

The study was carried out as essential for increasing the importance of the issue of introducing fuzzy modelling by means of fuzzyTECH to manage the risks of activities. It has been determined that the feasibility of using fuzzyTECH-based fuzzy modelling is explained by the fact that there is a possibility to specify the levels and values of linguistic variables for these levels. Moreover, the fuzzyTECH software package makes it possible to automate this process. A block diagram of the algorithm was built to introduce fuzzy modelling by means of fuzzyTECH into managing the risks of economic entities. The proposed steps are general for use by economic entities in various fields of activity. Based on the constructed block diagram of the managerial decision-making algorithm, it is advisable to apply it at the level of intermediate values of the intervals of each individual indicator, as well as for the obtained levels of risk of the activities of economic entities. These levels of risk were determined to be very high, high, medium, low, and very low. Depending on the level of risk to economic entities, it is advisable to develop appropriate measures and make managerial decisions. It is essential to include among them the development of measures for quick and gradual responses, tactical and strategic, as well as measures already at the level of the economic entity's strategy. In order to test the block of the algorithm responsible for the assessment, the system of techniques for assessing the risks of activities was tested for the studied economic entities. The intervals of the values of the scale selected to assess to indicators were obtained; a fuzzy model to estimate the risks of the economic entities by means of fuzzyTECH was built, set, and tested, and a system of fuzzy inference was obtained. Using the tools of fuzzy sets, a model for calculating the number of points for the aggregate assessment of the risks of the researched economic entities was built. It constitutes the preconditions for the transfer of the obtained scientific and practical results already into the system of risk-oriented management of economic entities

Keywords: fuzzy modelling, risks of activity, fuzzy set tools, linguistic variable

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IMPLEMENTATION THE FUZZY MODELING TECHNOLOGY BY MEANS OF FUZZYTECH INTO THE PROCESS OF MANAGEMENT THE RISKINESS OF BUSINESS ENTITIES ACTIVITY

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1. Introduction

Recently, fuzzy modelling has become one of the most active and promising areas of applied research in management and decision-making. Fuzzy modelling is especially useful when the description of the technical system includes uncertainty that complicates or even makes it impossible to apply accurate quantitative methods and approaches [1]. Moreover, using the fuzzyTECH software package, which specializes in fuzzy modelling, helps to automate this process.

Sustainable development of an enterprise is impossible without introducing innovations. With the constant growth of the market and increasing competition between economic entities, managers and administrators are supposed to find innovative methods of managing an enterprise to create advantages over economic competitors. Nowadays, innovations are becoming those determinants that motivate companies to seek new or improved managerial techniques to ensure profit growth and an enterprise development [2]. It confirms the expediency of introducing fuzzy modelling based on the fuzzyTECH software package.

The expediency of introducing the fuzzy modelling technology into any management process is explained by uncertainties, as fuzzy modelling integrates elements of fuzzy sets,

fuzzy logic, and limited resources, including time. This is implemented through the available appropriate environment and fuzzy modelling software packages, each of which has advantages and disadvantages in use.

Besides, the increasing impact of global crises and the stronger effect of risks on various areas of activity make it important to introduce a risk-based approach to the management system at various levels, in particular at the level of economic entities. This indicates the growing importance to introduce a modelling technology in management, with an impact on the risk management process. The constant influence of risk factors in various fields makes the activities of economic entities more risky. It is impossible to ensure the proper functioning of economic entities without reducing the level of risk of their activities.

The internal control system should ensure the identification, monitoring, control, reporting and minimization of all significant risks, taking into account the size, complexity, type, and nature of operations, as well as the organization structure and the risk type [3].

Thus, the issue of introducing fuzzy modelling in the management process to ensure effective and reliable risk assessment is particularly relevant for economic entities. The search for modern tools of estimating and processing the

assessment (a set of indicators/standards, the definition of a priority environment or a fuzzy modelling software package) is important given the current trends in modern science.

2. Literature review and problem statement

As a result of analysing the current scientific research, it has been determined that the emphasis of the studies is mainly on the use of fuzzy set tools to assess and/or diagnose the state of an object under consideration. An insufficiently researched aspect is the introduction of fuzzyTECH-based fuzzy modelling into managing and analysing the obtained results during the use of this toolkit to estimate the risks of economic entities.

In particular, in [4] it was determined that the success of constructing fuzzy models largely depends on the use of advanced software tools for synthesising and setting. A number of general requirements for these software tools were formed, and the weak point of their use was identified as the lack of pre-processing automation functions to determine fuzzy linguistic variables [4]. This suggests that when using an appropriate fuzzy modelling environment or software package, it is advisable to apply fuzzy set tools, which will ensure the possibility to identify and determine the values of the linguistic variables.

Paper [5] presented the results of a study on interpreting financial risk indicators for the cooperative sector by means of fuzzy logic using Xfuzzy. This suggests that the approach to using a specific fuzzy modelling environment or software package to solve scientific problems in the field of risk assessment is particularly relevant. In [6] it was analysed that Xfuzzy software is an available application that helps to identify the processes of planning and implementing the software in accordance with the stated objectives. Therefore, it is advisable to use those means of fuzzy modelling that will best meet the requirements and objectives of the research.

In [7] a model for project risk assessment was developed as a three-stage procedure: vulnerability assessment, impact assessment, and general risk assessment. At all stages, fuzzy considerations were used in the MATLAB environment to deal with the inherent uncertainty of the projects. A unique feature of the model is the integration of both qualitative and quantitative techniques into a systematic approach. Similarly, the model takes into account all types of uncertainties [7]. These results reinforce the significance and feasibility of research to construct fuzzy models taking into account the uncertainty factor.

The issues of risk identification, control and assessment were presented in [8], in which a prototype model of a risk measurement tool using fuzzyTECH 6.06c was built. All this makes it possible to argue in favour of the feasibility of introducing the tools to measure activity risks by fuzzyTECH in the managerial process specifically for economic entities.

Study [9] proposed a scientific and methodological approach to assessing the level of bankruptcy based on applying the fuzzy set method. This approach helped to obtain objective information about the financial condition and supported the management in taking managerial decisions on the appropriateness of adjusting tactical and strategic plans.

Article [10] presented the results of a study aimed at building an economic and mathematical model for diagnosing bankruptcy with the help of fuzzy sets. The results made it possible to classify entities into stable and bankrupt while having the possibility to adjust their own parameters to real data. Also, an algorithm was proposed for configuring the

model based on the method of backward propagation of errors adapted for fuzzy logic-based models. It was established that as a result of adjusting to the existing statistical material it is possible to optimize the parameters of the model. This made it possible to functionally link the input variables (performance indicators) with the value of the resulting variable (one of the classes: financially stable or potential bankrupt) [10]. However, the above studies [9, 10] were aimed at diagnosing bankruptcy using the tools of fuzzy sets. These studies differ by the quantity and combination of the indicators as well as the levels of qualitative characteristics of the obtained numerical information and their descriptions, and the risk management of an economic entity was not studied there.

Source [11] considered fuzzy logic as an effective, useful method applied to research in the field of crisis management. The sources of the obtained results were the Web of Science and Scopus databases. The study analysed the number of articles published from 1987 to 2017, examining the use of fuzzy logic and fuzzy sets; it determined that the relevance of this topic increased significantly from the mid-2000s. Thus, all this makes it possible to argue that the use of tools of fuzzy logic and fuzzy sets is an important issue in the field of scientific interests of researchers.

In [12] a study was described as conducted on using fuzzy logic in the field of finance. In [13] the methodology of applying fuzzy logic in risk assessment was taken into account. However, the practical application of the toolkit should be founded on a high-quality statistical base to obtain reliable results with the possibility of interpreting the results correctly.

In [14] a process-oriented risk management model was developed as a decision support system. This confirms the feasibility of substantiating the risk management process on the basis of certain processes and stages, without ignoring the feasibility of using qualitative and quantitative information in the management.

This suggests the feasibility of conducting a study aimed at introducing fuzzy modelling by means of fuzzyTECH into managing the risks of economic entities.

3. The aim and objectives of the study

The aim of the work described in the article was to develop recommendations for the introduction of fuzzyTECH-based fuzzy modelling into managing the risks of economic entities.

To achieve this aim, it was essential to solve the following objectives:

- to determine the preconditions for the introduction of fuzzy modelling by fuzzyTECH to manage the risks of economic entities;
- to develop an algorithm for the introduction of fuzzy modelling by means of fuzzyTECH to manage the risks of economic entities; and
- to test the system of techniques for assessing the risks of the activities of the studied economic entities.

4. Research methods for managing the risks of economic entities using the tools of fuzzy sets

To achieve the aim, the following methods were used: analysis and synthesis, logical generalization, construction of algorithms, mathematical statistics, grading, the Pareto

principle, as well as tools of fuzzy sets and fuzzy logic. The methodological basis of the study was the theory of fuzzy sets and fuzzy logic as well as the concept of control and fuzzy modelling. The software packages included MS Excel, Visio, and fuzzyTECH 6.10b Professional Demo.

5. The results of fuzzy modelling by means of fuzzyTECH for managing the risks to activities of economic entities

5.1. Prerequisites for the introduction of the fuzzy-TECH-based fuzzy modelling into managing the risks of economic entities

The most advanced environments and software packages aimed at building and configuring fuzzy models (the main stages of fuzzy modelling), according to [4], include: TILShell+, fuzzyTECH, CubiCALC, and Data Engine. These environments and software packages differ from others by a well-designed function range, a friendly interface, a very wide scope, etc. [4].

Like most of the other available fuzzy modelling software packages, fuzzyTECH has the functional capabilities that are important given the requirements for them.

The following basic requirements include [15]:

- the presence of an interface easily compatible with the modern operating systems;
- the setting of the model structure (description of the set of input and output variables by a set of linguistic variables);
- the assignment of various forms of membership functions for the terms of the linguistic variables;
- the possibility of designing product rules;
- the possibility to visualize the functions of the membership and rules (the presence of a developed graphic editor);
- the presence of linguistic communication operators (AND, OR) and operations on a fuzzy set of terms: addition (NOT) of “less” (<) and “more” (>);
- the prototype verification and error collection; the availability of alternative methods of dephasification;
- a graphical display of the results of the output machine;
- the presence of integrated algorithms for the prototype setup and optimization; and
- the possibility to create complete software applications.

However, a specific feature of the fuzzyTECH package is the lack of integrated algorithms for the prototype setting and optimization [4].

It is worth acknowledging that even the best environments and software packages (TILShell+, fuzzyTECH, CubiCALC, and Data Engine) do not have all the tools to take full advantage of fuzzy modelling. A common disadvantage of most of these software tools is their full focus on servicing the knowledge engineer (a specialist in fuzzy logic) rather than directly a subject matter expert. Another weakness of these environments and software packages, including fuzzyTECH, is the lack of pre-processing automation functions to identify fuzzy linguistic variables [4]. Other disadvantages of using fuzzyTECH [16] include the language restrictions on entering information; restrictions on the use of punctuation and spaces; as well as the English interface and the limited functionality of the free Demo versions (for example, the absence of a possibility to save the fuzzy model). However, the advantages of implementing the fuzzy modelling technology with the highly automated fuzzy-TECH functionality outweigh the weaknesses.

The expediency of fuzzyTECH-based fuzzy modelling in managing the risks of economic entities is explained by the

fact that it is possible to use levels and values of linguistic variables for these levels. This will help to quantify and provide qualitative characteristics of the level of risk to economic entities, which is especially important in conditions of uncertainty.

In this context, it should be noted that risk is a phenomenon that arises in different situations and develops to different extents depending on the context in which it occurs. As a result of the general nature of risk and the great diversity of this phenomenon, there is no single definition that identifies all planes of its existence. A risk can be estimated, on the one hand, in terms of its impact in action; on the other hand, it can be understood as a possible obstacle to achieving a goal [17].

The concept of risk is characterized by the following keywords: phenomenon (event), characteristics, level (degree), possibility (probability), and danger (threat) [18].

A risk to enterprises can be defined as a phenomenon that occurs at enterprises and is characterized by the level of a possible threat to the production and sale of products, the result of which is the failure to gain or make a profit [18].

An entrepreneurial risk is the activity of economic entities associated with overcoming uncertainty in a situation of inevitable choice in the process of which it is possible to assess the probability of achieving the desired result or facing failure and deviating from the goal, which are contained in the selected alternatives to all types of economic entities [19].

Risk management is a multistage process consisting of the risk assessment, analysis and management, the ultimate goal of which is to prevent or reduce the impact of the risk [20].

According to [20], it is important to obtain a quantitative value of the evaluation parameter by using certain economic indicators that can be established on the basis of the relationship between the level of risk and economic performance. This statement is the basis of the process of managing the risks of economic entities with the help of estimating the quantitative values of the indicators of an economic entity performance sensitive to the influence of risk factors.

Risk factors are possible violations, shortcomings, and problems that have adversely affected or may affect the level of managing an activity, achieving goals and objectives, using resources efficiently, obtaining results of financial and economic activities, etc. Reserves are also important for the purpose to increase the efficiency as well as financial and production performance of an economic entity [21].

Management is a set of activities of an organization related to the implementation of an activity [22].

Therefore, it is expedient to specify the conceptual idea and economic meaning of the concept of “risk to the activities of economic entities” in view of the derivative definitions such as “a risk to an economic activity” and “an entrepreneurial risk”.

Based on the definitions given in [18–22], the explanations of the concept of “risk to the activities of economic entities” and “management of a risk to the activities of economic entities” are as follows. The risk to the activities of economic entities is considered as a state of activity related to the possible effects of threats, hazards, and uncertainty due to the influence of those risk factors that may worsen the performance and lower the margin of safety of the economic entity. The management of a risk to the activities of economic entities is aimed at developing and implementing a set of measures to neutralize the impact of risk factors on this state in conditions of uncertainty. The difference between the process of managing a risk and risk management is that

the object of management in the first case is the state of activity assessed through those indicators that are sensitive to the influence of risk factors. In the second case, the object of attention is particularly the risk or risks.

In order to address the lack of pre-processing automation functions for the identification of fuzzy linguistic variables in the fuzzyTECH package, a recommendation for calculations using fuzzy set tools is proposed, with its applied testing to be performed in the future. It will not automate the process, but it will help to obtain reliable results (specific values of linguistic variables based on real statistics) to establish a correspondence between the values for the input and output variables and their corresponding values of linguistic variables represented by membership functions.

The fuzzy set toolkit uses the concept of fuzzy set [23, 24]. The very concept of fuzzy set has found application in various fields of research, in particular in research on risk assessment [25].

It should be noted that fuzzy subsets are described by the membership function μ_{NP} : A belongs to the interval $[0, 1]$, which corresponds to each indicator P_i belonging to A , μ_{NP} from the interval $[0, 1]$. This characterises the degree to which the P_i index belongs to the subset of the number of points (hereinafter NP) [28]. The technique of the theory of scales of measurement was used to construct the membership function of fuzzy sets [28, 29].

For a concise description of the membership functions $\mu(NP)$, they are described by numbers of the form according to formula (1). The numbers β are trapezoidal or T-numbers [28]:

$$\beta_k(a_{k1}, a_{k2}, a_{k3}, a_{k4}), \tag{1}$$

where a_{k1} and a_{k4} are the abscissas of the lower base of the trapezoid;

a_{k2} and a_{k3} are the abscissas of the upper base of the trapezoid, corresponding to $\mu_i(NP)$ in the area with the non-zero belonging of the NP carrier to the respective fuzzy subset.

There are many ways to set membership functions. The most common are triangular, trapezoidal, Gaussian and sigmoidal membership functions [1].

The appropriate type of membership function is determined by the needs of the studied subject area. According to [26], for qualitative variables, it is advisable to use a triangular membership function, and for quantitative variable, it is better to apply a trapezoidal membership function, which will best reflect the dependencies. Moreover, according to [27], for practical calculations, it is convenient to work with fuzzy numbers of a special kind: triangular and trapezoidal. Thus, the trapezoidal membership function is convenient for working with quantitative variables.

The values of the membership function (the values of μ_{ik} and $\mu_{i(k+1)}$) should be determined or calculated by formula (2) according to [28]:

$$\mu_{ik} = \begin{cases} 1, & \text{if } a_{k2} \leq P_i \leq a_{k3}, \\ \frac{a_{k2} - P_i}{a_{k2} - a_{k1}}, & \text{if } a_{k1} \leq P_i \leq a_{k2}, \\ \frac{a_{k4} - P_i}{a_{k4} - a_{k3}}, & \text{if } a_{k3} \leq P_i \leq a_{k4}. \end{cases}$$

$$\mu_{i(k+1)} = \begin{cases} 0, & \text{if } a_{k2} \leq P_i \leq a_{k3}, \\ 1 - \mu_{ik}, & \text{if } a_{k1} \leq P_i \leq a_{k2}, \\ 1, & \text{if } a_{k3} \leq P_i \leq a_{k4}. \end{cases} \tag{2}$$

The optimal method of constructing the number of points (NP) is its coordination with the selected number system $\{\beta\}$. This involves building a model for calculating the number of points (NP) in fuzzy form (3) according to [28]:

$$NP = \sum_{k=1}^n Y_k * \beta_k, \tag{3}$$

where $*$ is the operation of multiplying the real number by the fuzzy number.

To calculate the coefficient Y_k (in the formula below, the variable is written using the index) (4) is used according to [28]:

$$Y_k = \frac{\sum_{i=1}^N \mu_{ik}}{N}. \tag{4}$$

To determine the real NP, the transition from the fuzzy number β_k (5) is used based on [28]:

$$\beta_k = \frac{a_2 + a_3}{2}. \tag{5}$$

According to [28], it can be stated that if the value of $\mu_k(NP) > 0$ obtained during the analysis is considered, the risk to the economic entity is described by the linguistic value of the subset $\{NP\}$ with the level of correspondence $\mu_k(NP)$.

In other cases, $\{NP\}$ does not belong to the other subsets of $\{A\}$. In general, with the proposed choice of the system $\{\mu\}$, membership can be no more than two average subsets [28]. In order to build interval scales for the indicators, it is advisable to check the indicators for the normality of the distribution, which is appropriate according to [28]. With the normal distribution of the indicators, the values of mode, median, and mean for the indicators coincide [30].

Source [28] states that based on the discrepancy between the values of the median, mode, and mean in the presence of asymmetry in the distribution of intensities of the indicator, for constructing an interval scale, it is more appropriate to use the median instead of the mean.

To determine how much the distance between the intensities of the indicators in the asymmetric distribution will change relative to the values in the normal distribution, it is proposed to introduce an adjustment factor (k). The adjustment factor (k) is equal to S (that is, the location density of the indicators' intensities in the asymmetry of their distribution), which is reduced in proportion to the number of divisions of the scale (n) lying to the right and left of the median [28]. To determine this, formulae (6)–(8) were used according to [28]:

$$k = \frac{S}{n}, \tag{6}$$

$$S = \frac{M - M_0}{M}, \text{ with the right-side asymmetry,} \tag{7}$$

$$S = \frac{M_0 - M}{M_0}, \text{ with the left-side asymmetry,} \tag{8}$$

where M is the median, and M_0 is the mode.

When the indicators are not distributed according to Gauss's law, it is advisable to determine the allowable values of the intervals of the scale on the basis of the so-called three-sigma rule with the right-side and left-side asymmetry of the distribution, taking into account k [28].

According to [28], if the value of the mean (x) is located to the right of the mode (M), i. e., the arithmetic mean is bigger than the median, or the difference ($x-M$) and the asymmetry values are positive, this type of distribution is of the right-side asymmetry. In the presence of a normal law in the distribution of intensities, the value of the mean divides the distribution into two equal parts so that each could contain 50 % of the total distribution. With an asymmetric distribution, a more correct picture in this case is given by the median, which, moreover, in contrast to the arithmetic mean, does not depend on the extreme values of the indicator. The mode (M) in this case also differs from the mean and corresponds to the most common sample value [28].

To construct an interval scale according to the three-sigma rule, formula (7) is used for the right-side asymmetry and formula (8) for the left-side asymmetry. The resulting scale will have the range of values ($M-2\sigma k; M+2\sigma(k+1)$) with the right-side asymmetry and ($M-2\sigma(k+1); M+2\sigma k$) with the left-side asymmetry, where σ is the standard deviation, based on [28].

A five-point scale is used to consider the degree of bankruptcy risk. The following degrees are distinguished: extreme (very high), dangerous (high), borderline (medium), acceptable (low), and insignificant (very low) [31]. According to the author, it is advisable to build a five-level scale with the characteristics of the levels from "very high" to "very low", as was proposed in [31].

In addition, the feasibility of such a distribution is confirmed by the criteria for classifying the indicators to diagnose bankruptcy. These criteria include: very low level of the indicator, low level of the indicator, medium level of the indicator, high level of the indicator, and very high level of the indicator according to [5, 26]. It is proposed to use these criteria as indicators to assess the risks to economic entities. The same approach was stated in [9, 28].

The technology of grading the indicators to estimate the risks of economic entities according to the three-sigma rule in the right and left asymmetries of the distribution on the five-level scale was developed taking into account (6) according to [28]. This technology (calculation procedure) and the evaluation criteria are given in Table 1.

According to Table 1, it is highly important to provide a linguistic description of the intervals of the scales for any indicator (P_i) on the five-level scale, depending on whether the increase or decrease of the indicator (P_i) is positive.

To determine the intervals not of individual indicators (P_i) for assessing the risk of economic entities but of the aggregate level of risk, the task was to determine the intervals of these levels.

According to [9], the following intervals and classifications of the levels are appropriate to assess the probability of bankruptcy (Table 2).

Therefore, based on Table 2, the intervals of values for the risks to economic entities are defined as belonging to a certain level ("I" – very high, "II" – high, "III" – medium, "IV" – low, and "V" – very low); they are listed in Table 3.

As can be seen from Table 3, it is proposed to use a five-level scale with the description of the linguistic variables ranging from 'a very high level of risk to the activity' down to 'a very low level of risk to the activity'. This will serve as a basis for the conclusion on the possibility of neutralising the influence of risk factors.

Thus, the tools of fuzzy sets and linguistic variables were defined to estimate the level of risk to the activities of economic entities. The technology is determined to grade (construct a scale of) the indicators for assessing the riskiness of activities.

To make the right managerial decisions, it is important to choose the indicators (P_1, \dots, P_i) to assess the risk to the activities of economic entities.

To this end, it is proposed to perform a multicriteria selection of the indicators to form their composition according to the following six criteria:

- to select the indicators, it is advisable to take into account the scope of the activity of an economic entity;
- to select the indicators, it is advisable to take into account the types of the activity of an economic entity;
- the indicators must be quantitative, relative values and be calculated as a percentage;
- to select the indicators, it is advisable to take into account the implementation of the regulatory requirements established within the framework of the national regulation and supervision to ensure the proper functioning of an economic entity;
- to select the indicators, it is advisable to take into account the indicators that are sensitive to the influence of risk factors;
- the recommended number of the selected indicators should be from 3 to 7.

Table 1

The indicator grading technology and criteria for assessing the risks of economic entities

With the right-side asymmetry of distribution			With the left-side asymmetry of distribution		
The order of the assessment	The level of the indicator provided that its increase is positive	The level of the indicator provided that its decrease is positive	The order of the assessment	The level of the indicator provided that its increase is positive	The level of the indicator provided that its decrease is positive
$]-\infty; M-2\sigma k)$	Very low	Very high	$]-\infty; M-2\sigma(k+1)$	Very low	Very high
$[M-2\sigma k; M-0.67\sigma k)$	Low	High	$[M-2\sigma(k+1); M-0.67\sigma(k+1)$	Low	High
$[M-0.67\sigma k; M+0.67\sigma(k+1)$	Medium	Medium	$[M-0.67\sigma k; M+0.67\sigma(k+1)$	Medium	Medium
$[M+0.67\sigma(k+1); M+2\sigma(k+1)$	High	Low	$[M+0.67\sigma(k+1); M+2\sigma k)$	High	Low
$[M+2\sigma(k+1); +\infty[$	Very high	Very low	$[M+2\sigma k; +\infty[$	Very high	Very low

Table 2
Classification of the current value of the indicator V of the probability of bankruptcy

No.	The value range of V	Classification of the parameter level
1	$0 < V \leq 0.2$	V1 – "The risk of bankruptcy is critical"
2	$0.2 < V \leq 0.4$	V2 – « The risk of bankruptcy is high »
3	$0.4 < V \leq 0.6$	V3 – "The risk of bankruptcy is medium"
4	$0.6 < V \leq 0.8$	V4 – "The risk of bankruptcy is low"
5	$0.8 < V \leq 1$	V5 – "The risk of bankruptcy is insignificant"

Table 3
The value of a linguistic variable to characterize the level of risk to an economic entity

The reference designator of the level	Value range	Characteristics of the level
"I"	(0; 0.2]	A very high level of risk to the activity
"II"	(0.2; 0.4]	A high level of risk to the activity
"III"	(0.4; 0.6]	A medium level of risk to the activity
"IV"	(0.6; 0.8]	A low level of risk to the activity
"V"	(0.8; 1]	A very low level of risk to the activity

The number and set of the indicators is important given that managerial decision-making systems should be applied not only to the intervals obtained for the aggregate level of risk. It is also expedient to determine this at the level of intermediate values of the intervals of each individual indicator, which will be established on the basis of using the above-described tools.

It should be noted that the obtained intervals of the levels of risk and the intervals of the individual indicators (P_1, \dots, P_i) can be obtained on the basis of various statistics, the frequency of which can be a month, a quarter, half a year, and a year. In particular, it can be determined on the basis of statistics of one economic entity or on the basis of statistics of many entities. The results obtained from analysing many entities will ensure the applicability of the principle of 'bench learning', which is important given the possibility of comparing these results. The use of statistical information from a variety of entities, such as an industry or a field of activity, is important given the appropriateness of assessing the general trends in the industry or field of activity.

5.2. The algorithm for the introduction of fuzzy-TECH-based fuzzy modelling to manage the risks of economic entities

Given the research conducted by the authors of [33] to assess the level of interest of Google Search engine users in innovation, it can be argued about the high level of relevance and interest of the users in this issue. Therefore, it should be noted that the introduction of managerial innovations has an important impact on the development of an economic entity.

Managerial innovations are manifested in changing the content of the functions, techniques and organization of the managerial process as well as the methods of the management staff work [34].

In turn, organizational and managerial innovations are influenced by technological, which also have an impact on product, resource and market innovations, and all these types of innovations are interrelated [35].

According to [18], by the logic of the risk management process, all its stages are divided into risk "assessment", "analysis", and "management". The author details the process and stages of assessing the risks of economic entities and the process of taking managerial decisions to ensure the appropriate level of risk.

Based on the approaches to constructing algorithms, which were given in [18, 20, 28, 32], the main requirements for the construction are highlighted in this study. Taking into account the importance of introducing fuzzy modelling by means of fuzzyTECH into the process of managing the risks of economic entities, a block diagram of the algorithm (Fig. 1, 2) was developed with regard to [1, 16, 18, 20, 28, 32].

As can be seen from Fig.1, 2, the proposed block diagram of the algorithm takes into account the sequence of the stages and processes, which are represented by blocks of different forms ("the beginning" and "the end", actions and conditions), which are connected by lines in the block diagram. The algorithm uses the following: tools of fuzzy sets by formulae (1)–(5), formulae (6)–(8) to build scales of the indicators (P_1, \dots, P_i), and the values of the linguistic variables to characterize the levels of risk to the economic entities (Table 3). Besides, the stages of building and setting a fuzzy model, forming the base of fuzzy rules, and obtaining a fuzzy inference system [1] by means of the fuzzyTECH package, which are the main stages of the fuzzy modelling technology, are considered.

According to the developer's website, the last modification took place on 30 June 2020 by introducing fuzzy-TECH-8.77b. Previous versions – fuzzyTECH-8.62f, fuzzyTECH-8.40b, fuzzyTECH-8.30, fuzzyTECH-8.21c, fuzzyTECH-7.00g, fuzzyTECH-6.10b, and fuzzy-TECH-5.81d – are also available to users, and the choice just depends on the operating system parameters. Their Demo versions are also available [16].

The fuzzyTECH package [16] involves the use of the appropriate terms for each input variable (the indicators P_1, \dots, P_i) and output variable (the level of risk to the activities of economic entities) depending on the corresponding values of the linguistic variables. To use a five-level scale, the terms in the fuzzyTECH package for each input variable (the indicators P_1, \dots, P_i) that are appropriate to use include: very low; low; medium; high; very high. For the output variable (the level of risk to the activities of economic entities) they are as follows: very high; high; very medium; low; very low. This is due to the use of the English interface in the fuzzyTECH package.

Given the sequence of steps in the proposed block diagram of the algorithm, an important parameter for constructing a fuzzy model by means of fuzzyTECH will be to establish a correspondence between the values for input variables and output variable and their respective values of the linguistic variables represented by the membership functions. During the practical approbation of this stage of the developed block diagram of the algorithm on the basis of several economic entities, the values of the linguistic variables on the five-level scale for the input variables (the indicators P_1, \dots, P_i) will be obtained. These values of the linguistic variables will help to find reliable results for the levels of risk to economic entities. The use of the input variables (the indicators P_1, \dots, P_i), the base of the fuzzy rules, and the output variable (the level of risk to the activity) will ensure the possibility to obtain a system of fuzzy inference about the estimated level of risk.

Thus, the introduction of fuzzy modelling based on the use of fuzzy set tools and fuzzy logic by means of the fuzzyTECH package will provide the possibility, given the functionality of the package, to obtain a fuzzy inference system. Given this, it is important to form a base of the fuzzy rules.

It is also recommended not to use the standard values of linguistic variables that can be offered by the fuzzyTECH package for the input variables (the indicators P_1, \dots, P_i) and the output variable (the level of risk to the activity) for the five-level scale.

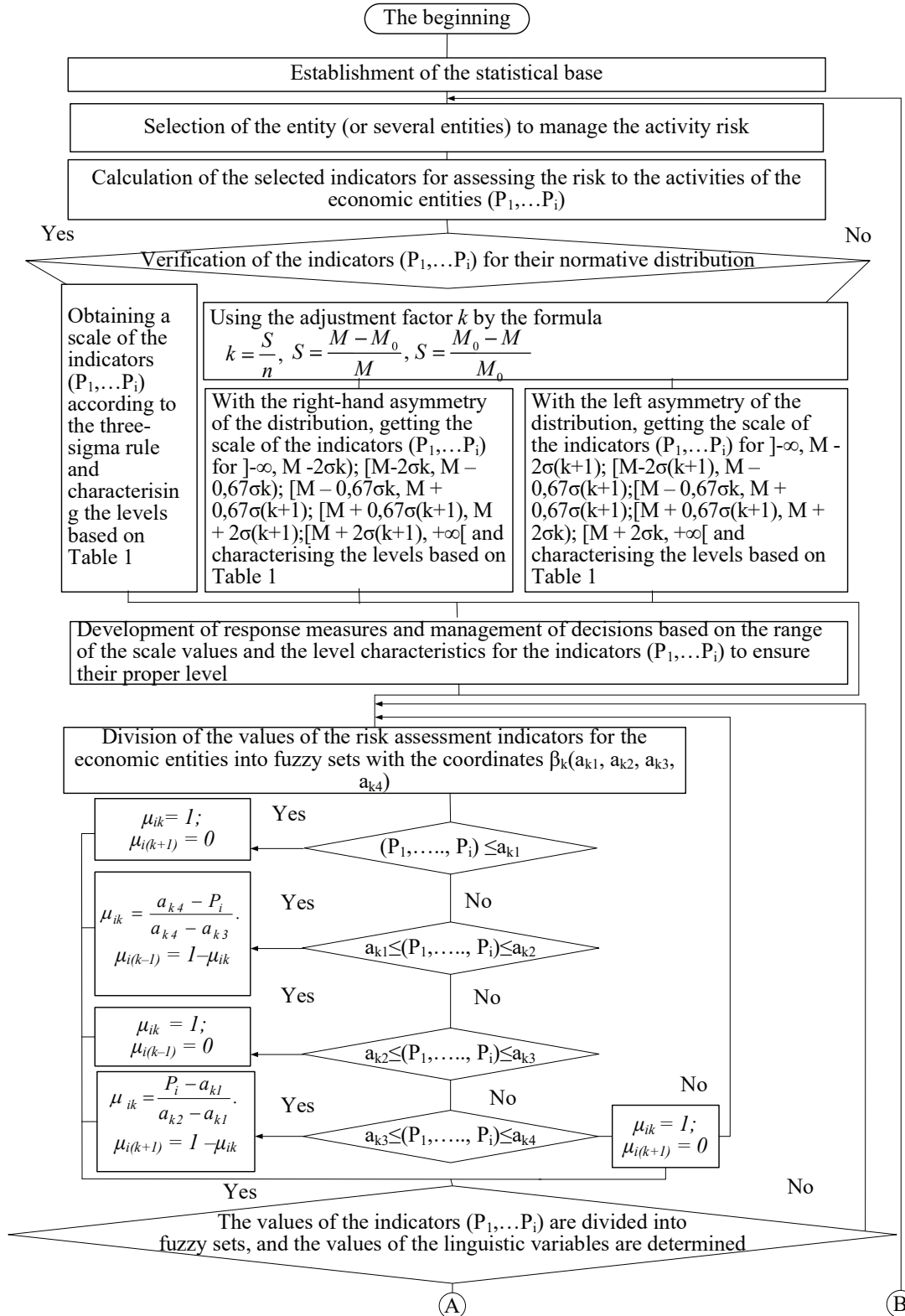


Fig. 1. The block diagram of the algorithm for the introduction of fuzzy modelling by means of fuzzyTECH to manage the risks of economic entities (the beginning)

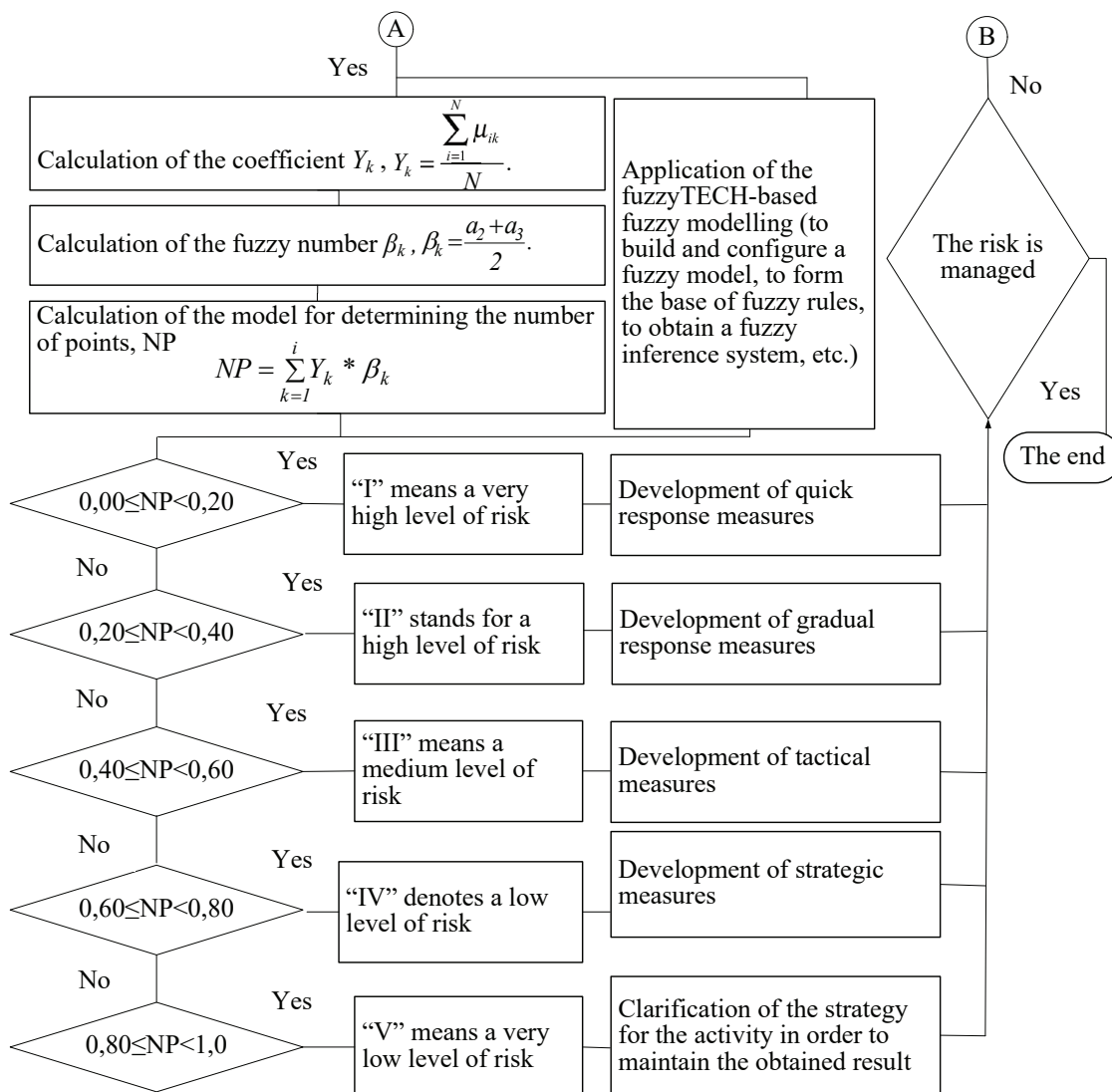


Fig. 2. The block diagram of the algorithm for the introduction of fuzzy modelling by means of fuzzyTECH to manage the risks of economic entities (the beginning) (the end)

According to the built block diagram, it is also important to develop a model for determining the number of points (NP), the use of which will make it possible to determine the level of risk as to the risks of economic activities. However, its construction takes into account only the tools of fuzzy sets. Its use will ensure the possibility to estimate more reliably the risks to economic entities, as the levels of risk are the same for both the fuzzy model and the model for determining the number of points (NP).

According to the developed algorithm (Fig. 1), managerial decisions should be applied not only to the obtained intervals for the aggregate level of risk but also at the level of intermediate values of the intervals of each individual indicator (P_1, \dots, P_i). Depending on the level of risk to the economic entities, it is advisable to develop measures of quick and gradual response, tactical and strategic, as well as measures at the level of the economic strategy. The basis for the selection of such measures is not only the scope of the measures but also the time constraints.

This approach to the introduction of fuzzyTECH-based fuzzy modelling into the process of managing the risks of economic entities on the basis of the developed algorithm

(Fig. 1) is general for economic entities of different fields of activity. That is why the task is to perform practical testing of the algorithm unit for assessing the risk to activities in the case of many economic entities.

5.3. Aprobation of the system of techniques to assess the risk to the activities of the researched economic entities

To test the system of techniques for assessing the risk of many economic entities, it is proposed to take into account the criterion of their increased social responsibility. According to [36], the set of the economic entities under consideration included those selected enterprises that have a double risk to their activities and are characterized by increased corporate social responsibility. The set of the studied economic entities comprised the following groups: by the type of enterprise (legal form of organization) – private joint stock companies; by the field of activity, according to the classification by [37], – insurance entities in the field of economic management.

The composition of the indicators to assess the risk to the studied economic entities (Table 4) was based on the proposed six selection criteria as well as information from [3, 38].

Table 4

The indicators proposed to assess the risk to the activities of the researched economic entities

Reference designation	Characteristics
P_1	The share of the amount of eligible assets in the base stock, %
P_2	The share of the amount of eligible assets in the base stock defined as the amount of reserves that are estimated in accordance with the law, %
P_3	The ratio of net income to the return on equity, ROE, %

Table 4 shows that the proposed composition of the indicators for assessing the risk to the economic activities includes 3 indicators, the symbol of which is used in subsequent calculations. P_3 is the general indicator; it is recommended to use it for economic entities of different fields of activity.

The Pareto principle, or Pareto law (also known as the 80/20 rule, the law of the vital few, or the principle of factor sparsity) is an empirical rule which states that for many phenomena, 80 per cent of the effects result from 20 per cent of the causes [39].

Applying the Pareto principle, the sample of the studied entities accounted for 20 % of the total number of entities registered in 2018. That is, 5 economic entities were studied, and the number of observations was 7, as data for 2018 and 2019 were obtained for two entities.

In the further research, it was determined expedient to avoid the influence of the received results on the reputation or image of the researched economic entities, for which the names were impersonalized as serial numbers (codes). At the next stage, the indicators P_1 , P_2 , and P_3 were calculated, which formed the statistical basis for further research.

Thus, a statistical database of the studied economic entities for 2018–2019 was formed taking into account the information of [40–48].

In order to build interval scales for the indicators P_1 , P_2 , and P_3 , these indicators were checked for the normality of their distribution, which is appropriate according to [28]. Using the approach described in [28], the quantitative characteristics of the risk assessment indicators of the researched economic entities were estimated, and the results are given in Table 5.

Table 5

The quantitative characteristics of the indicators to assess the risk to the activities of the researched economic entities

Indicator	Reference designator	P_1	P_2	P_3
Mean	x	110.63	152.01	18.52
Median	M	109.12	109.5	11.28
Mode	M_o	104.8	108.8	11.28
Mean squared deviation	δ	5.74	70.94	21.51
Asymmetry	A	0.7	1.65	1.11

As can be seen from Table 5, the indicators P_1 , P_2 , and P_3 are not distributed according to Gauss's law, i. e., there is a discrepancy between the values of the mode, median, and mean. Using the data of Table 5, it was determined that the

right-side asymmetry of the distribution was characteristic of all the three indicators, which is also confirmed by the positive value of the asymmetry ($A > 0$).

This proves the feasibility of determining the five-level scale for the indicators P_1 , P_2 , and P_3 , as well as the general characteristics of the level of risk to the activities of the researched entities.

Since five levels were defined for risk assessment, $n=5/2=2.5$, which was determined using formula 2 according to [28].

The intervals of the values of the scale of the indicators for assessing the risk to the activities of the studied economic entities with the right-side asymmetry are given in Table 6.

Table 6

The intervals of the values of the scale of the indicators for assessing the risk to the activities of the researched economic entities with the right-side asymmetry of the distribution

The calculation order	The level of the indicator	P_1	P_2	P_3
$]-\infty; M-2\sigma k]$	Very low	[0; 108.94)	[0; 109.14)	$]-\infty; -4.05]$
$[M-2\sigma k; M-0.67\sigma k]$	Low	[108.94; 109.06)	[109.14; 109.38)	$[-4.05; 5.13]$
$[M-0.67\sigma k; M+0.67\sigma(k+1)]$	Medium	[109.06; 113.02)	[109.38; 157.15)	$[5.13; 29.30]$
$[M+0.67\sigma(k+1); M+2\sigma(k+1)]$	High	[113.02; 120.77)	[157.15; 251.75)	$[29.30; 68.11]$
$[M+2\sigma(k+1); +\infty[$	Very high	$[120.77; +\infty[$	$[251.75; +\infty[$	$[68.11; +\infty[$

Thus, the scales of the risk indicators were obtained as listed in Table 6; they will serve as the basis for determining the membership functions $\mu(\text{NP})$.

$\{\mu\}$ is established by the set corresponding to the five fuzzy T-numbers $\{\beta\}$ of form (6) obtained on the basis of (1) according to [28]:

$$\begin{aligned}
 \beta_1 &= (0.00; 0.00; 0.15; 0.25); \\
 \beta_2 &= (0.15; 0.25; 0.35; 0.45); \\
 \beta_3 &= (0.35; 0.45; 0.55; 0.65); \\
 \beta_4 &= (0.55; 0.65; 0.75; 0.85); \\
 \beta_5 &= (0.75; 0.85; 1.00; 1.00).
 \end{aligned}
 \tag{6}$$

Table 7 shows the results of calculations by formula (2) according to [28] and the scale of the levels of values and the membership functions of the indicators for assessing the risk to the activities of the studied economic entities.

Table 7 shows the results describing the scales of the levels and membership functions of the values of the indicators to estimate the risk to the activities of the economic entities. Based on the data in Table 7, scales were constructed for the values of the estimated indicators (Table 8) as a criterion for division into fuzzy subsets.

The data obtained and given in Table 8 made it possible to determine the value of the membership functions of the indicators to assess the risk of the researched economic entities; a fragment is shown in Table 9.

Table 7

The scale of the levels of values and the membership functions of the indicators for assessing the risk to the activities of the researched economic entities

The range of the indicator values	The membership function (μ_{ik})	The value of the indicator level variable
P_1		
$0.00 \leq P_1 \leq 65.36$	1	Very low
$54.47 < P_1 < 108.94$	$\mu_1 = (108.94 - P_1) \div 65.36$	
$108.94 \leq P_1 \leq 109.00$	$1 - \mu_1 = \mu_2$	Low
$109.00 < P_1 < 109.06$	1	
$109.06 \leq P_1 \leq 111.04$	$\mu_2 = (109.06 - P_1) \div 0.06$	Medium
$111.04 < P_1 < 113.02$	$1 - \mu_2 = \mu_3$	
$113.02 \leq P_1 \leq 116.89$	1	High
$116.89 < P_1 < 120.77$	$\mu_3 = (111.04 - P_1) \div 1.98$	
$120.77 \leq P_1 < +\infty$	$1 - \mu_3 = \mu_4$	Very high
	1	
P_2		
$0.00 \leq P_2 \leq 65.48$	1	Very low
$65.48 < P_2 < 109.14$	$\mu_1 = (109.14 - P_2) \div 65.48$	
$109.14 \leq P_2 \leq 109.26$	$1 - \mu_1 = \mu_2$	Low
$109.26 < P_2 < 109.38$	1	
$109.38 \leq P_2 \leq 133.27$	$\mu_2 = (109.38 - P_2) \div 0.12$	Medium
$133.27 < P_2 < 157.15$	$1 - \mu_2 = \mu_3$	
$157.15 \leq P_2 \leq 204.45$	1	High
$204.45 < P_2 < 251.75$	$\mu_3 = (157.15 - P_2) \div 23.89$	
$251.45 \leq P_2 < +\infty$	$1 - \mu_3 = \mu_4$	Very high
	1	
P_3		
$-\infty < P_3 \leq -4.05$	1	Very low
$-4.05 < P_3 < -2.43$	$\mu_1 = (-4.05 - P_3) \div (-2.43)$	
$-2.43 \leq P_3 \leq 0.54$	$1 - \mu_1 = \mu_2$	Low
$0.54 < P_3 < 5.13$	1	
$5.13 \leq P_3 \leq 17.22$	$\mu_2 = (5.13 - P_3) \div 4.59$	Medium
$17.22 < P_3 < 29.3$	$1 - \mu_2 = \mu_3$	
$29.3 \leq P_3 \leq 48.71$	1	High
$48.71 < P_3 < 68.11$	$\mu_3 = (29.3 - P_3) \div 12.09$	
$68.11 \leq P_3 < +\infty$	$1 - \mu_3 = \mu_4$	Very high
	1	

Table 8

The scale of the values of the indicators for assessing the risk to the activities of the researched economic entities

Reference designation of the indicator	Intervals of the values of the linguistic variable 'The indicator level'				
	Very low	Low	Medium	High	Very high
P_1	(0.00; 0.00; 54.47; 108.94)	(54.47; 108.94; 109.00; 109.06)	(109.00; 109.06; 111.04; 113.02)	(111.04; 113.02; 116.89; 120.77)	(116.89; 120.77; $+\infty$; $+\infty$)
P_2	(0.00; 0.00; 65.48; 109.14)	(65.48; 109.14; 109.26; 109.38)	(109.26; 109.38; 133.27; 157.15)	(133.27; 157.15; 204.45; 251.75)	(204.45; 251.75; $+\infty$; $+\infty$)
P_3	($-\infty$; $-\infty$; -4.05; -2.43)	(-4.05; -2.43; 0.54; 5.13)	(0.54; 5.13; 17.22; 29.30)	(17.22; 29.30; 48.71; 68.11)	(48.71; 68.11; $+\infty$; $+\infty$)

Table 9

The values of the membership functions for the researched economic entities (a fragment)

The code of the researched economic entity (year) 1 (2019)							The code of the researched economic entity (year) 2 (2018)						
Indicator	Value	μ_1	μ_2	μ_3	μ_4	μ_5	Indicator	Value	μ_1	μ_2	μ_3	μ_4	μ_5
P_1	104.8	0.06	0.94	0.00	0.00	0.00	P_1	119.9	0.00	0.00	0.00	0.22	0.78
P_2	109.5	0.00	0.00	1	0.00	0.00	P_2	206.4	0.00	0.00	0.00	0.95	0.05
P_3	55.08	0.00	0.00	0.00	0.67	0.33	P_3	-2.18	1	0.00	0.00	0.00	0.00

For each indicator P_1 , P_2 , and P_3 , it is known that their increase leads to a decrease in the level of risk to the activities of the studied entities.

Based on the developed block diagram of the algorithm (Fig. 1), it is advisable to build and configure a fuzzy model for assessing the level of risk to economic entities by means of fuzzyTECH to obtain a system of the fuzzy conclusion.

During the above-mentioned practical approbation on the basis of the set of the researched economic entities, the values of the linguistic variables on the five-level scale for the input variables (the indicators P_1 , P_2 , and P_3) were obtained. The procedure of forming a fuzzy model by means of the package fuzzyTECH 6.10b Professional Demo and filling it with information involved the use of the obtained parameters for the indicators P_1 , P_2 , and P_3 shown in Tables 7, 8.

These values are used in the fuzzy model for the indicators and are named in the model under the codes In1, In2, and In3, which is related to the use of the English interface of the package fuzzyTECH 6.10b Professional Demo. Determining the values of the linguistic variables made it possible to obtain a reliable result on the level of risk to the activities of the researched economic entities.

For this purpose, the package fuzzyTECH 6.10b Professional Demo was used for the second studied economic entity according to the data of 2018; the output data on the values of the indicators P_1 , P_2 , and P_3 are presented in Table 9.

The constructed and configured fuzzy model to establish the base of the fuzzy rules in the package fuzzyTECH requires defining the set of various combinations of values of the linguistic variables for the input variables (the indicators In1, In2, and In3). This is shown in Fig. 3.

As can be seen from Fig. 3, the corresponding level of the output variable is set for the combinations of values of the linguistic variables for the input variables (the indicators In1, In2, and In3) on a five-level scale (very low; low; medium; high; very high).

Fig. 4 shows the use of the fuzzyTECH 6.10b Professional Demo package, which is based on fuzzy modelling to assess the level of the activity risk for the second researched economic entity with regard to the data of the year 2018.

Fig. 4 shows that a fuzzy model for assessing the risk to the economic entities was built and configured, and a fuzzy conclusion system was obtained using fuzzyTECH. Its approbation was carried out on the data of entity No. 2 for the year 2018. The characteristic of the output variable (the level of risk to the economic entity as the_level_of_riskiness) was determined as high, i.e., a high level of risk to the activity.

According to the calculations, the values of the coefficients Y_k , which were estimated using (4) as in [28], are given in Table 10.

The best method for building a model to calculate the number of points (NP) to assess the risks to economic entities is to comply it with the selected system of numbers $\{\beta\}$. This involves building a model for calculating the number of points (NP) in fuzzy form (8), which was modified to take into account the number of the indicators (three indicators) based on (3) according to [28]:

$$NP = \sum_{k=1}^3 Y_k * \beta_k, \tag{8}$$

where * is the operation of multiplying the real number by the fuzzy number.

To calculate the coefficient Y_k , formula (4) was used according to [28].

To determine the actual number of points (NP), the transition from the fuzzy number β_k (5) was used, which had been according to [28].

Thus, (3), (4) and (8) were used to obtain model (9) for calculating the number of points (NP) to assess the risk to the activities of the researched economic entities:

$$NP = 0.075Y_1 + 0.3Y_2 + 0.5Y_3 + 0.7Y_4 + 0.925Y_5. \tag{9}$$

Table 10

The values of Y_k coefficients for the researched economic entities

Code (year)	The value of Y					Code (year)	The value of Y				
	Y_1	Y_2	Y_3	Y_4	Y_5		Y_1	Y_2	Y_3	Y_4	Y_5
1 (2019)	0.013	0.387	0.20	0.00	0.00	4 (2018)	0.005	0.395	0.00	0.20	0.00
2 (2018)	0.20	0.00	0.00	0.234	0.166	4 (2019)	0.012	0.188	0.20	0.134	0.066
3 (2018)	0.004	0.196	0.354	0.046	0.00	5 (2018)	0.00	0.00	0.20	0.20	0.20
–	–	–	–	–	–	5 (2019)	0.00	0.128	0.272	0.00	0.20

Rule Editor 1

Rule Blocks

RB1

	If	And	And	Operators	Then
B1.G1	In1	In2	In3		The_level_of_riskiness
B1.G1.R1	In1.very_low	In2.very_low	In3.very_low	=>	The_level_of_riskiness.very_high
B1.G1.R2	In1.very_low	In2.very_low	In3.low	=>	The_level_of_riskiness.very_high
B1.G1.R3	In1.very_low	In2.low	In3.very_low	=>	The_level_of_riskiness.very_high
B1.G1.R4	In1.low	In2.very_low	In3.very_low	=>	The_level_of_riskiness.very_high
B1.G1.R5	In1.low	In2.very_low	In3.low	=>	The_level_of_riskiness.very_high
B1.G1.R6	In1.low	In2.low	In3.very_low	=>	The_level_of_riskiness.very_high
B1.G1.R7	In1.very_low	In2.low	In3.low	=>	The_level_of_riskiness.very_high
B1.G1.R8	In1.low	In2.low	In3.low	=>	The_level_of_riskiness.high
B1.G1.R9	In1.low	In2.low	In3.medium	=>	The_level_of_riskiness.high
B1.G1.R10	In1.low	In2.medium	In3.low	=>	The_level_of_riskiness.high
B1.G1.R11	In1.medium	In2.low	In3.low	=>	The_level_of_riskiness.high
B1.G1.R12	In1.low	In2.medium	In3.medium	=>	The_level_of_riskiness.high
B1.G1.R13	In1.medium	In2.medium	In3.low	=>	The_level_of_riskiness.high
B1.G1.R14	In1.medium	In2.low	In3.medium	=>	The_level_of_riskiness.high
B1.G1.R15	In1.medium	In2.medium	In3.medium	=>	The_level_of_riskiness.medium
B1.G1.R16	In1.medium	In2.medium	In3.high	=>	The_level_of_riskiness.medium
B1.G1.R17	In1.medium	In2.high	In3.medium	=>	The_level_of_riskiness.medium
B1.G1.R18	In1.high	In2.medium	In3.medium	=>	The_level_of_riskiness.medium
B1.G1.R19	In1.medium	In2.high	In3.high	=>	The_level_of_riskiness.medium
B1.G1.R20	In1.high	In2.high	In3.medium	=>	The_level_of_riskiness.medium
B1.G1.R21	In1.high	In2.medium	In3.high	=>	The_level_of_riskiness.medium
B1.G1.R22	In1.high	In2.high	In3.high	=>	The_level_of_riskiness.low
B1.G1.R23	In1.high	In2.high	In3.very_high	=>	The_level_of_riskiness.low
B1.G1.R24	In1.high	In2.very_high	In3.high	=>	The_level_of_riskiness.low
B1.G1.R25	In1.very_high	In2.high	In3.high	=>	The_level_of_riskiness.low
B1.G1.R26	In1.high	In2.very_high	In3.very_high	=>	The_level_of_riskiness.low
B1.G1.R27	In1.very_high	In2.very_high	In3.high	=>	The_level_of_riskiness.low
B1.G1.R28	In1.very_high	In2.high	In3.very_high	=>	The_level_of_riskiness.low
B1.G1.R29	In1.very_high	In2.very_high	In3.very_high	=>	The_level_of_riskiness.very_low
B1.G1.R30	In1.very_low	In2.very_low	In3.medium	=>	The_level_of_riskiness.very_high
B1.G1.R31	In1.very_low	In2.medium	In3.very_low	=>	The_level_of_riskiness.very_high
B1.G1.R32	In1.medium	In2.very_low	In3.very_low	=>	The_level_of_riskiness.very_high
B1.G1.R33	In1.low	In2.low	In3.high	=>	The_level_of_riskiness.high
B1.G1.R34	In1.low	In2.high	In3.low	=>	The_level_of_riskiness.high
B1.G1.R35	In1.high	In2.low	In3.low	=>	The_level_of_riskiness.high
B1.G1.R36	In1.medium	In2.medium	In3.very_high	=>	The_level_of_riskiness.medium
B1.G1.R37	In1.medium	In2.very_high	In3.medium	=>	The_level_of_riskiness.medium
B1.G1.R38	In1.very_high	In2.medium	In3.medium	=>	The level of riskiness.medium

Fig. 3. A fragment of the set of the fuzzy rules in fuzzyTECH 6. 10b Professional Demo for assessing the level of risk to the activity

Based on [28], it was determined that if the value obtained during the analysis was $\mu_k(NP) > 0$, it must be assumed that the risk to the entity would be described by the linguistic value of the subset {NP} with the level of compliance as to $\mu_k(NP)$.

In other cases, {NP} does not belong to other subsets of {A}. In general, with the proposed choice of the system $\{\mu\}$, the belonging is possible for no more than two average subsets [28].

Taking into account the non-uniform distribution of the values of the indicators when constructing the intervals of the scale made it possible to use a uniform scale from 0 to 1 when

determining the level of risk to the activities of the studied economic entities.

Using Table 10, the risks to the researched economic entities were assessed, and the results are presented in Table 11.

As can be seen from Table 10, most of the studied economic entities are at a high level of risk, i. e., the activities of the entities are sensitive to the influence of the risk factors based on the results of the retrospective assessment. Therefore, these entities do not have the sufficient safety to offset the impact of the risk factors. After receiving data for different years, the tendency was determined for the data of 2019 as the worsening of the level of risk to the fifth considered economic entity.

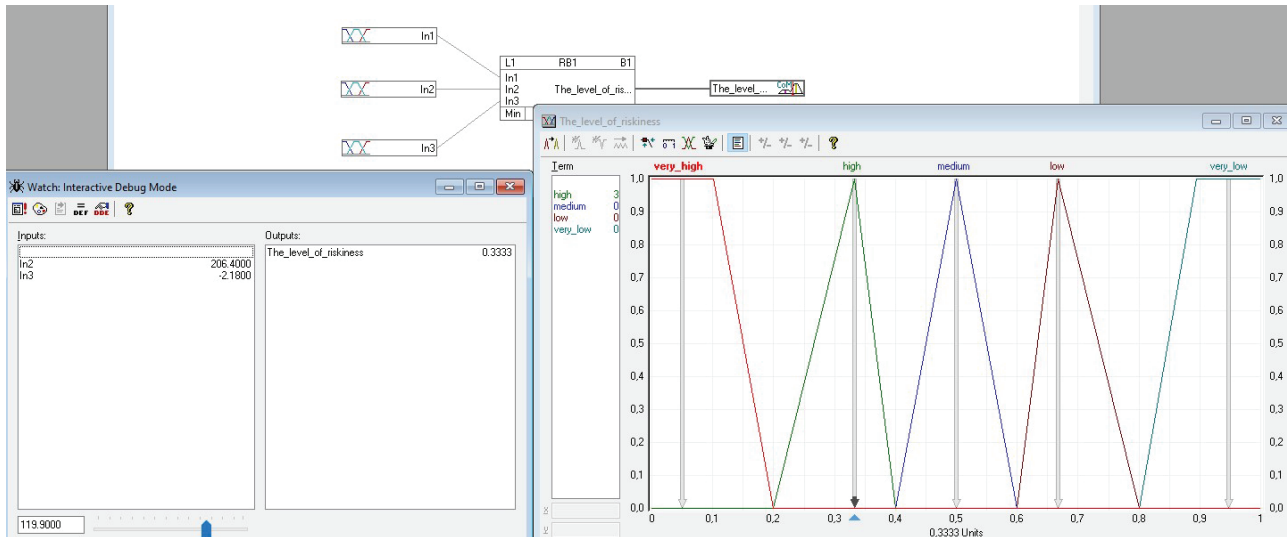


Fig. 4. The use of the tools of the fuzzyTECH 6.10b Professional Demo package to assess the level of the activity risk

Table 11

The results of assessing the risks to the activities of the researched economic entities

Code (year)	NP value	The reference designator of the level	Qualitative characteristics of the level
1 (2019)	0.22	“II”	A high level of risk to the activity
2 (2018)	0.33	“II”	A high level of risk to the activity
3 (2018)	0.27	“II”	A high level of risk to the activity
4 (2018)	0.26	“II”	A high level of risk to the activity
4 (2019)	0.31	“II”	A high level of risk to the activity
5 (2018)	0.43	“III”	A medium level of risk to the activity
5 (2019)	0.36	“II”	A high level of risk to the activity

6. Discussion of the research results on managing the risks to the activities of economic entities with the fuzzyTECH-based fuzzy modelling

There are objective difficulties associated with managing the risks of economic entities. This is due to the lack of certainty about the possibility of using fuzzy modelling with fuzzyTECH and the development of management measures based on the estimated level of risk.

Typically, when using fuzzy set tools, the level of risk of bankruptcy of economic entities was diagnosed, and management was based on the results of this estimation or on the results of financial analysis. When trying to overcome these limitations in risk management, there are objective difficulties associated with the uncertainty of processes and tools for assessing the level of risk. It is important to test certain tools for assessing the level of risk to economic entities. In the study described in the article, a way to overcome these difficulties was proposed. The approach to the introduction of fuzzyTECH-based fuzzy modelling into the process of managing the risks of economic entities based on the developed block diagram of the algorithm is general for use by economic entities of different fields of activity. When using stages such as constructing and setting fuzzy models, combining the tools of fuzzy sets and fuzzy logic with fuzzyTECH, and obtaining a fuzzy inference system, it is advisable to determine the level of risk to economic entities. The evaluation unit should be preceded not only by the use of a fuzzy model but also by the processes involved in constructing an interval scale of indicators to assess the activity risk.

This method helped, while testing it, to obtain intervals of the scale values according to the three-sigma rule with the right-side asymmetry of the indicators' distribution, i.e., to obtain a model for calculating the number of points (NP) to assess the risk to the activities of the researched entities (9). The findings in the form of the number of points (NP) for assessing the risk to the activities of the studied economic entities are interesting from a theoretical perspective. From a practical point of view, the built scales and criteria of the indicators for assessing the activity risk (very low, low, medium, high and very high levels) are valuable. Moreover, a fuzzy model was built and configured, combining the tools of fuzzy sets and fuzzy logic by means of fuzzyTECH, and that a system of fuzzy inferences about the level of risk to the activity was obtained. Model (9) was built to calculate the number of points (NP) for the aggregate risk assessment of the activities of the studied entities. Therefore, an applied aspect for using the obtained scientific results is the possibility of improving the typical process of neutralising the influence of risk factors on the state of activity based on applying the constructed and configured fuzzy model by means of fuzzyTECH. This is a prerequisite for the transfer of the scientific and practical results to the system of risk-oriented management of economic entities. Users of the obtained results can be various stakeholders (the management and management services, creditors, customers, etc.).

Fully agreeing with the authors of [49], it is important to take a systematic approach to assessing the adverse effects of economic events that may hinder the activities of economic entities. Based on this, the introduction of diagnostic

monitoring during the economic risk management can be a positive practice, which is the subject of further research.

That is why, given the above, when grading the indicators (P_1, \dots, P_i) to assess the risk of economic activities, an important prerequisite is to use a high-quality statistical base. Under these conditions, it is necessary to take into account the statistical base of economic entities of a certain field of activity, which imposes certain restrictions. The establishment and constant updating of a high-quality statistical tool, as well as calculations based on it, are essential for obtaining objective results. The formation of a statistical base for groups of economic entities, taking into account the affiliation of the latter to groups of different fields of activity and the use of other environments and software packages for fuzzy modelling, are the subject of further research. In particular, a promising research area is determining the features and practical benefits of using, for example, MATLAB with a fuzzy logic toolbox or other environments and fuzzy modelling software. In addition to the functional features that are important criteria for making decisions about the effectiveness of using software packages other than fuzzyTECH, i. e., other environments or software packages for fuzzy modelling, further research considerations will include the availability of the Demo version, the cost of the license, and the ease of calculation.

7. Conclusion

1. The study has determined the prerequisites for the introduction of fuzzy modelling by means of fuzzyTECH into the process of managing the risks of economic entities. They include the conditions that fuzzy modelling should involve the construction and configuration of fuzzy models, combining the tools of fuzzy sets and fuzzy logic. In addition, the existing functionality of the fuzzyTECH package has the same characteristics that meet the established requirements for the environments and software packages to perform fuzzy modelling. The expediency of using a fuzzyTECH-based fuzzy modelling technology in the economic risk management is also explained by the fact that it is possible to use levels and values of linguistic variables for these levels. The fuzzyTECH tool will automate this process. This will help to quantify and provide qualitative characteristics of the level of risk to an activity (estimated on the basis of using appropriate selected indicators, so the multicriteria selection in the study resulted in six proposed criteria). This is especially important in conditions of uncertainty. Therefore, having substantiated the importance of using levels, especially when building and setting a fuzzy model, a description was provided to clarify the levels of risk to economic entities on a five-level scale including: a very high level of risk to the activity; a high level of risk to the activity; a medium level of risk to the activity; a low level of risk to the activity; and a very low level of risk to the activity.

2. Given the fact that the introduction of managerial innovations has an important impact on the development of economic entities, a block diagram of the algorithm for implementing fuzzyTECH-based fuzzy modelling in the process of managing the risks to the activities of economic entities was developed. The algorithm is general for use by economic entities in various fields of activity. It takes into

account the stage of developing the model for calculating the number of points (using the tools of fuzzy sets) and the stage of constructing and setting the fuzzy model (the main stage of the fuzzy modelling technology) to assess the risk of economic activities. Given the sequence of steps in the proposed block diagram of the algorithm, an important parameter for constructing a fuzzy model by means of fuzzyTECH was to establish a correspondence between the values for the input variables and output variable and their corresponding values of the linguistic variables represented by the membership functions. During the practical approbation of this stage of the developed block diagram of the algorithm on the basis of several economic entities, the values of the linguistic variables on a five-level scale for the input variables (the indicators P_1, \dots, P_i) were obtained. These values of the linguistic variables helped to achieve reliable results on the level of risk to economic entities. The use of the input variables (the indicators P_1, \dots, P_i), the base of fuzzy rules, and the output variable (the level of risk to the activity) provided the possibility to obtain a system of fuzzy inferences about the estimated level of risk to an entity's activity. Moreover, it is recommended not to use the standard values of the linguistic variables that can be automatically suggested by the fuzzyTECH package for the input variables (the indicators P_1, \dots, P_i) and the output variable on the five-level scale.

According to the constructed algorithm, managerial decisions should be based not only on the obtained intervals for the aggregate level of risk (NP) but also on the intermediate values of the intervals of each individual indicator (P_i). Depending on the level of risk to an economic entity, it is advisable to take appropriate measures and managerial decisions. These include: the development of measures of quick and gradual response, tactical and strategic, as well as measures at the level of the entity's strategy.

3. The system of techniques for assessing the activity risk to economic entities was tested taking into consideration specific economic entities. The intervals of the scale values according to the three-sigma rule with the right-side asymmetry of the indicators' distribution were obtained. The indicators for assessing the risk of economic activities of the studied entities included three indicators selected on the basis of six criteria. The values of the linguistic variables for these indicators were obtained. A fuzzy model for assessing the risk to economic entities using fuzzyTECH was built, set, and tested, and a fuzzy inference system was obtained. Besides, a model for calculating the number of points for assessing the risk of the activities of the studied entities was obtained. The testing of this toolkit was carried out with 7 observations. This made it possible to determine that the researched economic entities were mostly characterized by a high level of risk of their activities. Therefore, it was determined as advisable to improve the margin of safety in order to neutralize the impact of the risk factors with the help of gradual response measures.

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