorithms based on known Combinatorial COMBI algorithm [Stepashko, 1981] are used for the modeling. Directed successive selection algorithm [Samoilenko, 2008] is realized in this component making it possible to effectively solve problems with large number of arguments.

Subsystem for integral evaluation of the state of a complex system based on interdependent primary indicators

To comprehensively analyze the performance of an economic system it is necessary to construct a generalized integral index for a group of interdependent primary indicators which jointly describe the state of such multidimensional system. This subsystem implements a new approach to quantitative calculating such integral index of a system state. This approach is based on non-linear normalization of the primary indicators taking into consideration certain expedient constraints on their optimal, satisfactory and unacceptable values [Stepashko, 2006].

Tools for dealing with complex data structures typical for governmental decision-makers are implemented. The data structures are displayed in a tree view. For example, sectors and sub-sectors of the economy may be represented as leaves and branches of this tree. Each structural element of the tree is associated with a set of panels based on a number of features specific for an appropriate type of this element. For example, integrated evaluation of process is done for any element and for the elements-leaves it is also possible to analyze the data using the implemented methods and conduct additional processing and analysis in the modeling subsystem.

The proposed subsystem provides support for such basic functional tasks:

– tracking the current state dynamics of the controlled process;
– data normalization by the developed technique;
– integrated and detailed evaluation of ongoing changes;
– analyzing the detected changes and finding main factors affecting them;
– identifying potentially dangerous phenomena and trends;
– visualization and documentation of the results.

Prediction of demographic indicators dynamics

The population size and age structure are fundamental data in definition of the state perspective revenues and expenditures including such important components as the pensions financing, social benefits, education and health facilities and so on. Without deep demographic substantiation it is impossible to determine the budget revenues amount, which depends on the labor force, the level of economic activity, education and qualification. Population is a major productive force as well as consumer of material goods. Rates and proportions of economic development, including production and consumption, and their changes significantly depends on the population, its age, educational, professional and social structures [Presidium, 2007].

Dynamics of population size and composition is characterized by a large degree of uncertainty. Processes of fertility, mortality and migration are stochastic in nature.

To build prediction model of demographic sphere in Ukraine, we used data from the Ministry of Economy for 1996-2010 years (15 points). The following 4 parameters were used:

x_1 – life expectancy at birth, years;

x_2 – conditional depopulation rate (the ratio of mortality to fertility factor), times;

x_3 – the proportion of the elderly population in the total population, %;

x_4 – the demographic burden of disabled on the working-age population, %;

The modeling of dynamics is executed in the class of multidimensional difference models when interdependence of the indicators is taken into account. Accordingly, structural and parametric identification is performed for models of the following type:

$$x_i(t) = \sum_{j=1}^{4} \theta_{ij} x_j(t-1) + \sum_{k=1}^{4} \theta_{ik} x_k(t-2) + \sum_{p=1}^{4} \theta_{ip} x_p(t-3), \quad i = \overline{1,4} \tag{1}$$

or in matrix form

$$X(t) = \Theta_1 X(t-1) + \Theta_2 X(t-2) + \Theta_3 X(t-3) \tag{2}$$

where X is the vector of 4 elements, Θ_1, Θ_2 i Θ_3 – matrices of model coefficients (3) with 4×4 dimension.

As noted above, we have a sample of 15 points (1996-2010 years). Three points (1996-1998 years) are used as lag (lag L=3). Thus, for each $x_i(t)$ as an output variable we have a sample with 12 arguments and 12 points ($t = \overline{1999, 2010}$).

For each indicator, linear models were constructed using combinatorial algorithm BSS (Backward Successive Selection) [Samoilenko, 2008]. The main goal of the BSS algorithm is to select the most informative arguments by sorting out the relatively small group of built models as compared to the exhausted search. This approach significantly reduces the number of models to be built in order to find the optimum model.

Models have complexity s = 1,…,12 and were built on 6 training points (1999-2004 years). The used lag is 3 (initial conditions 1996-1998 years).

Constructed models for one-step forward prediction were estimated by regularity criterion AR on 4 checking points (2005-2008 years). Prediction qualities of constructed models were tested on 2 points (2009 and 2010 years). Successive calculation of predictive values for all parameters and use of them to build the next prediction enables to obtain predictions for a given number of steps.

To construct the models normalized values are used. For each normalized indicator following models was built:

$$x_1(t) = 1.23x_1(t-1) + 1.67x_1(t-2) + 1.79x_2(t-2) - 1.29x_3(t-2),$$

$$x_2(t) = x_1(t-1) + 0.45x_4(t-2) + 0.17x_2(t-3) - 0.39x_3(t-3) + 0.97x_4(t-3),$$

$$x_3(t) = 1.02x_2(t-2) - 5.52x_4(t-2) + 2.24x_2(t-3) + 5.74x_4(t-3) + 0.37x_3(t-3),$$

$$x_4(t) = -0.07x_4(t-1) + 4.16x_2(t-2) - 8.03x_3(t-2) + 6.98x_2(t-3) + 4.57x_3(t-3) - 0.64x_4(t-3),$$

Figures 2 – 5 show predicted values compared to actual.

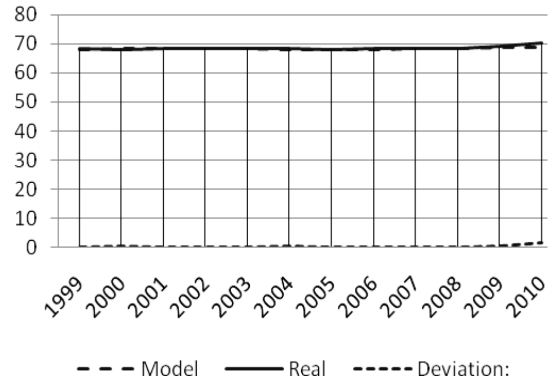

Fig. 2. Life expectancy at birth, years

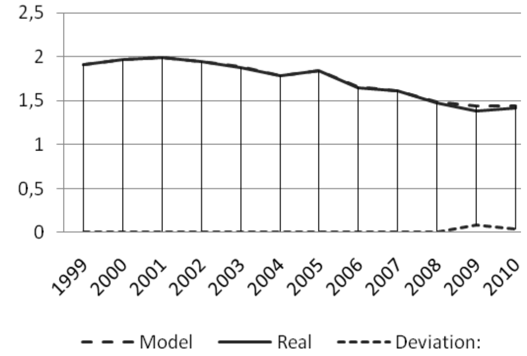

Fig. 3. Conditional depopulation rate (the ratio of mortality to fertility factor), times

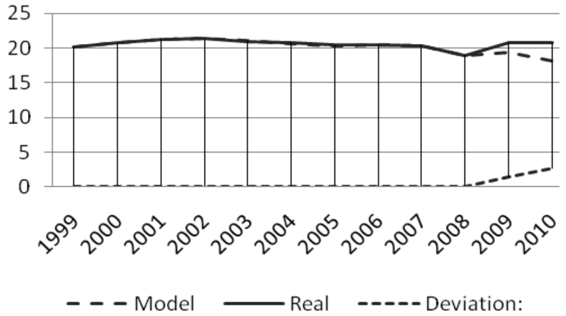

Fig. 4. The proportion of the elderly population in the total population, %

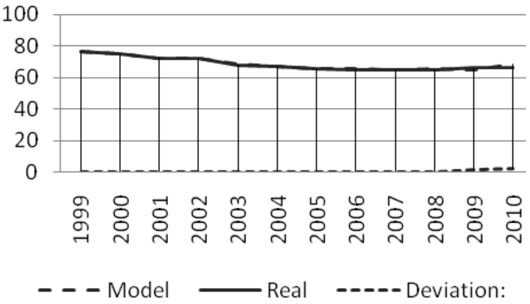

Fig. 5. The demographic burden of disabled on the working-age population, %

It is obvious that constructed models mostly show good prediction results even with a small learning sample.

The largest differences of predicted values to actual can be seen in the model constructed for the indicator reflecting the proportion of older people in the total population. Perhaps this is due to some external factors that are not taken into account in the model.

Construction of dynamic system models for investment activity indicators

The main aim of the state economic safety is to guarantee its stable and effective functioning now and high potential of development in the future. The investment component is a special subsystem of economic safety.

World experience indicates that countries with transition economies are unable to come out of economic recession without involvement of foreign investments, because in such a way they gain access to modern techniques, management technologies and so on. In addition, foreign investments make an important contribution to the macroeconomic stabilizing. Difficult economic state of a country as an independent state also constrains the country to apply to foreign investments.

Ukraine investment activity is characterized by a range of economic indicators. Ministry of Economy of Ukraine uses them to analyze the economic safety level. There are the following indicators in this area: accumulated depreciation level, share of direct foreign investments in general investments amount, ratio of investments amount to the fixed assets cost, ratio of investments amount in the capital asset to the Gross Domestic Product (GDP), direct foreign investments to GDP ratio.

To enhance the effectiveness of administrative decision making support in the investment activity field, it is necessary to predict the investment indicators taking into account its dynamic interdependence. This approach leads to the necessity to analyze and solve the problem of modeling and prediction of the given set of economic indicators in this area.

Similarly to the above, the modeling of Ukraine investment activity indicators was carried out with the use of multiple autoregression models in the form of multidimensional difference equations of interdependent indicators [Stepashko, 2010]. The structure and parametric identification was executed for model variants in the same form as (1) or (2) with limitation of model complexity by exhaustive search using combinatorial algorithm COMBI GMDH. Evidently that Θ_1 and Θ_2 in (2) are 5 by 5 matrices of parameters of the model of the type (1).

The models of the limited complexity from s=2 to s=6 (according to observations number of the training subset) for every index were built with the use of the combinatorial algorithm for models structure optimization. After building models being optimal by the regularity criterion [Ivakhnenko, 1985] for all indicators, the one step forward system predictions for every indicator were obtained. The sequential computation of all indicators values enables to get predictions for some steps forward.

Real data for the 5 mentioned above indicators of investment activity for years 1996 to 2008 was used for modeling. We have built the following dynamic system models:

$$x_1(t) = 0.524x_1(t-1) + 0.434x_1(t-2) + 0.174x_2(t-1) + 0.236x_2(t-2) - 0.281x_3(t-1)$$

$$x_2(t) = 0.408x_2(t-1) + 0.676x_2(t-2)\,,$$

$$\begin{aligned} x_3(t) = {} & 0.725x_1(t-1) - 1.581x_2(t-1) - 0.302x_2(t-2) - 0.345x_3(t-2) - \\ & -1.417x_4(t-1) + 8.954x_5(t-1) \end{aligned},$$

$$x_4(t) = 0.453x_1(t-1) - 0.186x_2(t-1) - 0.482x_2(t-2) + 1.356x_3(t-1)\,,$$

$$x_5(t) = -0.007x_2(t-1) + 1.144x_5(t-1)\,.$$

Real values of the indicators are illustrated in Fig. 6 – 10 by a firm line and computed values by a dotted line. The last 4 marked values are prediction for 1 to 4 steps, respectively. Errors of developed models in examination points (2007 and 2008 years) are presented in Table 1.

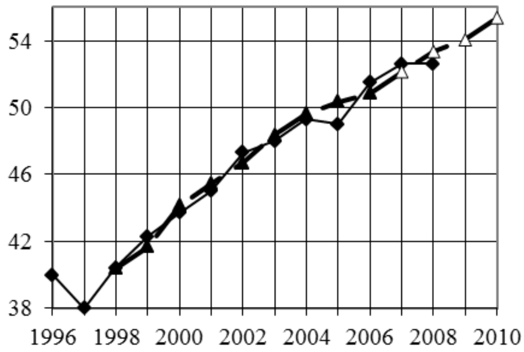

Fig.6. Accumulated depreciation level

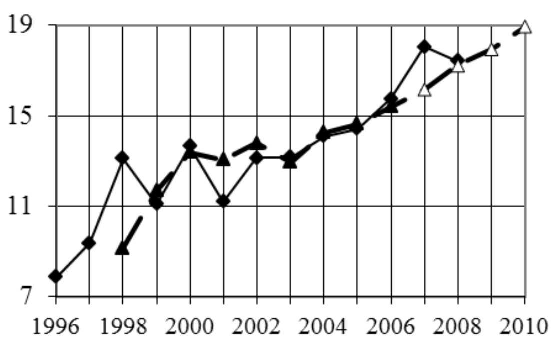

Fig.7. Share of direct foreign investments in general investments amount

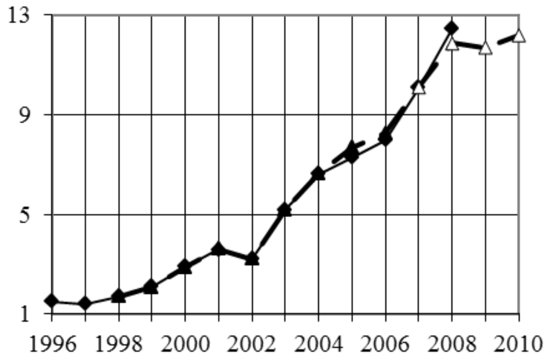

Fig.8. Ratio of investments amount to the fixed assets cost

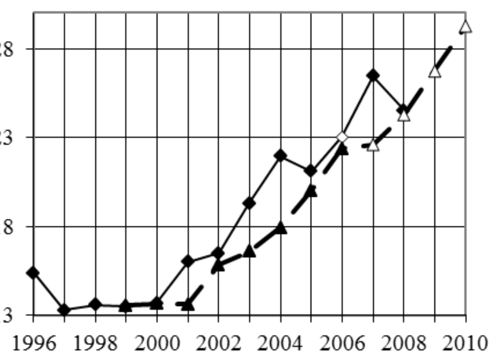

Fig.9. Ratio of investments amount in the capital asset to GDP

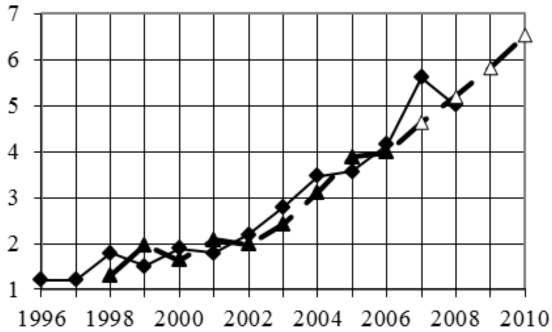

Fig. 10. Direct foreign investments to GDP ratio

Table 1. Errors of developed models for 5 indicators in examination points, %.

Indicator	1	2	3	4	5	Average
Accuracy	1.2	5.8	2.5	8.6	10.6	5.7

Investment activity index prediction

These models and calculated by them predictions were used to get the so-called *inertial prediction* of the integral index for investment area in Ukraine for 2011-2012 years. The respective results are shown in Fig. 2.

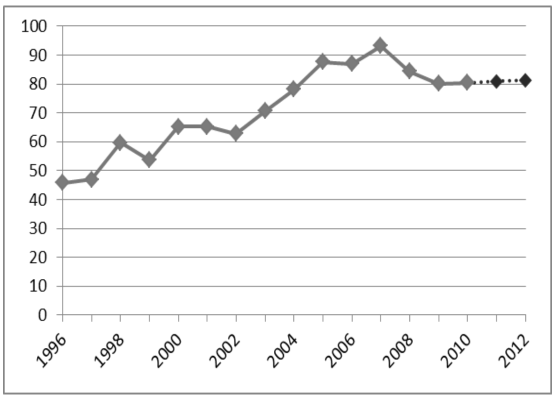

Fig. 11. Evolution and inertial prediction of the integral index dynamics for the investment area

This information, received using tools of the MDIS system, on predictive behavior of the integral index for investment area may be used to facilitate the managerial or administrative decision making process in relevant governmental bodies.

Conclusion

The proposed system for informational and analytical support of managerial decisions is aimed to evaluate, analyze and forecast complex economic processes with respect to their interdependence. It supports the following main tasks: import of statistic data; evaluation and analysis of ongoing changes; construction, analysis and correction of models; operative forecasting of processes in real time. This system contains data and models storage and consists of three main components: subsystem for current analysis and visualization of operational management information; subsystem for modeling and forecasting the interdependent primary indicators; subsystem for integral evaluation of the complex system state.

The system has an interface for tabular and graphical data analysis. The results of modeling and forecasting are presented graphically and analytically. Models and forecasts are corrected in real time. The system functioning is demonstrated on the example of current analysis of the investment activity as an important component of economic safety of Ukraine.

The developed information technology is intended for a comprehensive analysis of socio-economic processes to improve efficiency and quality of managerial decisions due to identifying hidden regularities of socio-economic processes and respective reduction of inefficient decisions at different levels of economical and political governance.

The experiments show the effectiveness of GMDH algorithms even at small size of the given data, when the number of statistical points is less than the number of variables that affect the output value. During the research, dynamic system models were built for demographic and investment areas using the data of the Ministry of Economy of Ukraine. Most of the built models in class of the multiple autoregression equations demonstrate good forecasting results confirming their effectiveness.

This paper presents project of an integrated environment for Managerial Decisions Informational Support System. Such kind of informational system can be applied to solve typical tasks of business intelligence including analysis, evaluation, modeling, forecasting, classification, visualisation and others. Applying GMDH algorithms in business intelligence systems gives particularly promising opportunities towards building complex models for business data analysis.

An illustrative example of informational support task solution in the field of economic safety by the developed MDIS System was presented using the built predictive model for the area of Ukraine investment activity. Estimations of future evolution of the activity are based on predictions of this model as useful information for managerial decision making.

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