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Developing the Expert System for Assessing the Resilience to Crisis of Enterprises with Weak Dynamics

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Abstract. In the last decade there has been considerable interest in the problem of enterprises crisis resolution. It is related to the fact that a number of economic crises hit many countries. This paper presents a new approach to assess the resilience to crisis of enterprises. For this purpose, we propose to develop the traditional expert system. The expert system is based on predicate rules that contain two premises and one logical judgment. We propose to use the integral index of the enterprise non-dynamism and the total number of enterprise employees as input variables. The output variable is a probabilistic assessment of the enterprise crisis resolution. The developed expert system makes it possible to identify the most vulnerable enterprises in a crisis period.

1. Introduction

The beginning of the 21st century is characterized by a number of significant crises in the global economy. These crises have different causes and structures. For instance, the global crisis of 2008-2009 was caused, among other things, by serious problems of mortgage lending in the USA [1-4]. The crisis of 2014 was provoked by the geopolitical disagreements of the major global powers [5, 6]. Local crises, for example, the crisis of the Cypriot banking system in 2012-2013 [7, 8] or the Greek external debt crisis of 2015 [9, 10], also have a negative impact, therefore, any economy must be resistant to the crisis in some degree for successful development. Improving such resistant, primarily due to the competent management of the most important index-numbers, is one of the most important tasks of today. Consequently, study of the crisis impact on various sectors of the economy and individual enterprises is important and well-timed.

The weak dynamics of production in this work will be understood as the inability to significantly change the volume of production in response to changing demand in a short period of time due to a number of objective reasons that are not related to the quality of management, but which are fundamental characteristics of the production process [11]. In [12] we distinguished three main reasons for the weak dynamics of production that are:

1. the long-run product campaign;
2. the inefficiency or even the impossibility of the normal operation of the production equipment with its partial load or periodic stoppage;
3. the high level of the intellectual capital [13-16].

It is enterprises with weak dynamics that are most vulnerable during a crisis.

2. Methods

Complex stochastic models are often used to assess the enterprise crisis resilience [17-19]. They make it possible to get results taking into account the real quality of management decisions. However, this approach does not allow for features of the production process and its organization in the case of production with weak dynamics. In some cases, for an enterprise with weak dynamics, its resilience to crisis can be more determined by the degree of non-dynamism than by the quality of management. Therefore, in this research, we propose to develop an expert system to assess the resilience to crisis of enterprises with weak dynamics. Its main advantage is the lack of a specific mathematical relationship between input variables and output variable. The assessment is based on a synthesis of the experience in the crisis resolution by real enterprises. The developing expert system is traditional and includes a set of predicate rules, their form is as follows:

$$R_1\text{: If } x_1 \text{ is } A_{11} \text{ and (or) } x_2 \text{ is } A_{21} \text{ and (or)... and (or) } x_n \text{ is } A_{n1}\text{, then } y \text{ is } B_1, \quad (1)$$

where $x_1...x_n$ is a set of input variables, A_{ij} is an input variable value, y is an output variable, B_i is an output variable value.

In the study, we assume that each predicate rule contains two premises and one logical judgment. Thus, there are two input variables and one output variable. We propose to use the integral index of the enterprise non-dynamism (x_1) and the total number of enterprise employees (x_2) as input variables. The integral index of the enterprise non-dynamism is a quantitative characteristic of the degree of the production non-dynamism, which distinguishes enterprises that are most vulnerable in a crisis period due to the characteristics of the production process and the production organization. The output variable is a probabilistic assessment of the enterprise crisis resolution at a management level close to optimal.

3. Results and discussion

The block diagram of the developed expert system is presented in Figure 1.

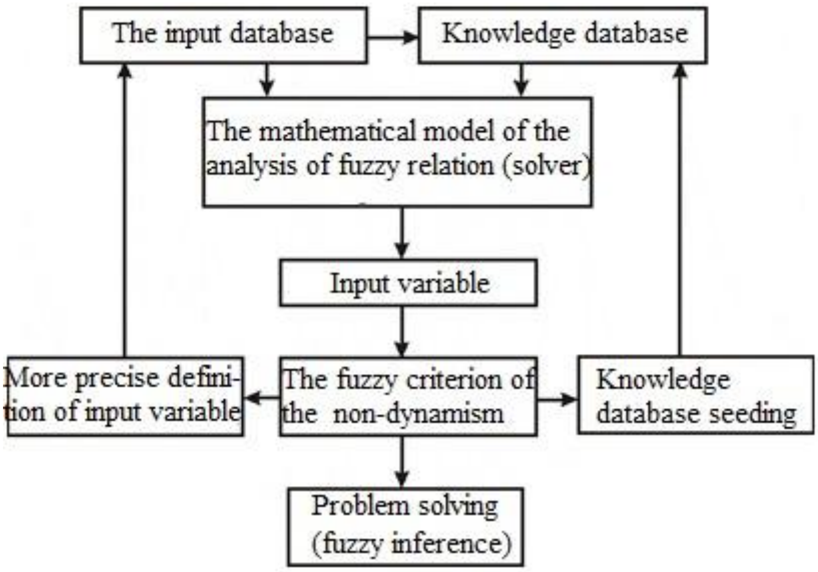

Figure 1. The block diagram of the developed expert system.

The input database is an important component of the expert system, which largely determines the accuracy and adequacy of the obtained solution. It includes the following elements:

– the linguistic variable "Enterprises with weak dynamics", which allows the decision maker to identify the most vulnerable enterprises and form the boundaries of fuzzy subsets of ground terms: "high degree of non-dynamism", "moderate degree of non-dynamism" and "low degree of non-dynamism";

– the ranked list of enterprises, which takes into account both the degree of the enterprise non-dynamism and the membership function of fuzzy subsets of ground terms of the linguistic variable "Enterprises with weak dynamics", and the level of enterprises specialization;

– the number of employees for each enterprise presented in the ranked list;

– the assessment of the main parameters of the looming crisis.

Knowledge database is blocks of predicate rules with two premises and one logical judgment. Blocks were assembled in accordance with crises with similar parameters or separately for each crisis depending on the amount of available data (Figure 2).

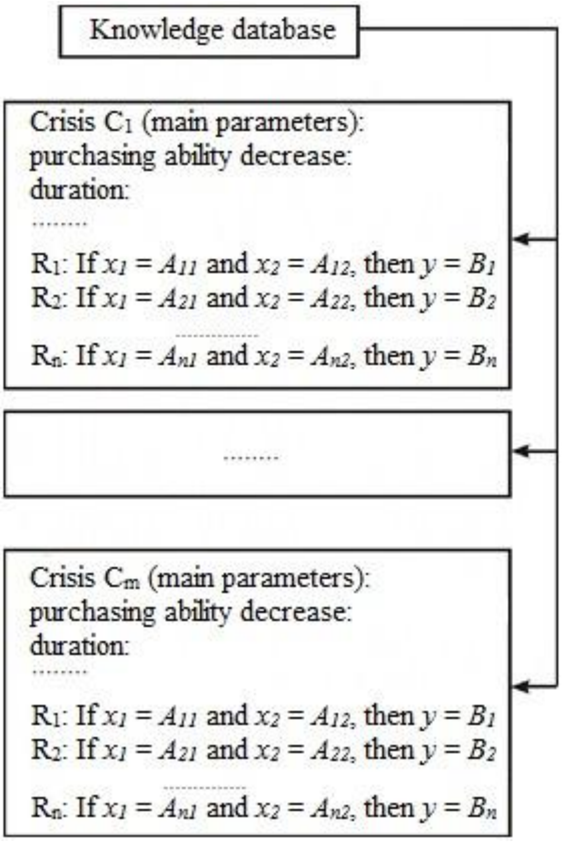

Figure 2. The block diagram of the knowledge database of the expert system.

The direct interaction of the input database with the knowledge database occurs in terms of choosing the most suitable blocks from the knowledge database for the real or model crisis situation by comparing the estimates of the main parameters of the looming crisis and the crises embedded in the knowledge database. Here we can select one or more blocks. In this case, it is necessary to take into account the differences between the main parameters of a real or model crisis and crises embedded in the knowledge database when we determine the degree of truth of the premises of predicate rules. Situations are possible when not all the main parameters of the crisis will be significant for the analysis. In this case, only differences of significant parameters should be considered.

Another interaction of the input database with the knowledge database occurs by means of a mathematical model of the analysis of fuzzy relations when we determine the degree of truth of the predicate rules premises of the selected blocks of the knowledge database, taking into account the correspondence of the main parameters of a real or model crisis and the similar parameters.

In case of updating or supplementing the database, it is necessary to repeat the choice of the most suitable blocks for a real or model crisis situation.

The mathematical model of the analysis of fuzzy relation (solver) is a mathematical implementation of the relationship of input variables with an output variable in the form of a fuzzy relation. The fuzzy relation analysis allows us to generate an output variable from the knowledge database taking into account the input database that corresponds to those enterprises and the crisis situation that were formalized in the input database.

$$R = (A_1 \times A_2) \to B, \tag{2}$$

where R is the fuzzy relation, A_1 and A_2 are the range spaces of input variables, $\times$ is the fuzzy direct product operation of ground sets of input variables, $\longrightarrow$ is the fuzzy implication, B is the range space of output variable.

As a result of the analysis of the fuzzy relation (2) we can form the output variable using the mathematical model:

$$B^* = (A_1^* \times A_2^*) \circ R = (A_1^* \times A_2^*) \circ ((A_1 \times A_2) \to B), \tag{3}$$

where B^* is the formed output variable, A_1^* and A_2^* are input variable values for a specific model situation, $\circ$ is the fuzzy convolution operation.

The output variable is formed by the solver in the form of fuzzy implication using the prune operations or scaling operations of membership functions of input variables [20], and then the composition of the integral membership function using the maximum or sum operation. An approximate form of the integral membership function for one enterprise with the use of prune operations with implication and maximum operations with composition is shown in Figure 3.

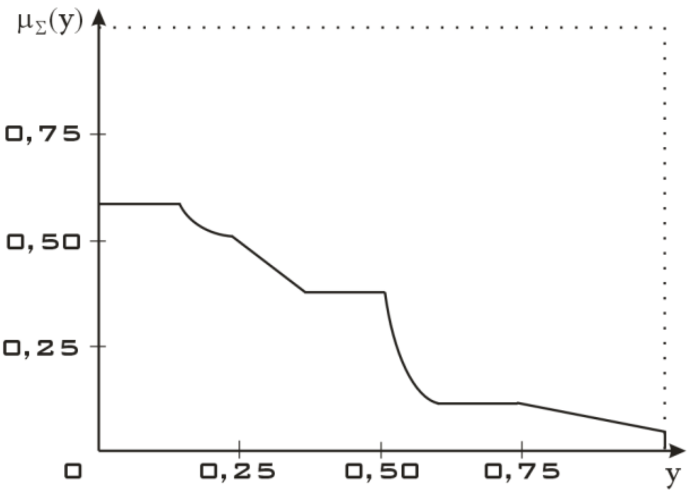

Figure 3. An approximate form of the integral membership function for the output variable**.**

The domain of the integral membership function and the acceptance region of values are unit segments: $[0, 1]$. The output variable is the final goal and result of the developed expert system.

Further, using one of the defuzzification methods, we can get the estimated probability of the successfully crisis resolution in the enterprise. The most common of these methods is the centroid method. This method is in determining the centroid of a figure, which is an integral membership function (Figure 3). The abscissa of the centroid is the estimated probability of an enterprise successfully crisis resolution.

4. Conclusions

Thus, the developed traditional expert system makes it possible to assess the resilience to crisis of the studied enterprises and to identify the most vulnerable ones. The ranking of enterprises will allow selectively developing a set of measures to increase the resilience to crisis of enterprises. The developed expert system contains the data on the crisis of 2008-2010 and is used today in practice to assess the resilience to crisis of enterprises with weak dynamics as an analysis of the criticality of their dynamism degree in the aspect of the main parameters of the looming crisis. Significant criticality means the need to increase the efficiency of production organization in a crisis period by reducing the non-dynamism. Based on the output variable obtained by an expert system, taking into account restrictions, a fuzzy criterion of non-dynamism will be formed in our further study.

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