MODELS AND SOFTWARE SOLUTIONS FOR THE PROBLEM OF DIAGNOSING THE FINANCIAL STATE OF IT-ENTERPRISE

Today, the economy of Ukraine is in a relatively unstable position; therefore, Ukrainian enterprises require effective management. But in order to effectively manage the enterprise, you need to know what state it is in. Solving the problem of diagnosing the financial state of an enterprise in the future will allow developing an apparatus of effective management decisions that will help maintain the enterprise at the proper level of functioning and ensure further development of both the enterprises and the economy as a whole. The relevance of research is manifested in the application of the results for operational and effective management. The problem is in the need to obtain a more accurate solution for the problem of diagnosing the financial state of the enterprise with the parameters that characterize the financial situation best of all. The main objective of the research was to solve the problem of diagnosing the financial state of an IT company, using a model that implements a certain approach in order to obtain a qualitative conclusion about the state of a company. A method based on the use of a fuzzy logic apparatus, namely, production models with a Mamdani fuzzy inference algorithm is proposed for solving the problem. There are 10 input parameters were allocated to determine the financial state. The criteria according to which the state was assessed were quantitative and qualitative indicators of the company’s activity over the selected period. The resulting mathematical model allows estimation of the financial state of a company, and can also be used in the future, for example, to solve the forecasting problem. The implementation of research results can help speed up the diagnosis of the financial state of the enterprise and make a right management decision based on the results of diagnosis in time.

Keywords: diagnosing, financial state, financial indicator, fuzzy logic, production model, Mamdani algorithm, rule base.

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MODELS AND PROGRAMMATIC SOLUTIONS TO THE PROBLEM OF DIAGNOSING THE FINANCIAL STATE OF IT-ENTERPRISE

On the one hand, economic policy in Ukraine is extremely unstable, therefore the enterprises in Ukraine follow effective management policies. In order to effectively manage the enterprise you need to know what state it is in. To solve this problem, identification of the financial state of an IT company, which implements a certain approach, allows to obtain a more accurate solution for the problem of managing the enterprise. The criteria according to which the state of company was assessed were quantitative and qualitative indicators of the company's activity over the selected period. The resulting mathematical model allows estimation of the financial state of a company, and can also be used in the future, for example, to solve the forecasting problem. The implementation of research results can help speed up the diagnosis of the financial state of the enterprise and make a right management decision based on the results of diagnosis in time.

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Today, the economy of Ukraine is in a relatively unstable position; therefore, Ukrainian enterprises require effective management. But in order to effectively manage the enterprise, you need to know what state it is in. Solving the problem of diagnosing the financial state of an enterprise in the future will allow developing an apparatus of effective management decisions that will help maintain the enterprise at the proper level of functioning and ensure further development of both the enterprises and the economy as a whole. The relevance of research is manifested in the application of the results for operational and effective management. The problem is in the need to obtain a more accurate solution for the problem of diagnosing the financial state of the enterprise with the parameters that characterize the financial situation best of all. The main objective of the research was to solve the problem of diagnosing the financial state of an IT company, using a model that implements a certain approach in order to obtain a qualitative conclusion about the state of a company. A method based on the use of a fuzzy logic apparatus, namely, production models with a Mamdani fuzzy inference algorithm is proposed for solving the problem. There are 10 input parameters were allocated to determine the financial state. The criteria according to which the state was assessed were quantitative and qualitative indicators of the company’s activity over the selected period. The resulting mathematical model allows estimation of the financial state of a company, and can also be used in the future, for example, to solve the forecasting problem. The implementation of research results can help speed up the diagnosis of the financial state of the enterprise and make a right management decision based on the results of diagnosis in time.

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enterprises, which in turn can lead to a sharp decline of the economy. Among a number of tasks that are solving in the field of effective management, an important role takes the task of diagnosing the financial state of an enterprise, because it is impossible to manage effectively without knowing the condition of the control object.

Solving the problem of diagnosing the financial state of an enterprise in the future will allow developing an apparatus of effective management decisions that will help maintain the enterprise at the proper level of functioning and ensure further development of both the enterprises and the economy as a whole. In modern conditions of development of information technology, the automation of the diagnostic process can also significantly improve the efficiency of the enterprise. Some IT-company is considered as an enterprise.

The relevance of diagnosing the financial condition of an enterprise over time is obvious, because obtaining financial states is a necessary tool for strategic planning and management in the economic sector. Accurate determination of financial status provides an adequate understanding of the situation and the direction in which you need to act. The relevance of research is manifested in the application of the results for operational and effective management.

Timely and accurate determination of the financial state of the company is one of the main conditions for its successful development and functioning. Accurate determination of the financial condition in modern conditions is the reason for the need to have approaches that help determine the financial state of an enterprise and bring enterprises out of their unsatisfactory condition, if they are in it, by managing and subsequently ensuring their proper financial and economic position.

**Formulation of the problem.** First of all, the management of the enterprise needs to know the state of the object of management. To do this it is necessary to solve the problem of diagnosing the financial state of the company and to develop actions to ensure its further effective functioning and development.

Diagnosing is the process of determining and studying indicators, which characterize the state of an object. It consists in certain research methods, analysis of the obtained results and their generalization in the form of a conclusion (diagnosis) to determine possible deviations and prevent disturbances in the normal functioning of an object.

The task of diagnosing the financial state of an enterprise is characterized by the difficulty of obtaining information, a large volume of analyzed data, and multicriteria, because a large number of indicators are calculated and investigated.

Existing models and methods of diagnostic of financial state do not take into account the parameters that are quite important in modern conditions, since they do not bring them into consideration; therefore, the financial situation can be determined insufficiently accurately. Some mathematical models take into account a series of key parameters, but do not have the optimal criteria, which are necessary for determining the financial state. Also, uncertain or unclear information may be contained in the initial data and knowledge about the controlled object and that information cannot be processed by traditional quantitative methods [1].

Therefore, in the current economic conditions, the issues of expanding and improving the models for diagnosing financial conditions are relevant.

The problem is in the need to obtain a more accurate solution for the problem of diagnosing the financial state of the enterprise with the parameters that characterize the financial situation best of all.

Thus, the main objective of the research was to solve the problem of diagnosing the financial state of an IT company, using a model that implements a certain approach in order to obtain a qualitative conclusion about the state of a company. The solution way, based on the obtained model, can be automated in the future, which is necessary for the quick and accurate determination of the financial condition of a company in order to improve the efficiency of the financial department and the company as a whole.

The subject of the research is the process of determining the financial state of the enterprise, and the object of the research is some IT-company.

The task and purpose of the research is to analyze the company's financial indicators and determine the financial condition with their help on the basis of the chosen diagnostic method.

The financial state in this case can be evaluated as good, normal or bad.

This article is aimed at implementing the practical aspects of diagnosis of the financial condition of the company. The approach to the diagnosis of the financial state of the company, realized in the construction of diagnosis model, differs from the well-known models of the mathematical apparatus, which allows to carry out diagnostic of the financial state of the company.

It is planned to build a model of diagnosing the financial state of the company such a way that it allows to take into account the optimal number of basic indicators that have a significant impact on the determination of the financial condition of the company with the greatest accuracy.

Thus, the need for accurate diagnosis of the financial condition of the enterprise is due to economic reasons and the reason for the need to make correct and effective management decisions. Solving this problem allows us to accurately assess the current financial position and activity of the enterprise.

**Solution Method.** The financial state of the company (which is an IT-company) depends on the results of its industrial, commercial and financial activities. It is determined on the basis of a series of indicators that most objectively reflect the trends of change in financial state, as a rule, it consists of four groups: liquidity indicators, financial stability indicators, profitability indicators (profitability), business activity indicators [2].

Analysis of Ukrainian and foreign publications and literary sources showed that the task of diagnosing the financial conditions of an IT-company can be solved using various mathematical approaches, such as: the classical coefficient method with calculating rating score, neural network technology, fuzzy logic apparatus and others [3–6].
In order to be able to evaluate and process indicators \( x_i \) \((i = 1,10)\) that can characterize a company in terms of financial condition, we define a single scale of three quality terms: L – a low level indicator, M – a middle level indicator, H – a high level indicator \( x_i \) [9].

\( Y \) will be used as the output linguistic variable. It is the financial state of the company.

The obtained output parameter \( Y \) allows us to characterize the financial state of the company as: G – good, N – normal, B – bad.

Solving the assigned problem also requires solving two subtasks, namely, the problem of parametric and structural identification, i.e. the possible range of variation of the selected parameters \( x_i \) and the output variable \( Y \) must be determined and the type of membership functions of fuzzy terms should be set for the input parameters which are used and for the output parameter too.

The membership function reflects elements from the set \( x \) on the set of numbers in the interval \([0, 1]\), which indicate the degree of belonging of each element to different qualitative terms [9].

Input indicators may correspond or do not match to recommend or standard values, which are presented in the form of some established intervals. Therefore, the trapezoidal membership function will be used to solve the problem, because it allows us to specify the basis of a fuzzy set as an interval and is simple to set [10].

The levels of all terms of each of the indicators \( x_i \) \((i = 1,10)\), of a particular enterprise are set in accordance with standard values for classical criteria. If standards for the indicator do not exist, then the levels of the terms are divided on the basis of expert judgments or by comparing the values of the desired indicator for similar enterprises in different periods of time.

We reflect the ranges of change of parameters \( x_i \), to a single universal set \( x \) in order for constructing the membership functions of three fuzzy terms of the input variable \([L, M, H]\) [11].

Three fuzzy subsets are set whose membership functions are shown in Figure 1.

![Figure 1 – Fuzzy variable x with a trapezoidal membership function](image)

As an example, we can take the analytical form of writing a trapezoidal membership function of one fuzzy term L of the input variable \( x \), shown in Figure 1:
Next fuzzy logic equation will correspond to previous linguistic statement:

\[ \mu_H(x_1, x_2) = \mu_H(x_1) \cdot \mu_H(x_2) \vee \mu_M(x_1) \cdot \mu_M(x_2). \]

The entire knowledge base is formed using the available data in this way, and a system of fuzzy logic equations will derive from it.

**Algorithm for solving the problem.** Fuzzy inference is the obtaining of a conclusion in the form of a fuzzy set corresponding to the current values of the inputs, using a fuzzy knowledge base and fuzzy operations [12]. The final result of the fuzzy inference is the precise value of the variable \( Y \), obtained from the initially defined precise values \( x_i \) (\( i = 1, \ldots, 10 \)).

It is proposed to use one of the most common logical inference algorithms in fuzzy systems – the Mamdani algorithm for solving the problem.

The Mamdani fuzzy inference algorithm is implemented by the following steps [12].

At the first step, the predicate rule base is formed in the subject area, for example, using the full enumeration method; next action is checking the input variables: if the variables are precise sets, then go to the next step, which is called the fuzziness introduction stage – fuzzification [12].

In the second step, the fuzzification procedure is performed: each value of a separate input variable is associated with the value of the membership function of the corresponding term of the input linguistic variable [12]:

\[ \mu_1(x), \mu_2(x), \ldots, \mu_n(x), \]

where \( \mu_1(x), \ldots, \mu_n(x) \) – membership functions for variable \( x \).

The third step is the aggregation of prerequisites in fuzzy production rules. Paired fuzzy logic operations are used to find the degree of truth of the conditions of each of the rules of fuzzy products [12]:

\[ \alpha_1 = \min\{\mu_{A_{i1}}(x_1), \mu_{A_{i2}}(x_2), \ldots, \mu_{A_{in}}(x_n)\}, \]
\[ \alpha_2 = \min\{\mu_{A_{21}}(x_1), \mu_{A_{22}}(x_2), \ldots, \mu_{A_{2n}}(x_n)\}, \]
\[ \ldots \]
\[ \alpha_m = \min\{\mu_{A_{m1}}(x_1), \mu_{A_{m2}}(x_2), \ldots, \mu_{A_{mn}}(x_n)\}, \]

where \( m \) – number of variables;
\( n \) – number of rules in the base.

The fourth step is the activation procedure – finding the truncated membership function for the output variable, which is made according to the formulas [12]:

\[ \mu_{B_1'} = \min\{\alpha_1, \mu_{B_{11}}(Y)\}, \]
\[ \mu_{B_2'} = \min\{\alpha_2, \mu_{B_{12}}(Y)\}, \]
\[ \ldots \]
\[ \mu_{B_m'} = \min\{\alpha_m, \mu_{B_{1m}}(Y)\}. \]

The fifth step is the procedure of accumulating or combining the found truncated functions in order to obtain the final fuzzy set for the output variable and the resulting
Membership function, which is performed according to the formula [12]:

$$\mu_{Y'}(Y) = \max\left\{\mu_{B_1}(Y), \mu_{B_2}(Y), \ldots, \mu_{B_n}(Y)\right\}.$$

The sixth and final step is defuzzification, or bringing to precision. Most often, the Mamdani model uses defuzzification by the centroid method, when a precise value of the output variable is defined as the center of gravity for the curve:

$$Y' = \frac{\sum_{i=1}^{n} Y_i \mu_{B_i}(Y_i)}{\sum_{i=1}^{n} \mu_{B_i}(Y_i)},$$

where \( n \) – the number of single-point fuzzy sets, each of which characterizes a single value of the considered output linguistic variable;

\( Y' \) – financial condition of the company [12].

Thus, having a rule base and using the algorithm above, we can get the result of a fuzzy inference, represented by the output parameter of a given model, namely, the financial condition of the company.

**Numerical research.** The process of solving the problem of diagnosing the financial state of IT-company can be illustrated using the MATLAB package.

Table 1 shows the values of the financial indicators of the studied company, obtained on the basis of the reporting forms of the company’s financial activities (balance sheet) over the past few years.

Table 2 shows the trapezoidal numbers characterizing the corresponding membership functions for each indicator \( x_i \).

Membership functions were built for the linguistic variable "Indicator" with the help of the MATLAB environment. An example of building the membership functions of the linguistic variable "Indicator" for the parameter \( x_1 \) is shown in Figure 2.

![Figure 2](image)

**Figure 2** - Graphs of the membership functions of the linguistic variable "Indicator" for the parameter \( x_1 \).

The membership functions of the linguistic variable "Indicator" is constructed for the remaining parameters \( x_i \) by the similar way.

Then, a rule base is created for each level of the system using data and MATLAB tools: first for determining the generalized indicators \( X_1, \ldots, X_4, X_5 \), then for obtaining the complex criterion \( X_6 \) and finally for determining the output parameter \( Y \) – the financial state of the company. As a result, the rule base will contain 135 rules.

Examples of the first two and the last two rules, which were formed in MATLAB, are given below.

Rules formed in MATLAB:
1. If \((x_1 \text{ is Low}) \land (x_2 \text{ is Low})\) then \((X_1 \text{ is Low});\)
2. If \((x_1 \text{ is Low}) \land (x_2 \text{ is Middle})\) then \((X_1 \text{ is Middle});\)

3. If \((X_2 \text{ is High}) \land (X_5 \text{ is Low})\) then \((Y \text{ is Normal});\)
4. If \((X_0 \text{ is Low}) \land (X_5 \text{ is Low})\) then \((Y \text{ is Bad});\)

We can illustrate the obtaining of a generalized liquidity index \( X_1 \) using the Mamdani algorithm, implemented in MATLAB (Fig. 3).

**Table 1** – Values of the selected financial indicators of the company

| Indicator / Year | \( x_1 \) | \( x_2 \) | \( x_3 \) | \( x_4 \) | \( x_5 \) | \( x_6 \) | \( x_7 \) | \( x_8 \) | \( x_9 \) | \( x_{10} \) |
|------------------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|
| 2018             | 12.6    | 8.82    | 0.4     | 0.31    | 0.26    | 0.13    | 0.7     | 3.8     | 8.5     | 9       |
| 2017             | 3.92    | 0.89    | 0.29    | 0.58    | 0.48    | 0.57    | 3.23    | 4.95    | 7.5     | 7.9     |
| 2016             | 2.6     | 0.52    | 0.33    | 0.48    | 0.17    | 0.46    | 2.73    | 4.38    | 5.5     | 7.6     |
| 2015             | 1.7     | 0.03    | 0.53    | 0.67    | 0.19    | 0.15    | 1.67    | 4.25    | 4.9     | 3.6     |

**Table 2** – T-numbers for the values of the linguistic variable "Indicator"

| Value / Indicator | Low           | Middle        | High          |
|-------------------|---------------|---------------|---------------|
| \( x_1 \)         | [0 1 1.5 2]   | [1.75 2.25 2.75] | [2.75 3.4 \( \infty \)] |
| \( x_2 \)         | [0.2 0.1 0.15 0.2] | [0.2 0.25 0.5 0.75] | [0.7 0.9 \( \infty \)] |
| \( x_3 \)         | [0.2 0.15 0.5 0.3] | [0.25 0.3 0.5 0.6] | [0.5 0.75 1 1] |
| \( x_4 \)         | [0.2 0.2 0.4 0.5] | [0.45 0.5 0.6 0.7] | [0.65 0.75 1 1] |
| \( x_5 \)         | [0.4 0.3 0.15 0.2] | [0.2 0.3 0.4 0.5] | [0.4 0.5 1 1] |
| \( x_6 \)         | [0.2 0.1 0.15 0.25] | [0.2 0.3 0.4 0.5] | [0.45 0.5 1 1] |
| \( x_7 \)         | [0.5 0.5 1 1.5]  | [2.3 5.5 7.5]  | [7.8 10 \( \infty \)] |
| \( x_8 \)         | [0.2 3.5 4.5]   | [4.4 6.7 8.5]  | [8.5 9 10 \( \infty \)] |
| \( x_9 \)         | [0.1 3.5]       | [4.5 5.7 8.5]  | [8.9 10 10]   |
| \( x_{10} \)      | [0.1 3.4]       | [3.75 5.7 8]   | [7.5 8 10 10] |

\( x_i, i = 0.5 \) | [0.1 2.25]   | [2.5 3.3 5.4]  | [4.42 4.75 5] |

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Figure 3 – Obtaining a generalized liquidity ratio $X_1$ (for 2018)

Figure 3 shows the result of accumulation, i.e. obtaining the final fuzzy set for the output variable $X_1$ and also shows the result of defuzzification using the centroid method.

Thus, it is clear that the generalized liquidity ratio is high. We obtain the remaining generalized indicators $X_1, \ldots, X_4, X_5$ and $X_0$ by the similar way (Table 3).

Table 3 – Generalized indicators of the company and $X_0$

| Year | Generalized indicator | Value | Description |
|------|-----------------------|-------|-------------|
| 2018 | $X_1$                 | 4.5   | High        |
|      | $X_2$                 | 1.36  | Low         |
|      | $X_3$                 | 3.25  | Middle      |
|      | $X_4$                 | 1.33  | Low         |
|      | $X_5$                 | 4.5   | High        |
|      | $X_0$                 | 3.25  | Middle      |
| 2017 | $X_1$                 | 4.5   | High        |
|      | $X_2$                 | 2.56  | Middle      |
|      | $X_3$                 | 4.12  | High        |
|      | $X_4$                 | 3.25  | Middle      |
|      | $X_5$                 | 4.24  | High        |
|      | $X_0$                 | 4.5   | High        |
| 2016 | $X_1$                 | 2.75  | Middle      |
|      | $X_2$                 | 2.47  | Middle      |
|      | $X_3$                 | 1.77  | Low         |
|      | $X_4$                 | 2.61  | Middle      |
|      | $X_5$                 | 3.58  | Middle      |
|      | $X_0$                 | 3.25  | Middle      |
| 2015 | $X_1$                 | 1.29  | Low         |
|      | $X_2$                 | 3.54  | Middle      |
|      | $X_3$                 | 1.27  | Low         |
|      | $X_4$                 | 1.3   | Low         |
|      | $X_5$                 | 2.87  | Middle      |
|      | $X_0$                 | 1.35  | Low         |

Next, we need to build membership functions for the linguistic variable "The financial condition of the company." The graphs of the membership functions for the linguistic variable "The financial condition of the company" are shown in Figure 4.

We can get the output parameter $Y$ – the financial condition of the company using the Mamdani algorithm and having data of input parameters (quantitative – a complex indicator $X_0$ and qualitative – a generalized indicator $X_5$) (Fig. 5).

Figure 5 shows the result of accumulation process – obtaining the final fuzzy set for the output variable $Y$, and also shows the result of defuzzification by the centroid method.

After completing all the above steps, we got the conclusion that the company’s financial state is normal.

Table 4 shows the results of the research, which reflect the state of the company over the past few years.

Table 4 – The financial state of the company, obtained as a result of research

| Year | Value | State |
|------|-------|-------|
| 2018 | 3.25  | Normal|
| 2017 | 4.5   | Good  |
| 2016 | 3.25  | Normal|
| 2015 | 1.33  | Bad   |

Investigate the change of membership functions depending on changes in the values of input parameters.

To do this, we change the parameters $x_1, x_2$ (leaving the remaining values of the financial indicators for 2018) affecting the generalized liquidity ratio, investigate the changes in the value of the generalized indicator $X_1$, the complex indicator $X_0$ and the financial condition $Y$. The results are presented in table 5.

Similarly, we change the parameters $x_3, x_4$, affecting the generalized profitability index, investigate the changes in the value of the generalized indicator $X_3$, the complex indicator $X_0$ and the financial condition $Y$. The results are presented in table 6.

Next, we change the parameters $x_5, x_6$, investigate the changes in the value of the generalized quality indicator $X_5$, and the financial state $Y$. The results are presented in table 7.
Table 5 – Changes in values $X_1, X_0, Y$

| Indicator | Generalized indicator $X_1$ | Description | Complex indicator $X_0$ | Description | Financial state $Y$ | Description |
|-----------|-----------------------------|-------------|-------------------------|-------------|---------------------|-------------|
| 2018      | 12.6                        | 8.82        | 4.5                     | High        | 3.25                | Middle      | 3.25        | Normal      |
| 2017      | 3.92                        | 0.89        | 4.5                     | High        | 3.25                | Middle      | 3.25        | Normal      |
| 2016      | 2.6                         | 0.52        | 2.75                    | Middle      | 1.31                | Low         | 1.36        | Bad         |
| 2015      | 1.7                         | 0.03        | 1.29                    | Low         | 1.36                | Low         | 1.36        | Bad         |

Table 6 – Changes in values $X_2, X_0, Y$

| Indicator | Generalized indicator $X_3$ | Description | Complex indicator $X_0$ | Description | Financial state $Y$ | Description |
|-----------|-----------------------------|-------------|-------------------------|-------------|---------------------|-------------|
| 2018      | 0.26                        | 0.13        | 3.25                    | Middle      | 3.25                | Middle      | 3.25        | Normal      |
| 2017      | 0.48                        | 0.57        | 4.12                    | Middle      | 3.25                | Middle      | 3.25        | Normal      |
| 2016      | 0.17                        | 0.46        | 1.77                    | Low         | 1.36                | Low         | 1.36        | Bad         |
| 2015      | 0.19                        | 0.15        | 1.27                    | Low         | 1.36                | Low         | 1.36        | Bad         |

Table 7 – Changes in values $X_5, Y$

| Indicator | Generalized indicator $X_5$ | Description | Financial state $Y$ | Description |
|-----------|-----------------------------|-------------|---------------------|-------------|
| 2018      | 8.5                         | 9           | 4.5                 | High        | 3.25 | Normal     |
| 2017      | 7.5                         | 7.9         | 4.24                | High        | 3.25 | Normal     |
| 2016      | 5.5                         | 7.6         | 3.58                | Low         | 3.25 | Normal     |
| 2015      | 4.9                         | 3.6         | 2.87                | Low         | 3.25 | Normal     |

Conclusions. After analyzing the problem and the relevance of the research problem, the statement of the problem was formulated. The existing approaches for solving the problem of diagnosing financial states were considered during the research. As a result of the review, and to illustrate the example, the authors suggested using an approach based on the use of a fuzzy logic apparatus, namely, production models with the Mamdani fuzzy inference algorithm.

To determine the financial state were selected 10 input parameters. The criteria by which the state is assessed were quantitative and qualitative indicators of company’s activity. The presented mathematical model allows to take into consideration both quantitative and qualitative indicators and also allow to analyze financial groups of indicators (liquidity, financial stability, profitability and business activity), and assess the level of managerial skills.

The implementation of research results can help speed up the diagnosis of the financial state of the enterprise and make a right management decision based on the results of diagnosis in time.

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