Fuzzy Audit System of Enterprise Activity

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Abstract

The article analyzes the problems and conceptual directions of conducting an audit of the enterprise activities sustainability based on a fuzzy-multiple approach. A feature of modern business activity is the emergence of a significant number of destabilizing factors that can affect the sustainability of activity in the long term. It is proposed to carry out an audit assessment of the activity sustainability in five directions, namely by analyzing the Financial stability indicator, Key production indicator, Sales activity indicator, Social indicator, Ecological indicator. Based on these coefficients, a fuzzy model was developed that excludes the subjectivity of judgments, is easily scalable and works in real time. This approach makes it possible to assess the sustainability of the company's activities to make current and prospective management decisions regarding the improvement or reengineering of business processes.

Keywords

Fuzzy Logic, Fuzzy System, Enterprise Activity, Audit of Sustainability

Introduction

In the modern conditions of the functioning of the economy, which is under the influence of significant destabilizing factors, for example, the COVID-19 pandemic and military operations, significant migration of the working population, currency devaluation, and redistribution of sales markets, the achievement of stability of activity acquires special relevance. In order to overcome the risks of a significant impact of destabilizing factors, the development and implementation of control systems for the current state of the enterprise in order to prevent crisis states of the enterprise becomes important. As a tool of information support, audit plays a key role in ensuring the stability and development of the enterprise, focusing on the future and preventing potential crises. Audit, as one of the most modern and effective control systems, is of crucial importance for the development of a long-term enterprise strategy, harmonization of the work of various divisions, strategic planning of resources, and in solving key business management tasks. Each stage of management is an important part of the management system, which is constantly reproduced and is characterized by the presence of direct and feedback links.

The main goal of the research work is the development of a fuzzy analytical system that will allow improving the work of the audit service at the enterprise by automating the analytical process based on the processing of large arrays of information with the selection of vaguely specified intervals of indicators. This system is necessary for speeding up the process of responding to the occurrence of adverse factors in destabilizing economic conditions and reducing the company's costs for ensuring the process of analysis and management of sustainability indicators.

The sustainability of the business entity's functioning is determined by its ability to continue the production of goods in the planned volumes and according to the specified assortment nomenclature during emergency situations, as well as to quickly restore operations after a minor or moderate impact of destabilizing factors using its own resources in a minimum period of time [1].

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When determining the problems of the researched industry and with the aim of forming the relevance of the development of an analytical fuzzy system, qualitative and quantitative methods of assessing the market situation, development dynamics and the cessation of business activities due to bankruptcy were applied based on statistical information.

The object of the study is the indicator of the sustainability of the enterprise. The subject of the study is the assessment of the sustainability of activities based on vaguely defined intervals to determine impact variables in special software.

Significant conditions of uncertainty in recent years necessitate the use of modern methods of analytical research, which will allow the formation of information about the current and prospective state of business operations. Technologies based on the theory of fuzzy sets make it possible to effectively structure input data for analytical tasks under conditions of ambiguity, providing processing of both quantitative and qualitative information [2, 3]. In particular, in [4] reveals a new alternative method to translate the parameters of the Harrington desirability function, which are represented as linguistic variables. This method is used in the author's methodology for evaluating the effectiveness of investment projects of world and national importance. In conditions of uncertainty, the relevance of accounting and presentation of noneconomic indicators in unclear scales becomes obvious. The parameters presented in fuzzy scales in the form of linguistic variables allow to take into account the ambiguity of the assessment.

Respondents are not always able to clearly indicate which numerical value or linguistic term is most appropriate to express their opinion. However, responses are mostly stored in classic relational databases, so responses must be distinct values. In this way, valuable information related to the vagueness of thoughts is lost. To avoid this drawback, the data must be stored in a database capable of handling fuzzy data. Customizing classic relational databases to store fuzzy data is a promising option, which is discussed in [5]. Thus, when analyzing data, it is possible to make full use of the remaining fuzziness.

1. Audit of the Enterprise

A sustainability audit is a systematic assessment of an organization's performance in terms of environmental, social, and economic aspects of sustainable development. This can help identify gaps, risks, and opportunities for improvement, and demonstrate commitment to stakeholders and customers. However, preparing for a sustainability audit can be difficult, especially if you don't have a clear structure or plan [6].

An audit plays a key role in confirming the reliability of financial statements and is one of the main services that is gaining increasing importance in the modern world because it is a reliable independent confirmation of data based on systematic and scientific approaches [7].

Taking into account the importance of the indicator of stability of activity in order to prevent the occurrence of risky situations, it is proposed to conduct an audit study taking into account five influencing factors that most fully reflect various areas of activity. Such factors include:

1. Financial stability indicator
2. Key production indicator
3. Sales activity indicator
4. Social indicator
5. Ecological indicator

One of the most important factors influencing the company's activity is the indicator of financial stability. The coefficient of financial stability is an indicator that indicates the company's ability to remain solvent in the long term. The coefficient of financial stability is calculated on the basis of financial reporting data according to the formula [8] as Equity and Long-term Debt to Total Liabilities and Equity.

The standard range for this indicator is between 0.7 and 0.9. If the value exceeds this limit, it is not characteristic of actively operating companies, since they are constantly accumulating

short-term liabilities. On the other hand, an indicator lower than this range may indicate an insufficient level of financial stability of the company for the long term.

The second factor influencing the sustainability of activity is the Key production indicator. This indicator of the enterprise is defined as the highest potential volume of produced products, including extraction and processing of raw materials, or the volume of services provided, in accordance with the previously established nomenclature, assortment and quality standards, subject to the optimal use of modern technologies and organizational approaches to production [9].

Measures to determine enterprise productivity may differ depending on the specifics of the production process and the sectoral affiliation. The universal rule is that productivity is measured in the same units as accounting for products produced or services provided. Preferably, these are physical units of measurement, specific for each type of product or service [10]. For multi-item productions, the value indicator of the entire volume of products (services) can also determine the capacity. In the passport of such an enterprise, capacity is indicated by two measures: natural indicators by type of products and a total value (monetary) indicator.

In general, this indicator takes into account overall equipment efficiency, downtime, production capacity, equipment maintenance, and labor productivity. Therefore, for each company, it is advisable to develop a production capacity that will reflect the maximum possible volume of production under normal operating conditions with a division into low, medium and high, which will allow us to assess the actual state of economic activity.

Another indicator that has a direct impact on income is the sales activity indicator. In the conditions of the modern market economy, the key aspect for the successful existence of manufacturing companies is the development and purposeful improvement of sales strategies. This necessity stems from the intensification of competition, the increase in operating costs and the increase in service standards expected by consumers. Therefore, issues related to the quality and productivity of the company's sales system gain special importance.

The main missions of an industrial company are the production and sale of products, which are considered key elements of its operational activity [11]. These processes are closely related and interdependent, which requires a different approach to measuring their effectiveness: the volume of goods prepared for sale, while the volume of goods that have found their buyer evaluates sales success measures production.

The regular and efficient operation of the enterprise involves the correspondence of production and sales volumes during certain periods, such as a quarter. The discrepancy between production and sales is usually temporary and not long-lasting because a decrease in production when sales increase will quickly lead to a drop in sales due to a lack of goods. Such a decrease in sales, in turn, negatively affects production due to a shortage of working capital, so the long-term consequences of such an inversion are usually absent.

An important indicator of consistency between production and sales is the Sales activity indicator, which determines the ratio of volumes sold to products produced for a certain period. The closer this indicator is to one and the more stable it is, the more harmonious and consistent is the work of the company's production and sales departments.

Therefore, in order to evaluate the indicator of sales activity, it is appropriate to determine the ratio of sold products to the actual availability of products in warehouses. This indicator also takes into account the amount of expenses incurred for marketing and sales, because if there are significant expenses for the sale of the product, the profit from its sale decreases.

The next two indicators, namely Social indicator and Ecological indicator, have an indirect effect on the sustainability of business activity, however, through charity or social protection, eco-orientation of business increases the investment attractiveness, improves the image in front of customers, strengthens the reputation, and increases the commercial success of companies. Social responsibility means the obligation of individuals, managers, organizations and government structures to make decisions and carry out actions aimed at increasing the well-being and satisfaction of the interests of society, the company, local communities and each person, thus reflecting ethical and moral principles in relations between people [12]. This indicator is a qualitative reflection of the expenses incurred in the social sphere.

The result of the activity of industrial enterprises is the presence of a significant amount of waste, which can significantly pollute the environment. The transition to sustainable development requires significant changes in the interaction between market players and their impact on the environmental situation. This gave rise to the concept of environmental responsibility within the framework of corporate responsibility, which is focused on minimizing damage to the environment. Environmental responsibility, which goes beyond simple compliance with the law on the payment of environmental tax, is a choice of companies that contributes to the growth of their competitive advantages and positive image through interaction with social and economic institutions.

Increasing the responsibility of business to society forms an indirect influence on consumer decisions, which in turn will ensure the stability of demand in the market. Development and implementation of environmental projects [13]

Therefore, for an individual enterprise, a group of qualified experts develops a scale of social costs and environmental costs for a separate research period (quarter, half-year or reporting year), which will allow to assess the level of the conducted activity and the qualitative effect of its implementation.

2. A model of a fuzzy audit system of enterprise activity

The application of fuzzy logic to audit tasks allows developing software or hardware tools that work in real time, are easily scalable, and exclude the subjectivity of an individual expert [14-16].

To model the fuzzy system of auditing the enterprise, it is necessary to select financial stability (FSI), indicators of production and sales activity of the enterprise (KPI, SAI), social and environmental indicators (SI, EI) as input variables. Based on processing the dependence of these inputs according to the basis of production rules, the system issues an indicator of the stability of the enterprise's activity (Sustainability).

The general view of the proposed fuzzy audit system of the company's activities, modeled in the Matlab environment, is presented in Figure 1.

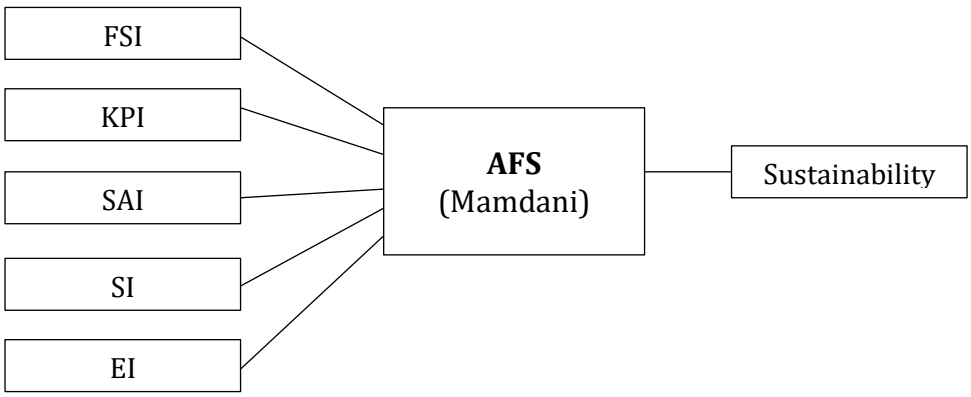

Figure1: Membership functions of the financial stability indicator

Binary membership functions that show the best representation for data processing are chosen to specify the input variables. The indicator of financial stability of FSI is within [0;1]. The standard range for this indicator is between 0.7 and 0.9. If the value exceeds this limit, it is not characteristic of actively operating companies, since they are constantly accumulating short-term liabilities. On the other hand, an indicator lower than this range may indicate an insufficient level of financial stability of the company for the long term.

For convenience of processing, the representation of low stability was chosen by the membership function $s\epsilon[0;0.8)$, medium stability – $m\epsilon(0.6;0.9)$ and high stability $h\epsilon(0.8;1)$ was chosen. Interval values intersect for more stable work of a fuzzy system, especially in cases of "boundary" values of membership functions.

Figure 2 shows the general view of the membership functions of the variable FSI.

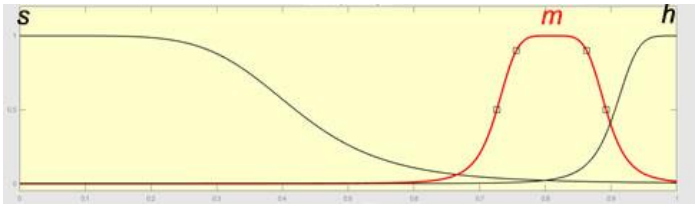

Figure 2: Membership functions of the financial stability indicator

All input and output variables of the developed system are given conditional values in the range [0;1], however, if necessary, these intervals can easily be translated into the required ranges. It should be noted that the membership functions will retain their ratios.

The fuzzy variable of the KPI production activity indicator is given by the following membership functions:

- A low indicator is [0;0,4);
- The average level is (0.2; 0.8);
- The high level is (0.7; 1).

The general view of the membership functions of the KPI variable is presented in Figure 3.

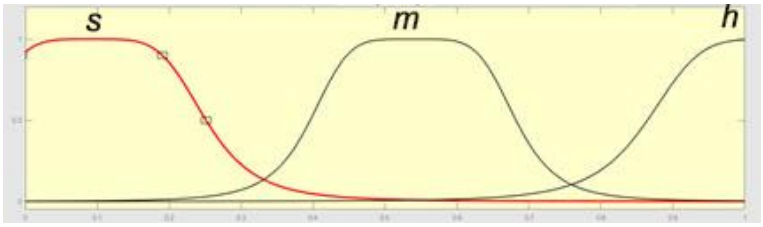

Figure 3: Functions of ownership of the indicator of production activity of the enterprise

The indicator of the sales capacity of the SAI enterprise is also given by bell-shaped membership functions in the following ranges:

- A low indicator is [0;0,4);
- The average level is (0.3; 0.8);
- The high level is (0.7; 1).

Figure 4 presents a graphical representation of the membership functions of the marketability indicator is presented in Figure 4.

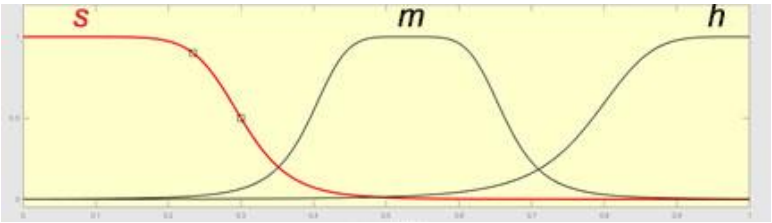

Figure 4: Functions of ownership of the enterprise's marketability indicator

The social indicator of the enterprise is also represented by three membership functions presented in Figure 5: low indicator sϵ[0;0.35), medium level mϵ (0.3;0.8), high level hϵ (0.7;1).

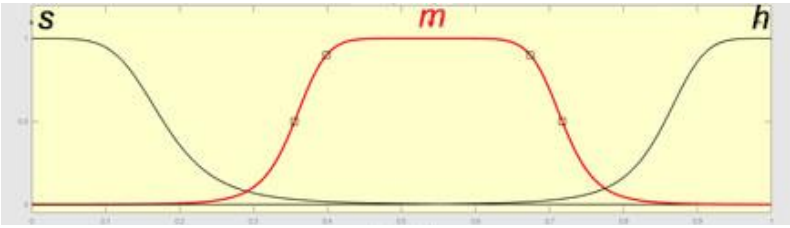

Figure 5: Functions of belonging to the social indicator of the enterprise

The functions of belonging to the environmental indicator of the enterprise are presented in Figure 6. They are also divided into three ranges: low indicator sϵ(0;0.35), medium level mϵ(0.3;0.7), high level hϵ(0.6;1].

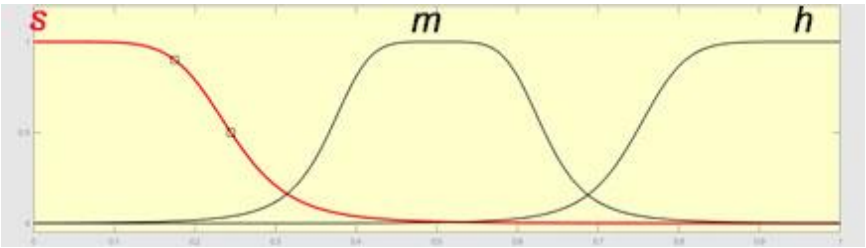

Figure 6: Functions of ownership of the environmental indicator of the enterprise

In order to obtain a conclusion of a vague audit system of the enterprise, it is necessary to use the Mamdani mechanism, since the dependence of the output on the input variables is a logical conclusion "if - then". To obtain a more probable result, it is necessary to use trapezoidal membership functions for the output variable, which demonstrates the stability of the enterprise's activity (Figure 7):

- A low indicator is [0;0,4);
- The average level is (0.3; 0.8);
- The high level is (0.7; 1).

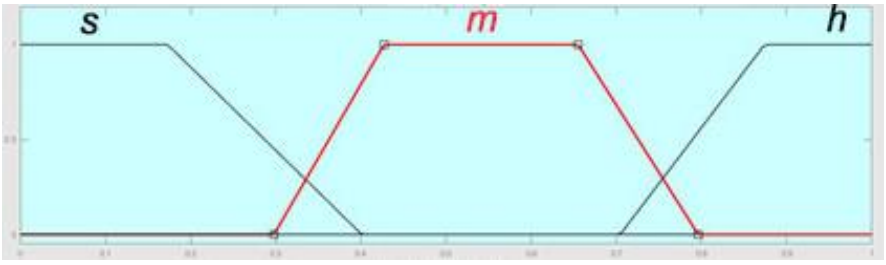

Figure 7: The membership functions of the output of the fuzzy audit system of the enterprise

Each input variable can have another "none" state, indicating that the corresponding variable has no value. However, if the input variables of the financial stability and production activity of the enterprise have the status "none", then it is impossible to conduct an audit of the stability of the activity. In addition, in the case when three variables simultaneously have the state "none", it is also impossible to conduct an audit of the enterprise. Therefore, the base of production rules of the proposed fuzzy system consists of $3 * 3 * 4 * 4 * 4 - 10 = 566$ rules of the "if something" type. An example of building a base of production rules is given in Figure 8.

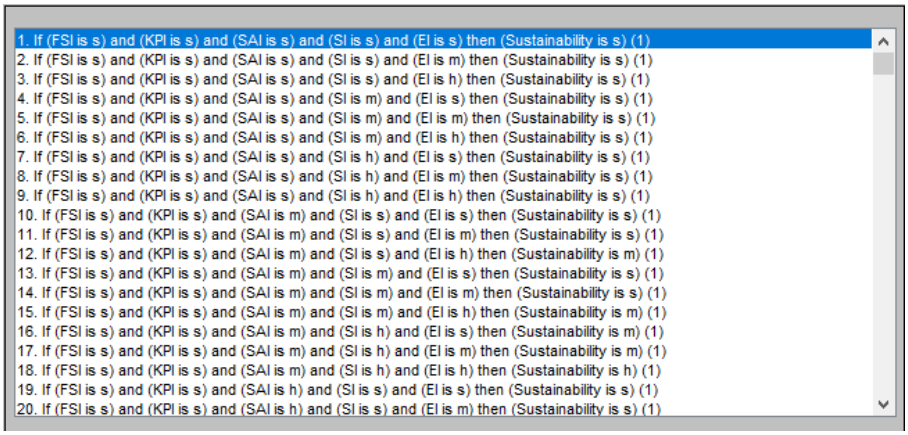

Figure 8: A fragment of the rule base of the fuzzy audit system of the enterprise

The inference of the fuzzy system is carried out on the basis of the Mamdani mechanism, which works according to the min-max composition.

3. The experimental results

To investigate the correctness of the work of the fuzzy audit system proposed by the authors, it is necessary to consider the value of the output variable from the given values of the input variables presented in Table 1.

Table1

The results of the unclear system of auditing the enterprise's activities

financial stability (FSI)	enterprise performance indicator (KPI)	enterprise sales activity indicator (SAI)	social index (SI)	environmental index (EI)	indicator of the stability of the company's activity (Sustainability)
0.111	0.277	0.385	0.85	0.168	0.48
0.894	0.5	0.079	0.684	0.429	0.66
0.474	0.066	0.843	0.952	0.882	0.55
0.035	0.0286	0.0286	0.0732	0.124	0.15
0.156	0.417	0.627	0.894	0.086	0.188
0.92	0.952	0.895	0.959	0.952	0.468
0.39	0.49	0.89	0.53	0.474	0.54
0.15	0.42	0.168	0.93	0.959	0.823
0.31	0.65	0.761	0.022	0.035	0.24
0.02	0.965	0.06	0.92	0.04	0.13

The results of Table 1 demonstrate that the data obtained as a result of modeling the fuzzy system comply with the given rules. For example, if the value of the FSI input variable is 0.111, which corresponds to the linguistic value “low stability”, the value of the KPI variable is 0.277, i.e. “low indicator”, the SAI value is 0.385 (“medium level”), the SI is 0.85 (“high level”) and the value EI 0.168, i.e. "low indicator", then the output variable Sustainability must correspond to the value "average level" according to the rule base, which confirms the result of modeling, which is equal to 0.48. Similarly, other data in Table 1 can be checked.

The dependence of the value of the output variable on some inputs is well represented by the surfaces of values presented in Figures 9-11.

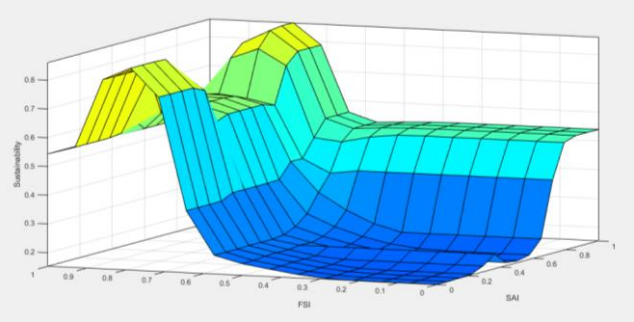

Figure 9: The surface of the dependence of the values of the output variable on the values of the input variables FSI and SAI

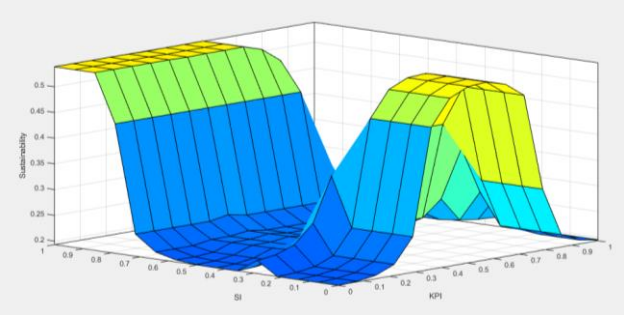

Figure 10: The surface of the dependence of the values of the output variable on the values of the input variables SI and KPI

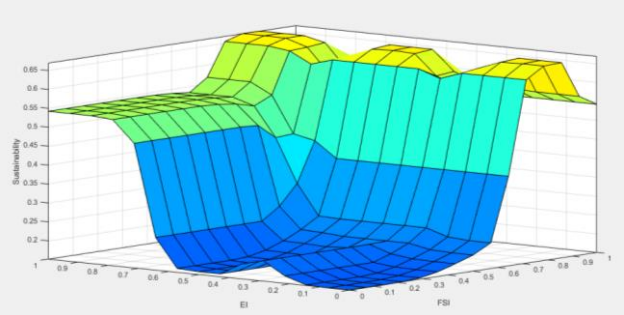

Figure 11: The surface of the dependence of the values of the output variable on the values of the input variables EI and FSI

The results of the dependence of the output variable on a pair of input variables, presented in Figures 9-11, do not have linear dependencies, which confirms the correctness of the development of the rule base of the proposed fuzzy system.

The analysis of the obtained results shows that the developed vague system of auditing the enterprise's activity works correctly and can be used on real objects.

Conclusions

The mechanism of sustainable development of an industrial enterprise, especially in the conditions of an unstable environment, requires the availability of effective management tools. The management toolkit covers a variety of methods, tools, and techniques necessary for collecting and analyzing information, processing data, determining the state of the management system, and making informed management decisions, based on the reliable information obtained by conducting an internal audit. The use of these tools of internal audit research aims to solve specific problems, determining the optimal path of enterprise development, evaluate the

effectiveness of management decisions, prevent errors, and monitoring the achievement of sustainable development goals.

The main goal of the practical implementation of the proposed model is to assess the risks of loss of business sustainability, which will directly affect the short-term and long-term prospects of the business through improvement or reengineering of business processes. The proposed fuzzy system can be implemented in software or hardware in the form of a fuzzy controller, depending on the need and technical capabilities of the enterprise.

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