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ОЦІНЮВАННЯ ФІНАНСОВОГО СТАНУ ПІДПРИЄМСТВ З ВИКОРИСТАННЯМ НЕЧІТКОЇ ЛОГІКИ

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Розглянуто значущість аналізу фінансового стану організацій у сучасній ринковій економіці, оскільки саме завдяки цьому процесу отримується важлива частина інформації для прийняття управлінських рішень керівниками підприємств, та в якій зацікавлені майже всі суб'єкти ринкових відносин: власники, акціонери, банки та інші кредитори, інвестори, аудитори, постачальники та покупці, страхові компанії та інші. Акцентовано увагу на те, що одним із сучасних і перспективних напрямів наукових досліджень у галузі аналізу, прогнозування та моделювання економічних явищ і процесів є нечітка логіка. Нечітко-множинні моделі дають можливість менеджерам різного рівня і власникам підприємств приймати економічно обґрунтовані рішення.

Сформовано на основі даних фінансової звітності підприємства, а саме бухгалтерського балансу і звіту про фінансові результати показники, що характеризують фінансовий стан підприємства, а саме, показник "фінансової незалежності", "швидкої ліквідності", "маржі валового прибутку" і "рентабельності активів" (ROA). Побудовано та обґрунтовано терм-множини і функції належності для кожної змінної з метою отримання нечітких значень, необхідних для подальшого аналізу фінансового стану підприємства, визначено множину правил аналізу стану підприємств. За допомогою побудованої нечіткої моделі оцінено поточний фінансовий стан підприємства з використанням методу формування логічного висновку Мамдані. За допомогою обраних показників та множини сформованих правил отримано логічний висновок, який є значенням вихідної змінної, що характеризує поточний фінансовий стан організації.

Ключові слова: фінансовий стан підприємства, нечітка логіка, множина правил, логічний висновок, лінгвістичні змінні.

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EVALUATION OF FINANCIAL CONDITION OF ENTERPRISES USING FUZZY LOGIC

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The importance of financial analysis of enterprises in the modern market economy is considered in this article. As a result of this process we receive an important piece of information for decision making by enterprise managers. Almost all subjects of market relations: owners, shareholders, banks and other lenders, investors, auditors, suppliers and buyers, insurance companies and others are interested in this information. One of the current and future directions of research in analysis, forecasting and modelling of economic phenomena and processes is fuzzy logic. Fuzzy multiple-models enable managers at various levels and business owners make economically sound decisions.

On the basis of the financial statements, such as balance sheet and income statement indicators which characterize the financial condition were formed, namely, the rate of "financial independence", "quick ratio", "gross profit margin" and "return on assets" (ROA). Term-sets and membership functions were constructed for each variable to obtain fuzzy values necessary for further analysis of the financial condition of the company, the set of rules of

enterprise analysis were defined. The current financial condition of the enterprise was estimated using the constructed fuzzy model that implements Mamdani's fuzzy inference method. With the selected parameters and set of rules the logical conclusion was formed, which is the value of the output variable that characterizes the current financial condition of the enterprise.

Key words: financial condition of enterprise, fuzzy logic, set of rules, logical implication, linguistic variables.

Formulation of the problem. To improve the quality of decision-making at production enterprises it's needed to perform analysis of their current financial condition based on statistical data and using modern methods of mathematical modelling. The transition from financial analysis to statistical analysis begins with the computation of an infinite number of parameters that do not express anything and have outdated names.. Thereby, we need a complex assessment of the financial condition of enterprises based on statistical data in order to improve the quality of forecasts of financial processes and management decisions made on their basis. Today there is a wide range of methods for assessing the financial condition using regression models and methods of data mining, one of which is fuzzy logic.

Analysis of recent research and publications. Fuzzy logic is one of the modern and promising areas of research in analysis, forecasting and modelling of economic phenomena and processes. Fuzzy models make it possible to managers of various levels and business owners to make economically reasonable decisions. Since the number of variables are unavailable for accurate measurement, in their evaluation appears an inevitable subjective component, which can be presented as fuzzy estimates like "poor", "good", "critical", "watch", "standard", "unlikely "etc. Something appears that is scientifically described as a linguistic variable with its term-set of values and the relationship of quantitative value of some factor with its qualitative linguistic description is given by the so-called membership functions of fuzzy sets of values of the factor [1, 2].

1. Due to the possibility of forming logic inference using appropriate models, fuzzy logic is used to solve many practical problems and to obtain high quality results in the form of models, forecasts or final decisions [1, 2, 3].

Entire article. 1. To consider principles of use of fuzzy logic to solve the problem of assessment of the financial condition of enterprises. 2. To provide an example of applying the described fuzzy method based on of statistical data on the activities of existing enterprise.

The main material of research

Application of the theory of fuzzy logic. The most striking feature of human intelligence is the ability to make the right decisions in conditions of incomplete and fuzzy information. Building a model close to human thinking and their use in computer systems today represents one of the most important problems of science.

The main task of modern information technology financial management is accurate and timely submission of the required number of information professionals and managers to analyze and make informed decisions. Fuzzy description of the structure of the model appears in the corporate communications expert with uncertainty, which arises in the classification of indicators. For example, an expert cannot clearly distinguish between "high" and "maximum" likelihood, or if you want to spend the border between medium and low setting. In such cases, the application of fuzzy descriptions means the following:

–   expert fixes rate and its quantitative carrier;

–   the selected media expert builds linguistic variable with its term-set of values; for example, the variable "level indicator X" may be a term-set values: "very low", "low", "medium", "high" and "very high";

–   then, the value of each linguistic variable (which by its construction is a fuzzy set of values in the interval (0, 1) (the field values of the level of management), in correspondence of the management function of a particular fuzzy set [2].

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Experience in financial modeling systems using fuzzy set-descriptions can identify a number of advantages in using these formalisms in problems of financial management, including:

- fuzzy sets perfectly describe the subjective activity of decision making people. Uncertainty in expert evaluation of membership function can be modeled, which acts as a carrier acceptable set of values of the analyzed area. In addition, the decision maker has an opportunity to quantitative interpretation, originally formed qualitatively, in terms of natural language;

- fuzzy numbers (variety of fuzzy sets) are ideal for planning parameters at the time when their future is related to the difficulty score (it is blurred, there is little probability study). Thus, all the scenarios in this or other indicators can be summarized in one combined scenario in the form of triangular numbers, where there are three terms : the smallest possible, most expected and the maximum possible value of the index. Thus the weight of the individual scenarios in the structure of the consolidated scenario formalized as a triangular membership function of fuzzy set parameter "approximately equal average ";

- Researcher of the financial system may be formalized within the same model as the economic features of the object, and cognitive features associated with this object manager and business analyst, generating an expert model of the structure of a generalized financial model. Thus, there is a platform for integration is fundamentally heterogeneous knowledge within a quantitative financial models;

- it is possible to get a completely new class of complex financial analysis, based on the integration of a number of individual financial ratios into a single comprehensive indicator of the financial condition of the economic entity [2].

Mamdani algorithm to form a logical implication
1. Introduction of fuzziness to describe the variables in the form of fuzzy sets:
$$A_1(x_0), A_2(x_0), B_1(y_0), B_2(y_0), C_1(z), C_2(z).$$
2. Formulation of rules, namely a model of the process in the form of sets of rules:
$$\Pi_1 : \text{Якщо } x \in A_1 \text{ і } y \in B_1, \text{то } z \in C_1;$$
$$\Pi_2 : \text{Якщо } x \in A_2 \text{ і } y \in B_2, \text{то } z \in C_2.$$
Information provided in the form of statements containing the conjunction and implication.

The final result – the logical conclusion formed by disjunction of the results. So you need to build a fuzzy answer as the relative values of the characteristic features:
$$\mu_{\Sigma \text{ EMBED Equation.3 } \Box\Box\Box}(z) = A_1(x_0) \wedge B_1(y_0) \wedge C_1(z) \vee A_2(x_0) \wedge B_2(y_0) \wedge C_2(z), \tag{1}$$
then go to the definition. Consider the sequence: the first half of the rules can be represented as
$$A_1(x_0) \wedge B_1(y_0) = \propto_1 \tag{2}$$
$$A_2(x_0) \wedge B_2(y_0) = \propto_2. \tag{3}$$
The second half as:
$$\propto_1 \wedge C_1(z)$$
$$\propto_2 \wedge C_2(z),$$
where (x_0, y_0) – specific input variables.

3. Logical conclusion: find the level of "cut-off" for the preconditions of each rule (using transaction level):
$$\propto_1 = A_1(x_0) \wedge B_1(y_0) \tag{4}$$
$$\propto_2 = A_2(x_0) \wedge B_2(y_0). \tag{5}$$
Where with "∧" is designated minimum logical operation (min).

Then there are "truncated" membership function:
$$C'_1 = (\propto_1 \wedge C_1(z)) \tag{6}$$
$$C'_2 = (\propto_2 \wedge C_2(z)) \tag{7}$$

4. Composition. Active association found truncated functions using real MAXIMUM (max, denoted hereinafter as "∨"), that leads to obtain the result of fuzzy subsets for the variable out of the membership function:
$$m\sum = C(z) = C_1^2(z) \vee C_2^2(z) = (\propto_1 \wedge C_1(z)) \vee (\propto_2 \wedge C_2(z)) \tag{8}$$

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5. To bring "clarity" will apply the following tsentroyidnyy method:

$$z_0 = \frac{\int zm \sum (z)dz}{\int m \sum (z)dz} \qquad (9)$$

So, due to the described mathematical tools we can mathematically describe the essential quality indicators (" good", "critical", "bad", and so on.). With "fuzzy" type variable, with some distribution function and then use them as accurate. This theory was founded over half a century ago in fundamental studies Lotfi Zadeh [3].

Description of input fuzzy model to determine the financial condition of the company
To solve this problem we introduce the following linguistic variables evaluating financial condition of enterprise:

1. The factor "financial independence" $= \dfrac{\text{Own funds}}{\text{Borrowed funds}}$ (10)
Measures the level of funds of enterprise.

2. The factor "quick ratio" $= \dfrac{\text{Cash + Securities + Receivables}}{\text{Current liabilities}}$ (11)
Ability to pay its current liabilities using most liquid assets. The most valuable indicator of liquidity, because it does not take into account reserves.

3. Ratio of "gross margin" $= \dfrac{\text{Gross profit}}{\text{Net sales}} \times 100\%$ (12)
It shows how much of the company's profits remaining after payment of wages, raw materials and so on.

4. Factor "return on assets" (ROA) $= \dfrac{\text{Gross profit + Interest expense}}{\text{Total assets}}$ (13)
This indicator shows how profitable a company is relative to its assets.

5. Starting the resulting variable is the assessment of the financial condition of the company, which is the basis for further decision.

Method of constructing a fuzzy model to determine the financial condition of the company
When building a fuzzy model for analyzing the financial condition of the company can be divided into several stages.
1. Choice of indicators. To build a model for determining the financial condition of the company will form a set of key indicators to assess this condition and provide them with the ratios for calculations. A similar set of indicators and setting the values of these parameters is an option, since it creates an expert for each company taking into account the specifics of the company and the economic situation of the country.

2. Constructing membership functions

1) The factor "financial independence"
The coefficient ranges from 0 to 4.
– Membership function (FN) coefficient "financial independence" to terms "bad" (triangular form):

$$\mu(d) = \begin{cases} 2.5, & \text{якщо } 0 \le d \le 0.4; \\ 1, & \text{якщо } d = 0.4; \\ 1.8 - 2d, & \text{якщо } 0.4 < d < 0.9; \\ 0, & \text{якщо } d = 0.9. \end{cases} \qquad (14)$$
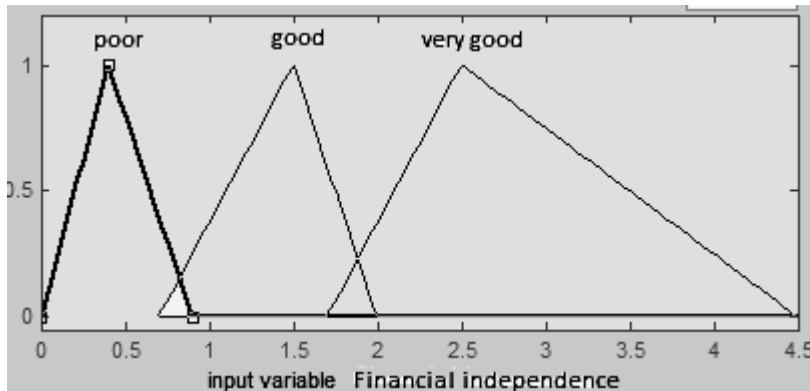
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– FI coefficient "financial independence" to terms "good" (triangular form):

$$\mu(d) = \begin{cases} 1.25d - 0.875, & \text{якщо } 0.7 \leq d < 1.5; \\ 1, & \text{якщо } d = 1.5; \\ 4 - 2d, & \text{якщо } 1.5 < d < 2; \\ 0, & \text{якщо } d = 2. \end{cases}$$

(15)

– FI coefficient "financial independence" to terms "very good" (triangular form):

$$\mu(d) = \begin{cases} 1.25d - 2.125, & \text{якщо } 1.7 \leq d < 2.5; \\ 1, & \text{якщо } d = 2.5; \\ 2.25 - 0.5d, & \text{якщо } 2.5 < d < 4.5; \\ 0, & \text{якщо } d = 4.5. \end{cases}$$

(16)

Fig. 1. The first variable – the factor of "financial independence":
T1 = {" poor", "good", "very good" }

2) The factor "**quick ratio**"

The coefficient ranges from 0 to 4.

– FI coefficient "quick ratio" to terms "poor" :

$$\mu(d) = \begin{cases} 2.5d, & \text{якщо } 0 \leq d < 0.4; \\ 1, & \text{якщо } d = 0.4; \\ 1.8 - 2d, & \text{якщо } 0.4 < d < 0.9; \\ 0, & \text{якщо } d = 0.9. \end{cases}$$

(17)

– FI coefficient "quick ratio" to terms "good" :

$$\mu(d) = \begin{cases} 1.25d - 0.875, & \text{якщо } 0.7 \leq d < 1.5; \\ 1, & \text{якщо } d = 1.5; \\ 4 - 2d, & \text{якщо } 1.5 < d < 2; \\ 0, & \text{якщо } d = 2. \end{cases}$$

(18)

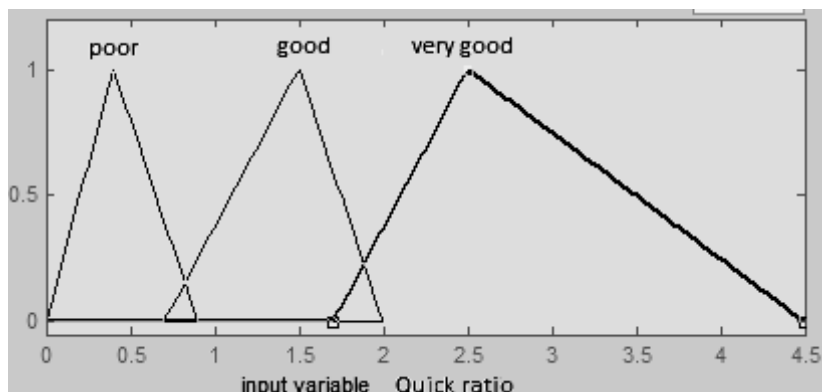*Fig. 2. The second variable – factor "quick ratio" –*
T2 = {" poor", "good", "very good" }

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– FI coefficient "quick ratio" to terms "very good" :

$$\mu(d) = \begin{cases} 1.25d - 2.125, & \text{якщо } 1.7 \le d < 2.5; \\ 1, & \text{якщо } d = 2.5; \\ 2.25 - 0.5d, & \text{якщо } 2.5 < d < 4.5; \\ 0, & \text{якщо } d = 4.5. \end{cases} \tag{19}$$

3) Ratio of "gross margin"

The coefficient ranges from 0 to 45 (%).

– FI coefficient "gross margin" to terms "poor" :

$$\mu(d) = \begin{cases} 0.17d, & \text{якщо } 0 \le d < 6; \\ 1, & \text{якщо } d = 6; \\ 2 - 0.17d, & \text{якщо } 6 < d < 12; \\ 0, & \text{якщо } d = 12. \end{cases} \tag{20}$$

– FI coefficient "financial independence" to terms "good" :

$$\mu(d) = \begin{cases} 0.17d - 1.67, & \text{якщо } 10 \le d < 16; \\ 1, & \text{якщо } d = 16; \\ 3.67 - 0.17d, & \text{якщо } 16 < d < 22; \\ 0, & \text{якщо } d = 22. \end{cases} \tag{21}$$

– FI coefficient "financial independence" to terms "very good" :

$$\mu(d) = \begin{cases} 0.1d - 2, & \text{якщо } 20 \le d < 30; \\ 1, & \text{якщо } d = 30; \\ 3 - 0.07d, & \text{якщо } 30 < d < 45; \\ 0, & \text{якщо } d = 45. \end{cases} \tag{22}$$
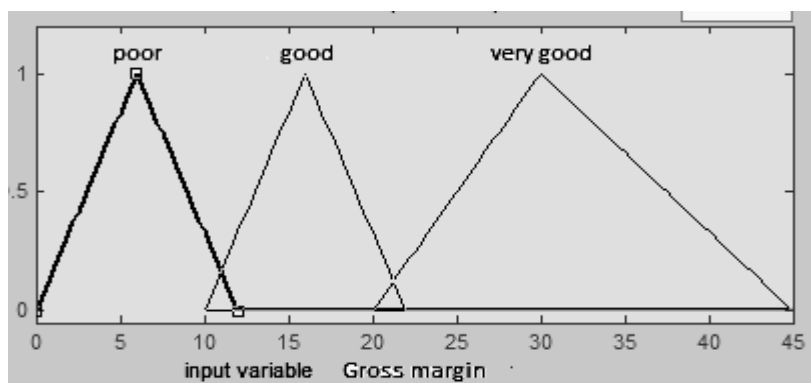

Fig. 3. The third variable – ratio "gross margin"
– T3 = {" poor", "good", "very good" }

4) Factor "return on assets" (ROA)

The coefficient ranges from 0 to 15 (%).

– FI coefficient "ROA" to terms "poor" :

$$\mu(d) = \begin{cases} 0.67d, & \text{якщо } 0 \le d < 1.5; \\ 1, & \text{якщо } d = 1.5; \\ 2 - 0.67d, & \text{якщо } 1.5 < d < 3; \\ 0, & \text{якщо } d = 3. \end{cases} \tag{23}$$

– FI coefficient "ROA" to terms "good" :

$$\mu(d) = \begin{cases} 0.5d - 1, & \text{якщо } 2 \le d < 4; \\ 1, & \text{якщо } d = 4; \\ 2.33 - 0.33d, & \text{якщо } 4 < d < 7; \\ 0, & \text{якщо } d = 7. \end{cases} \tag{24}$$

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– FI coefficient "ROA" to terms "very good" :

$$\mu(d) = \begin{cases} 0.2d - 1, & \text{якщо } 5 \le d < 10; \\ 1, & \text{якщо } d = 10; \\ 3 - 0.2d, & \text{якщо } 10 < d < 15; \\ 0, & \text{якщо } d = 15. \end{cases}$$
(25)

As the term-set of the output linguistic variable "financial state" use plural T5 = {" critical", "poor", "average", "good", "excellent" }.
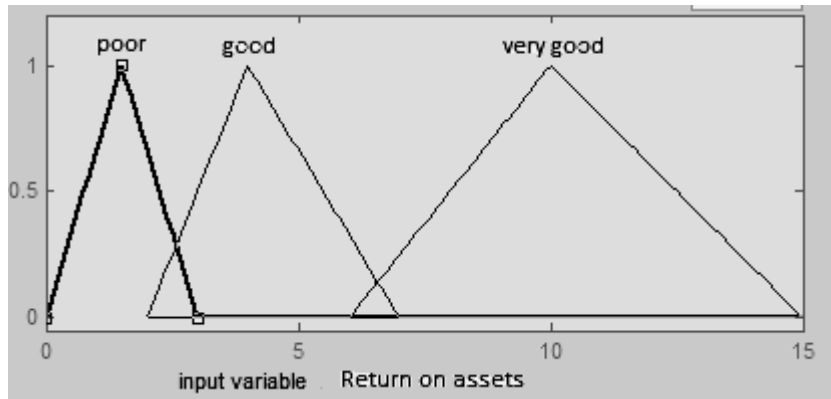

Fig. 4. The fourth variable – rate "return on assets" (ROA) –
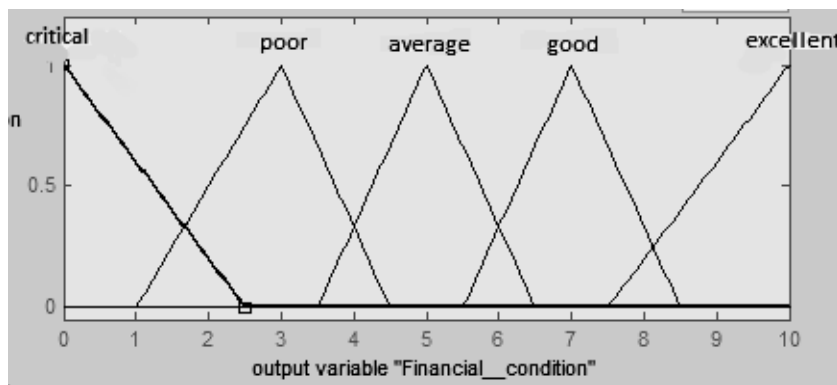*T4 = {" poor ", "good", "very good" }*

Fig. 5. Output variable "financial position"

The method of Mamdani as a method of forming a fuzzy output that provides acceptable accuracy estimates.

3. Formation sets of rules
Total generated 25 rules. Here are some of them, for example.

1. If the ratio of "financial independence" – *bad;* factor "quick ratio" – *bad*; factor "gross margin" – *bad*; factor "return on assets" – *bad*, then condition – ***critical.***

2. If the ratio of "financial independence" – *good*; factor "quick ratio" – *bad*; factor "gross margin" – *bad*; factor "return on assets" – *bad*, then condition – ***critical.***

.....

6. Factor "financial independence" – *bad*; factor "quick ratio" – *good*; factor "gross margin" – *bad*; factor "return on assets" – *the good*, the condition – ***poor.***

7. If the ratio of "financial independence" – *good*; factor "quick ratio" – *bad*; factor "gross margin" – *good*; factor "return on assets" – *bad*, the condition – ***poor.***

.....

11. If the ratio of "financial independence" – *bad*; factor "quick ratio" – *good*; factor "gross margin" – *good*; factor "return on assets" – *good*, the condition – ***average.***

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12. If the ratio of "financial independence" – *good*; factor "quick ratio" – *good*; factor "gross margin" – *good*; factor "return on assets" – *bad*, the condition – **average.**

.....

15. Factor "financial independence" – *good*; factor "quick ratio" – *good*; factor "gross margin" – *good*; factor "return on assets" – *a very good*, condition – **good.**

16. If the ratio of "financial independence" – *very good*; factor "quick ratio" – *good*; factor "gross margin" – *good*; factor "return on assets" – good, the condition – **good.**

.....

21. If the ratio of "financial independence" – *very good*; factor "quick ratio" – *very good*; factor "gross margin" – *very good*; factor "return on assets" – good, the condition – **excellent.**

.....

25. If the ratio of "financial independence" – *very good*; factor "quick ratio" – *very good*; factor "gross margin" – *very good*; factor "return on assets" – *a very good*, condition – **excellent.**

The results are

For example, set the following values of the input variables:
1) The factor "financial independence" = 2.5 (" very good").
2) The factor "quick ratio" = 1.52 (" good").
3) Ratio of "gross margin" = 15.5 (" good").
4) Factor "return on assets" = 4.35 (" good").
As a result, the financial evaluation of enterprise takes the value = 7 (" **good**"), rule № 16.
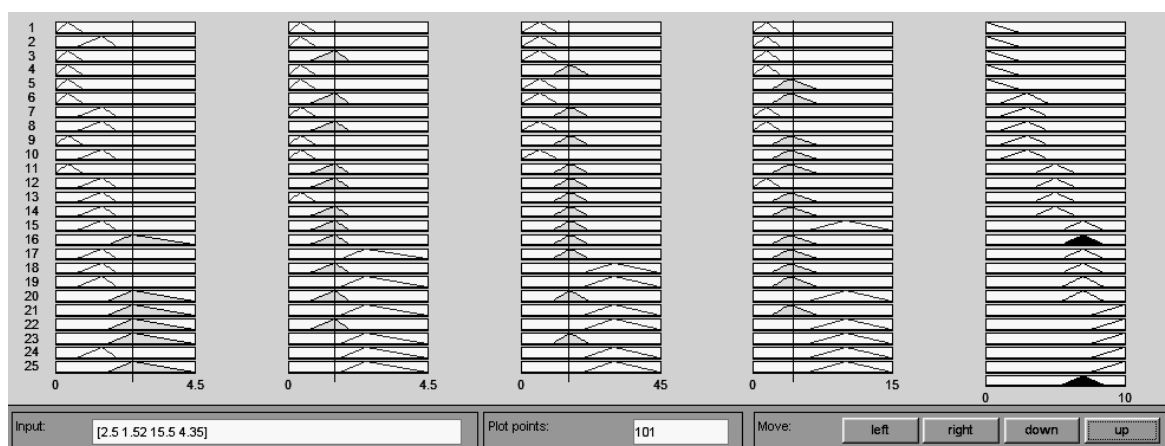

Fig. 6 Results of the review after the implementation of the rules of procedure of the fuzzy conclusion

Conclusions. Accordingly, based fuzzy model which has high accuracy that leads to its successful use in practice to assess the financial condition of the enterprise and an opportunity to get more accurate results compared with traditional analytical (regression) models.

In further studies to improve the accuracy of output results need to consider additional parameters that affect the assessment of the financial condition of the enterprise and expand the set of rules depending on the sector of the enterprise. Also, it is advisable to build an information system to support decision making based on the set of complementary models for solving problems of this class.

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