Запропоновано систему прогнозування стану безпеки підприємства, яка вимірюється станом нечітких слабо-структурованих технічних показників, рівнем технічного вдосконалення засобів праці і технології виробництва, що суттєво впливає на розвиток підприємства. Визначено, що запропонована система має спеціальне призначення та складається з блоків класів індикаторів, та бази фактів індивідуальних екземплярів класів та може застосуватись для реалізації задач прогнозування у будь-якій галузі

Ключові слова: семантика, фрейм, моделі знань, база знань, машина висновку, регресійні динамічні моделі, прогнозування, безпека, потенціал, експертні знання, таксономія

Предложена система прогнозирования состояния безопасности предприятия, которая измеряется состоянием нечетких слабо-структурированных технических показателей, уровнем технического совершенствования средств труда и технологии производства и существенно влияет на развитие предприятия. Определено, что предложенная система имеет специальное назначение и состоит из блоков классов индикаторов, базы фактов индивидуальных экземпляров классов и может примениться для реализации задач прогнозирования в любой отрасли

Ключевые слова: семантика, фрейм, модели знаний, база знаний, машина вывода, регрессионные динамические модели, прогнозирование, безопасность, потенциал, экспертные знания, таксономия

UDC 330.341.1
DOI: 10.15587/1729-4061.2017.119100

DEVELOPMENT OF THE SYSTEM FOR PREDICTION OF SECURITY STATE OF AN ENTERPRISE USING SEMANTIC-FRAME FUZZY MODELS OF KNOWLEDGE BASE

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1. Introduction

Support to forecasting economic security of enterprises, avoidance of bankruptcy is currently one of the key problems for the Ukrainian economy. Rapid growth of the number of bankrupt and liquidated enterprises stimulates the search for the ways of solving this problem not only at the level of a certain industry, but also at the level of the State [1]. The present research is closely connected with the State target program of reforming dairy industry of Ukraine for 2010–2019, with “The unified comprehensive strategy for development of agriculture and rural areas for 2015– 2020” and the Decree of the President of Ukraine No. 96/2016 “On decision of the National Security and Defense Council of Ukraine as of 27 January, 2016 “On the strategy of cybersecurity in Ukraine”.

Dynamics of bankruptcy of Ukrainian enterprises is presented in Fig. 1, which shows that the highest level of bankruptcies was registered in 2007 and was 4,359 enterprises and the largest number of bankruptcy proceedings were instituted in 1999 and was 6,932.

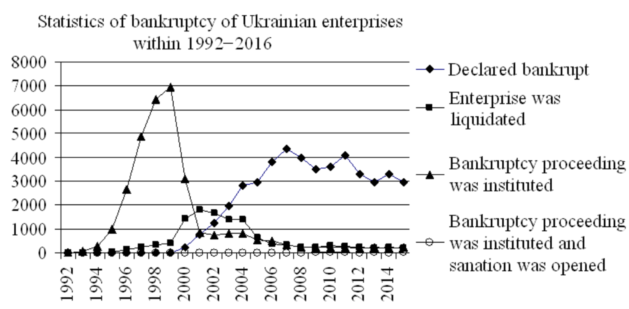

Fig. 1. Bankruptcy statistics for Ukrainian enterprises over the period 1992–2016 [2]

According to Fig. 1, the number of instituted proceedings about bankruptcy of enterprises began a relentless rise from 1995 to 1999, however, since the year 2000, the tendency of its decline has been observed: in 2000 – 3,101; in 2001 – 837; in 2002 – 759 enterprises, and the lowest rate was in 2012 – 192. At the same time, starting from 2000, the number of liquidated enterprises has been growing. Since

2000, a trend to a rapid growth of enterprises' bankruptcy has been observed, especially in the pre-crisis period up to 2008. After 2009, the number of enterprises recognized as bankrupts has been rising: in 2010 there were 3,614 of them; in 2011 – 4,086 bankrupt enterprises. And only after 2011, the tendency of bankruptcy dynamics started to decline, which is due to the reform of the legislation related to bankruptcy [2, 3].

The level of liquidation of Ukrainian enterprises allows us to assert existence of problems in predicting the state of economic security of enterprises and in determining of probability of bankruptcy. The main cause of cyclic crises of economic systems is wear of the production funds [4].

Critical economic conditions cause the need for development, formulation and implementation at an enterprise of the system of prevention, prediction and overcoming of bankruptcy, which is designed to create conditions for effective activity of an enterprise and, as a result, to achieve business goals in terms of competition and economic risk, through timely detection and weakening of the influence of various hazards and threats.

Economic security of an enterprise (EcSE) is a fuzzy, dynamic process of determining of conditions of harmonization of the enterprise's functional capabilities. In accordance with the first stage of the semantic-frame model, formalization of functional potentials was carried out and indicators of their evaluation were determined. Internal production potential of EcSE include technical and technological, financial, marketing, personnel and intellectual, political and legal, informational, ecological, logistic, and power indicators. External production potentials of EcSE include marketing and interface potentials.

As an example, one of the important component, in particular technical and technological potential, which influences probability of bankruptcy of an enterprise and its economic security level, was chosen as an example in the article.

The basic idea of modeling of functional components of EcSE with the help of semantic models lies in the fact that the model stores data about actual objects and relationships between them in an obvious way, which greatly facilitates access to knowledge. Network model of presentation of EcSE knowledge is an oriented graph, the vertices of which correspond to certain concepts (frames), and the arcs correspond relationships and connections between these components.

This system should protect a company from bankruptcy by previous detection of critical conditions. In this respect, the main tasks facing modern enterprises are the use of a system of forecasting of security state with all components.

2. Literature review and problem statement

The issues of development of a control system, modeling and prediction of economic security state by separate components were tackled by many authors [1, 5–7]. However, despite significant advances in the field of modeling, there arise a number of issues related to the practical nature of using of these models and systems, quantitative measurement, effectiveness analysis and development of a system of prediction of components by separate elements of economic activity of an enterprise. These problems remain not sufficiently solved, debatable, they need clarifications and further development, which causes the need for doing this scientific research.

Currently, there are a large number of models of knowledge presentation, among which logical, productive, network, frame and algorithmic models are the most used [8, 9]. Despite a large number of studies in the area of semantic models, knowledge modeling and obvious merits of such systems, the use of them is quite restricted so far. One of the main reasons here is the use of precise quantitative methods in complexly-structured and fuzzy areas [10, 11]. A mathematical model of knowledge presentation based on the theory of fuzzy sets, unlike the others, allows taking into account semantic uncertainty of knowledge evaluation by an expert [12]. The indicated papers offer theoretical substantiation of the use of presented models, but lack practical implementation of fuzzy knowledge bases in semantic-frame networks.

A separate class of models for evaluation of the state of a company is discriminant integral assessment of the state of a company [13], which is based on application of methodology of discriminant analysis based on financial indicators of a random set of enterprises and comprehensive evaluation of the financial state of an enterprise based of matrix models [14]. These methods make it possible to identify trends in dynamics only of financial state of a company. But this is not enough to assess the security state of an enterprise as a whole. The disadvantage of most methodological approaches, which employ simulation of security processes of an enterprise, is the fact that prediction of the indicated processes is based on retrospective analysis and linear projection of series of dynamics of separate factors.

The problem of innovative activity as a whole is being explored [16]. Despite a large number of different approaches to evaluation of technical and technological potential of industrial enterprises, the issue of assessment of technical and technological level of development is not enough investigated, in particular, its practical aspect.

In the literature, one can also find existing systems of optimization of integrated security [17], which consist of an object of integrated security optimization, a control object, a decision-making unit, a unit of receiving clear input data, a unit of defining of expert knowledge, an object of security state evaluation in the form of ranks.

But this system has its shortcomings due to the following:

– information that is used is obtained as a result of processing opinions of experts. The expert knowledge unit increases dependence of making objective management decisions on subjective knowledge of experts;

– the state of all existing functional systems of the enterprise in terms of fuzziness, conflict, technical and technological, financial, marketing risks, etc., is not taken into account. That is why it is impossible to give comprehensive evaluation of the security state of an enterprise.

The problem of evaluation of the level and prediction of economic security state of modern enterprises is in the process of research, which results in the need for its comprehensive solution with consideration of modern trends of development of enterprises, the use of new technologies and the problems, caused by current critical states. The article offers an individual vision of a system's modeling, which must correspond to the method of estimation of a level of the enterprise's economic security.

It should be noted that the proposed system of prediction of security state of an enterprise (SSE) makes it possible to measure the state of fuzzy loosely-structured technical indicators of the level of technical improvement of means of labor and production technology that significantly influence development and security state of an enterprise.

3. The aim and objectives of the study

The aim of present research is to develop and study a prediction system based on computational object models and technologies.

To achieve the set goal, the following tasks must be solved:

– to develop the system for prediction of security state of an enterprise using semantic-frame fuzzy models of the knowledge base;

– to construct an object-oriented semantic-frame network of base of knowledge about the state of technical and technological potential of a company, which provides clear current values of indicators of performance of an enterprise, properties, permissible limits of these properties;

– to explore the knowledge base which consists of classes of indicators, slots, facts of individual instances of classes and clear and fuzzy output machines;

– to develop regressive-differential models (RDM) of the prediction unit.

4. Materials and methods of research into the system of prediction of enterprise's security state

4. 1. Research into semantic-frame model of the system of prediction of enterprise's security state

The use of semantic models enables accumulation of knowledge in the base and implementation of automatic construction of semantic networks directly from classes of indicators. The characteristic feature of semantic models of EcSE system is an integrated description of procedure and static semantics, permissible procedures of operations on the objects that are determined in conjunction with determining of the data structures of a network.

The structure of the proposed system includes the object-oriented semantic-frame network (SFN) of presentation of knowledge about the state of technical and technological potential of an enterprise. The system provides precise current values of performance indicators of an enterprise, properties, and permissible limits of these properties. The system includes units of classes of indicators, and bases of the facts of separate instances of classes [4, 18, 19].

Object-oriented SFN on the example of technical and technological potential (TTP) is presentation of knowledge about the state in time using frame taxonomies. Frame taxonomy determines classes and subclasses of economic indicators and properties, as well as permissible limits. Taxonomy sets structures for presentation of actual data and relationships between them. SFN represents a model of knowledge about TTP with the help of relationships and regularities.

SFN consists of classes and relations between them. Thus, a set of arcs of homogenous informational SFN structure determines classifying relationships, similar to *ako*-relation and *isa*-relation.

SFN of potentials can intersect. That is, the elements of one SFN of TTP can also be the elements of another SFN. Classes of indicators of SFN of TTP are shown in Table 1 [18].

Table 1

Indicators of semantic-frame network of technical and technological potential of an enterprise

Indicators of TTP (Classes of SFN)	Properties-slots of TTP (calculation of clear conclusion of SFN in machine)
$c_{1,1}$ – capital productivity of fixed assets $c_{1,2}$ – average annual cost of fixed assets, UAH, enterprise, UAH. $z_{3,10}$ – total receipts (Source→SFN of marketing potential), UAH.	$c_{1,1}=z_{3,10}/c_{1,2}$
$c_{1,3}$ – capital-labor ratio, UAH; $c_{1,4}$ – average number of employees by list, people	$c_{1,3}=c_{1,2}/c_{1,4}$
$c_{1,5}$ – coefficient of retirement of fixed assets; $c_{1,6}$ – cost of fixed assets, retired within reporting period, UAH; $c_{1,7}$ – cost of fixed assets at the beginning of reporting period, UAH.	$c_{1,5}=c_{1,6}/c_{1,7}$
$c_{1,8}$ – coefficient of capital renewal; $c_{1,9}$ – cost of acquired fixed assets within reporting period, UAH.	$c_{1,8}=c_{1,9}/c_{1,7}$
$c_{1,10}$ – coefficient of wear and tear of fixed assets; $c_{1,11}$ – coefficient of wear and tear of fixed assets for correspondent period, UAH.	$c_{1,10}=c_{1,11}/c_{1,7}$
$c_{1,12}$ – material consumption; $c_{1,13}$ – material costs, UAH. $z_{3,10}$ – total receipts, UAH.	$c_{1,12}=c_{1,13}/z_{3,10}$
$c_{1,14}$ – coefficient of profitable use of materials; $c_{1,15}$– cost of wastes by prices of fully-fledged raw materials, UAH.	$c_{1,14}=(c_{1,13}-c_{1,15})/c_{1,13}$
$c_{1,16}$ – coefficient of faulty production; $c_{1,17}$ – costs of faulty production by cost value of sold production, UAH. $q_{1,10}$ – full cost value of sold production, UAH. (Source – SFN of financial potential).	$c_{1,16}=c_{1,17}/q_{1,10}$

Graphical view of the structural SFN of TTP of an enterprise consists of sequentially and in parallel connected units: classes, slots, the facts of individual instances of classes and is shown in Fig. 2 and developed by the Protégé system (Stanford University), which is one of the most professional systems of working with semantic-frame models (languages for recording semantic models of RDF, RDFS) [20, 21, 23]. A semantic model is used in order to display all the richness of attributes and relationships of the elements of the system that are modeled. Logical and mathematical calculations that allow finding the optimum solution are made on this model. As a rule, such modeling is sliding: the model is constantly updated due to arrival of new information about the state of the system.

4. 2. Description of schema of the system of prediction of the state of technical and technological potential of an enterprise

Today, there is a sufficient number of enterprise management systems of ERP and ERPII classes. These systems contain special functional modules that automate solution of problems of evaluation of technical and economic state of an enterprise. But implementation of these systems is not devoid of challenges that arise from the cost of the system, difficulties in staff training, focusing of the system mainly on internal processes, delayed responses to changes in the market, as well as complexity of knowledge of actualization in ERP [24, 25].

The system of prediction of security state of an enterprise with the use of semantic-frame fuzzy models of knowledge base was proposed. This system can be used by small and medium enterprises for solving specific tasks, it does not require significant investments and can be adapted in the form of an application to ERP systems.

The block-diagram of SSE prediction consists of sequentially and in parallel connected structural elements-units (Fig. 2):

Unit c1_j (j=1,...,16) is the unit of frames of classes of TTP indicators, which presents clear current values of TTP indicators of operation of an enterprise and properties of SFN classes.

Unit fact_t_t_p is the fact base (FB) of separate incidents of classes, structures by SFN.

Unit z3_10 is the indicator "total receipts" (Source – SFN of marketing potential).

Unit q1_10 is the indicator "full cost value of sold produce" (Source – SFN of financial potential).

Units AU1–AU8 are the arithmetic units of clear output machines (COM), for calculation of clear rules of BCR of COM of SFN.

Units LU1–LU8 are the logic units of the clear output machine for calculation of permissible restrictions of BCR of COM of SFN

Unit BCR is the base of clear rules of a clear output machine.

Units UF1–UF8 are the units of fuzzification of fuzziness (introduction of fuzziness), which transforms numerical input values into the degree of correspondence to linguistic variable by the rules. Degrees of truth for prerequisites of each rule: $\mu_{jp}(x_i^*)$, i=1, 2,..., n; j=1, 2,..., m; p=1, 2,..., k_j.

Using fuzzification, clear value is in conformity with the degree of its membership in fuzzy sets, the determined membership functions of fuzzy sets are used in fuzzy rules.

Unit UC is the composition unit. All fuzzy subsets, assigned to each variable – an output indicator, are combined to form a single fuzzy subset for all output variables. At a similar combination, operations max (maximum) or sum (sum) are used. At composition of maximum, combined output of a fuzzy subset is constructed as point-by-point maximum of all fuzzy subsets. At composition of sum, combined output of a fuzzy subset is formed as point-by-point sum of all fuzzy subsets, assigned to output variable by rules of inference.

Unit FBK is the fuzzy base of knowledge about the impact of indicators $x=\{x_1, x_2,..., x_n\}$ on the value of the parameter, which is a set of logic expressions like:

$$\bigcup_{p=1}^{k_j}\left[w_{jp}\bigcap_{i=1}^{n}\left(x_i = a_i^{jp}\right)\right] \rightarrow y = d_j, \quad j = 1, 2,...,m,$$

where a_i^{jp} is the fuzzy term, which assesses variable x_i in the line with number jp (p=1, 2,..., k_j); k_j is the number of lines–conjunctions, in which output is assessed by fuzzy term d_j, j=1, 2,..., m; m is the number of terms, used for linguistic assessment of output parameter y, w_{jp} is the weight of the p-th line of conjunctions of the j-th rule of knowledge base.

Current FBK of SFN consists of a set of fuzzy rules, membership functions of fuzzy sets, sets of input and output linguistic variables. SFN in the Protege is constructed as a tree and is made up of classes and relations between them [20].

Thus, a set of arcs of homogenous informational SFN structure determines classifying relationship, similar to *ako*-relation and i*sa*-relation. FBK of SFN was reduced and implemented by plug-in JESS for Protégé [21, 22]:

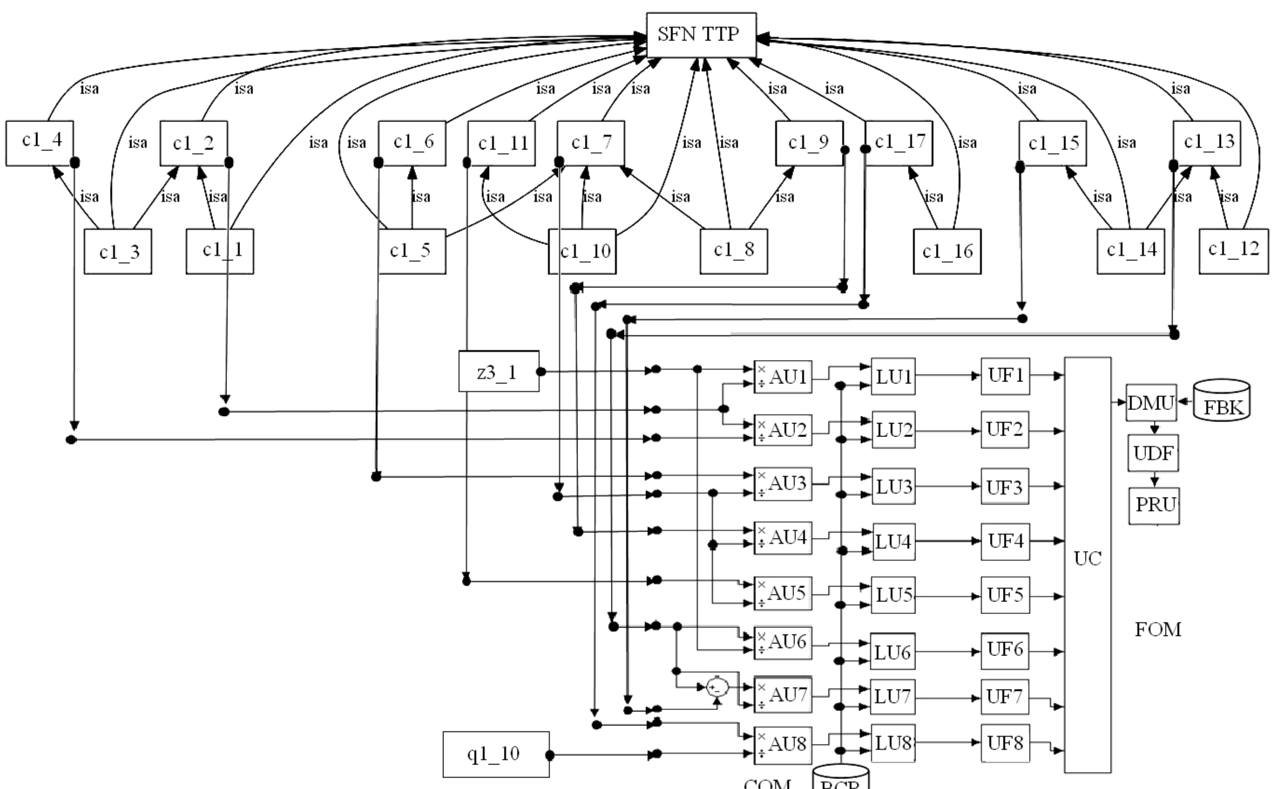

Fig. 2. Block-diagram of prediction of security state of technical and technological potential of an enterprise

1) (c1_1==mf1) or (c1_3==mf1) or (c1_5==mf1) or (c1_8==mf1) or (c1_10==mf3) or (c1_12==mf1) or (c1_14==mf1) or (c1_16==mf1) => (TT_ potential=Low_level)

2) (c1_1==mf3) or (c1_3==mf3) or (c1_5==mf3) or (c1_8==mf3) or (c1_10==mf1) or (c1_12==mf3) or (c1_14==mf3) or (c1_16==mf3) => (TT_ potential=High_level)

3) (c1_1==mf2) & (c1_3==mf2) & (c1_5==mf2) & (c1_8==mf2) & (c1_10==mf2) & (c1_12==mf2) & (c1_14==mf2) & (c1_16==mf2) => (TT_ potential=Middle_level)

4) (c1_1==mf1) or (c1_3==mf1) or (c1_5==mf1) or (c1_8==mf1) or (c1_10==mf3) or (c1_12==mf1) or (c1_14==mf1) or (c1_16==mf1) => (TT_ potential= Middle_level_50)

5) (c1_1==mf3) & (c1_3==mf3) & (c1_5==mf3) & (c1_8==mf3) & (c1_10==mf1) & (c1_12==mf3) & (c1_14==mf3) & (c1_16==mf3) => (TT_ potential=High_level_50)

6) (c1_1==mf1) & (c1_3==mf1) & (c1_5==mf1) & (c1_8==mf1) & (c1_10==mf3) & (c1_12==mf1) & (c1_14==mf1) & (c1_16==mf1) => (TT_ potential= Middle_level_50)

Membership functions can be assigned in the form of a list with explicit enumeration of all elements and corresponding values of membership function or analytically as formulas.

Indicators were separated for TTP, and for each of them polar values $\mu_A(x)\in[0, 1]$, corresponding to values of membership function 0 or 100, were determined, and vector membership function $\{\mu_A(x_1), \mu_A(x_2),..., \mu_A(x_n)\}$ was stated. The type of membership function of SSE in a considerable degree determines properties of a fuzzy system of a fuzzy output machine (FOM).

Unit DMU is the decision-making unit that performs output operations based on existing fuzzy rules of NBZ of SFN.

Calculated value of truth for the prerequisites for each rule is applied to conclusions of each rule. This leads to one fuzzy subset that will be assigned to each output variable for each rule.

Then, using one of the fuzzy composition methods, we find the values of membership functions of conclusions of the right parts by each of the rules of fuzzy production. These values of membership functions are either the sought-for output result or can be used as additional terms in base of rules of considered productions.

Levels of "cutting off" for prerequisites of each rule (using the operation minimum) are found:

$$\mu_j(y) = \min_{i,p} \mu_{jp}(x_i^*),\ i=1, 2,..., n; j=1, 2,..., m; p=1, 2, ..., k_j.$$

Next, the "clipped" membership functions are derived:

$$\mu'_j(y) = \min(\mu_j(y), \mu_{d_j}(y)),\ j=1, 2,..., m.$$

If $\mu_{jp}(x_i)$ is membership function of output x_i to fuzzy term a_i^{jp}, $i=1, 2,..., n; j=1, 2,..., m; p=1, 2,..., k_j$, and $\mu_{d_j}(y)$ is membership function in fuzzy term d_j, $j=1, 2, ..., m$, then degree of belonging of particular input vector $x^* = \{x_1^*, x_2^*, ..., x_n^*\}$ to fuzzy terms d_j from knowledge base is determined by the following system of fuzzy logic equations:

$$\mu_{d_j}(x^*) = \max_{p=1, 2, ..., k_j} \min_{i=1, 2, ..., n} \left(\mu_{jp}(x_i^*)\right),\ j=1, 2,..., m.$$

Fuzzy set y, corresponding to input vector x^*, which has upper and lower limits of the range of values $\overline{y}$ and $\underline{y}$, respectively, is determined as:

$$y = \bigcup_{j=1}^{m} \int_{\underline{y}}^{\overline{y}} \min\left(\mu_{d_j}(x^*), \mu_{d_j}(y)\right) dy.$$

Clear output value y^*, which corresponds to input vector x^*, is determined as a result of de-fuzzification of fuzzy y.

Unit UDF – The unit of de-fuzzification is used to convert a fuzzy output set into a clear number of transition to clear (numeric) value, which converts output results into numerical values. It is the procedure of transformation of a fuzzy set into a clear number by membership degree.

Output value is derived as weighted average of results of meeting each rule, for each of which de-fuzzification is carried out separately;

Clear value of output variable y^* for fuzzy set $y=\{\mu_j(y)|d_j\}$ is determined based on the centroid method.

Unit PRU is the prediction unit. Rate of change of SSE $\left(\frac{d\psi_c(t)}{dt}\right)$ is calculated by using the regressive-differential model (RDM), received by minimization of the root-mean-square deviation of calculation value $\psi'(t_i)$ from the known in nodes of annual series of values of criterion $\psi_i''(t_i)$. Output parameter is the approximated perspective value of the indicator of security state of technical and technological potential of an enterprise in time. Preconditions of bankruptcy occur well before the danger of bankruptcy appears. Introduction of the prediction unit makes it possible to more accurately and objectively consider and evaluate a full range of indicators of operation of an enterprise and calculate approximated perspective value of SSE indicator in a critical situation on the verge of bankruptcy.

The necessary condition of SSE is calculation of prediction of a critical situation for one last year. If coefficients of a model are obtained by the data from previous years, value of reaction, which is not much different from the known, is calculated. A decrease in the "known" years allows us to determine the permissible horizon of SEE prediction in first approximation.

5. Results of research into system of prediction of potentials' dynamics

The specific feature of the author's approach is that generally accessible annual series of statistical data of an enterprise are used as a basis.

Using the above methods, we created SSE, which implements the model and numerical methods and provides convenient tools for studying of the system.

To obtain value $\frac{d\psi(t)}{dt}$, approximating polynomial of the tenth order, which allow obtaining the derivative of estimated value, was calculated.

The introduction of the prediction unit makes it possible to consider and assess more accurately and objectively a whole range of indicators of the enterprise's efficiency and calculates approximated prospective value of the indicator of the state of the enterprise's technical and technological potential.

The use of RDM leads to a qualitative increase in prediction and decision making. Although in this example, the model is initially based on the first-order differential equation, of course, predictive models, based on polynomials, produce worse approximation than RDM.

The use of RDM based on the ordinary differential equation of the first order gives an opportunity to detect some new effects in objects, and in addition, at least not worse prediction error.

The latter consideration is based on the fact that the methods of solution of various problems of control, optimization, and prediction are based on this or that way of presenting the operator of a dynamic system, for which the correspondent task is solved. Thus, the structure of a dynamic regressive model, the number of unknown parameters of which includes coefficients of the operator of a selected type can be diversified. In most cases, a similar structure is non-linear. A variety of such structures of dynamic regressive models requires using modern methods of evaluation and analysis for estimation of unknown parameters.

The most common regressive economic-mathematical models, in particular those used for prediction purposes, are models of dynamics of the form

$$\frac{d\psi(t)}{dt}=\theta_0+\sum_{i=1}^{m}\theta_i\cdot x_i(t-\tau_0)+ +\sum_{i=1}^{m}\sum_{j=1}^{m}\theta_{ij}\cdot x_i(t-\tau_0)\cdot x_j(t-\tau_0)+\xi\cdot\psi(t-\tau_0), \quad (1)$$

where θ_0 is the constant that describes the influence of one N-th derivative of reaction when constructing a trend, ξ is the "feedback" coefficient, which describes the influence of value of the reaction on its *N*-th derivative, θ_i is the coefficients of the influence of factors, θ_{ij} is the coefficients of mutual (synergic) influence of the i-th and the j-th factors, $\theta_{ij}{:}i\neq j$ are the coefficients of mutual influence of factors, $\theta_{ij}{:}i=j$ are the coefficients of influence of the square of factors.

Model (2) was constructed based of the first-order differential equation with linear interpolation of factors and taking into account coefficients of mutual influence. With the help of minimization of the root-mean-square deviation of calculation value $\psi^{'}(t_i)$ from the known $\psi_i^{''}(t_i)$ values of criterion in nodes of the annual series

$$\Delta=\sum_{I=1}^{m}\left(\psi'(t_i)-\psi_i''(t_i)\right)^2$$

adequately approximated and predicted SSE

$$\frac{d\psi_c(t)}{dt}=\left\{\begin{array}{l}+22,72*+64,83*c1\_1-80,28*c1\_5-\\-34,31*c1\_8-9*c1\_10+13,3*c1\_12+\\+9,88*c1\_14+1,6*c1\_16\ +\\+140,25*c1\_1*c1\_8+27,36*c1\_1*c1\_12+\\+39,99*c1\_1*c1\_14-48,85*c1\_1*c1\_16-\\-34,81*c1\_3*c1\_5\text{-}83,14*c1\_3*c1\_8-\\-115,49*c1\_3*c1\_10-37,49*c1\_3*c1\_12\\+4,32*c1\_3*c1\_14+51,85*c1\_3*c1\_16-\\-8,23*c1\_5*c1\_8\text{-}32,17*c1\_5*c1\_12-\\-60,59*c1\_5*c1\_14+69,09*c1\_5*c1\_16\ +\\+18,3*c1\_8*c1\_12-79,65*c1\_8*c1\_14+\\+19,59*c1\_8*c1\_16\text{-}9,09*c1\_10*c1\_12+\\+11,14*c1\_10*c1\_16+11,14*c1\_10*c1\_16\end{array}\right\}-0,9812*\cdot\psi_c(t-\tau_0).$$

The potentials of existing functional subsystems were taken into account, the consequence of which can be the proposed corporative strategy of control over enterprise development processes.

Using RDM, it was possible to adequately approximate and predict SSE of an enterprise of dairy industry.

Thus, this technique, based on the use of regressive ordinary differential equation of the first order, allows prediction of SEE as a linear multi-factor model.

Thus, the models based on ordinary differential equations have obvious advantages, compared with conventional models, such as a possibility to describe naturally all positive and negative effects from the influence of separate indicators and a possibility to obtain asymptotic solutions.

The result of operation of the system of prediction of safety state of an enterprise using semantic-frame fuzzy models of knowledge base was shown on the example of VAT "Ivano-Frankivsk city milk factory" and is presented in Fig. 3.

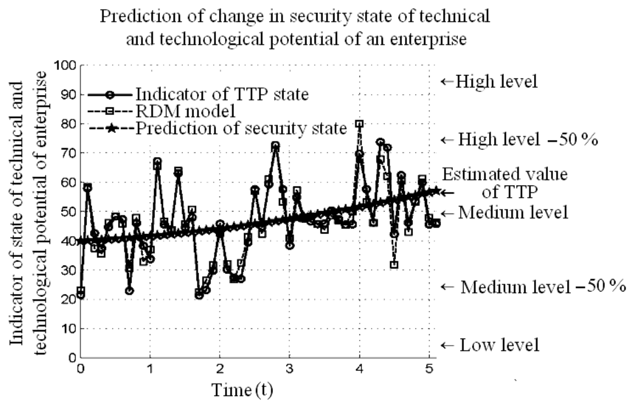

Fig. 3. Result of operation of the system of prediction of security dynamics of technical and technological potential over past years $\psi_a(t-\tau_0)$

As prediction result shows, the system responds to changes in the external and internal environment. The system allows prediction of implementation of a part of fixed assets, which do not take direct part in the production process, the use of reverse leasing, optimization of working capital investment within a calendar year. However, importance of this development for effective functioning of an enterprise of the dairy industry is considerable. The prediction system can be used for complex processes with fuzzy logic when there is no simple mathematical model and expert knowledge can be formulated without fuzzy logic only in the linguistic form.

6. Discussion of results of examining the system of prediction of security state of an enterprise and the conclusions drawn

The benefits and effectiveness, provided by the system, are achieved due to significant features, sufficient to achieve a technical result.

First, the object-oriented semantic-frame model of presentation of knowledge about security status of the technical and technological potential of an enterprise was proposed. The system provides clear current values of indicators of the enterprise's performance, properties, and permissible limits. The structure of the system is presented by units of classes of indicators and database of facts of individual instances of classes.

Second, in the prediction system, the clear output machine, as a part of arithmetic and logical units, and the base of clear production rules were formed. The base of clear rules calculates numerical values of indicators, checks admissible restrictions of properties and individual instances of classes using clear production rules.

Two arithmetic units were introduced to the input of the clear output machine for performing calculations, classes with semantic-frame network of marketing and financial potentials were included.

Third, the fuzzy output machine as a part of fuzzification units provides a transition to fuzziness of each indicator.

Due to introduction of fuzziness, the system becomes suitable for solving complex logical problems in terms of fuzzy uncertainty of SEE and processing of information in real time of the search for fuzzy output.

Conducted research makes it possible to argue that the developed prediction system enables us to consider and assess more accurately and objectively a whole range of indicators of the enterprise's efficiency and calculates approximated prospective value of the indicator of the state on the example of enterprise's technical and technological potential in time. This allows us in this way to assess the impact and predict the state of all other potentials and see, which one has the greatest influence on probability of bankruptcy of an enterprise.

7. Conclusions

1. The system of prediction of security state of an enterprise with the use of semantic-frame fuzzy models of knowledge base was developed.
2. The object-oriented semantic-frame network of base of knowledge about the state of technical and technological potential of an enterprise, which provides clear current values of indicators of enterprise's operation, properties, permissible restrictions of these properties, was examined.
3. The knowledge base, which consists of units of indicator classes, and the base of facts of individual instances of classes were obtained Knowledge base is combined with the clear and the fuzzy output machines. This allows saving qualitative indicators, linguistic rules, and getting linguistic or numerical productive conclusion. Knowledge base gives explanation about the state and dynamic changes of the level of technical and technological potential of an enterprise in time for enterprises of dairy industry of Ukraine.
4. Regressive-dynamic models for the prediction unit, which takes into account approximated prospective value of the indicator of the state of technical and technological potential of the enterprise in time, were developed.

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UDC 621:658.264
DOI: 10.15587/1729-4061.2017.119083

A PROCEDURE FOR OPTIMIZATION OF ENERGY SAVING AT HIGHER EDUCATIONAL INSTITUTIONS

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Запропоновано методику удосконалення системи енергозбереження у вищих навчальних закладах України як складової підвищення результативності діяльності. Запропонована методика базується на розробленій моделі оптимального управління тепловим режимом приміщень з мінімізацією витрат енергії на опалення та енергетичних втрат при підтримці заданого рівня теплового комфорту на прикладі Київського національного університету технологій та дизайну (Україна)

Ключові слова: теплонадходження, тепловтрати, ABC-XYZ-аналіз, теорія ігор, оптимальний режим теплоспоживання, вищі навчальні заклади

Предложена методика усовершенствования системы энергосбережения в высших учебных заведениях Украины как составляющей повышения результативности деятельности. Предложенная методика базируется на разработанной модели оптимального управления тепловым режимом помещений с минимизацией затрат энергии на отопление и энергетических потерь при поддержке заданного уровня теплового комфорта на примере Киевского национального университета технологий и дизайна (Украина)

Ключевые слова: теплопоступления, теплопотери, ABC-XYZ-анализ, теория игр, оптимальный режим теплопотребления, высшие учебные заведения

1. Introduction

At present, energy saving is one of the priority tasks due to the deficit of basic energy resources and the increase in the cost of extraction, as well as global environmental problems. Large consumers of energy resources are educational institutions of various levels, which include higher educational institutions (HEI). According to the National Report on the Status and Prospects of Implementation of the State Energy Efficiency Policy in 2015, the specific energy con-