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# Modeling Study on Risk Identification in the Process of Anti-Crisis Enterprise Management

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**Abstract:** The study provides solutions for the scientific task related to the improvement of theoretical and development of methodological and applied principles, and the identification and evaluation of risks and threats as factors of anti-crisis management of the enterprises. Based on the developed concept of quantitative risk analysis, we constructed a fuzzy hierarchical model, which gives the possibility to get the estimates: risk factors; specific types of threats in the framework of a process; risk processes, identified in the anti-crisis management; and the integrative risk of anti-crisis management. Furthermore, the proposed model makes it possible to identify the threats that are the risks of the highest (catastrophe) layer. The fuzzy hierarchical model construction process includes the determination of linguistic variables, term-varieties, and universal sets for quantitative evaluation of figures and risks, the establishment of parameters of the membership functions for indicators and risks, the formation of fuzzy knowledge bases, the construction of a fuzzy hierarchical model in the MATLAB environment, the evaluation of adequacy of model based on the learning sample, the correction of a model, and the adoption of a resolution regarding its final variant. The use of the model in the anti-crisis enterprise management will provide the anti-crisis team with the possibility to give early warning of all negative factors, give their quantitative evaluation, and take them into account in the course of making managerial decisions.

**Keywords:** risk evaluation; hierarchical model; anti-crisis management; a zone of risks; economic security



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## 1. Introduction

Entrepreneurship activities are always influenced by a range of external and internal factors. Taking these factors into account in the course of the adoption of managerial decisions decreases the probability of underpayment (lost) of earnings or profit, the appearance of a crisis, or bankruptcy of the enterprise.

In general, each of the above-mentioned subsystems is focused on laying the groundwork for the steady activity of the enterprise during the current period and achievement of its strategic objectives in a long-term perspective. Herewith, these sub-systems have their specific nature that was discovered in the course of a profound analysis of their features, such as a subject, an object, a strategy, an objective and functions, methods, and instruments. Anti-crisis management features specific methods and tools for finding the way out of a crisis: bailout, restructuration, reengineering, etc. One distinguishes the following specific

methods in the system of economic security: business intelligence, fight against raiding, spying activity, and other illegal activities of physical or legal persons.

Due to a great number of external and internal factors that negatively affect the enterprise and can lead to variance from the planned indexes, the following management sub-systems are applied: anti-crisis management, risk management, and enterprise's economic security management. Each of these sub-systems should be aimed at provision of the enterprise's strategic objectives achievement. That is why anti-crisis management processes, risk management, and economic security should have their individual, clearly determined objectives and tasks, methods, and instruments, which may intersect in some cases but have their individual specifics.

In general, any type of managerial activity involves conduction of a series of actions, application of techniques and methods, through which the desired result is achieved. The sequence of such actions, techniques, and methods reflects the management process, which can be divided upon the following main phases: (1) determination of an objective; (2) situation assessment; (3) problem detection; (4) making an appropriate managerial decision; (5) implementation of the adopted decision; and (6) control over the realization of a decision, identification of variance, and making decisions on their elimination.

The goal of the research is the improvement of theoretic and development of methodological and applied fundamentals of identification and evaluation of risks and threats as factors of anti-crisis management of the enterprises.

## 2. Literature Survey

In the process of analysis of scientific works and enterprise management, it was found that researchers integrate the following functional subsystems for tracking the influence of the destructive factors: anti-crisis management (Parker 2018), risk management (Sperotto et al. 2017), and economic security management of an enterprise (Tsang et al. 2017). All these three management systems are closely connected. At the same time, each of them has its specific peculiarities. Thus, crisis management focuses on developing the company's economic behavior, which will enable the achievement of the objectives in the event of a crisis.

The question regarding the risks management and threat prevention were considerably highlighted in the scientific works. (Florio and Leoni 2017) examined the external factors, affecting the formation and assessment of risks in enterprise management. Herewith, the authors insisted on the thesis that it is socio-political factors that influence the state of the internal resources, managed by the enterprise.

(Khan et al. 2019) analyzed methods that could be applied in the risk management practice. This study enables the company's management practice to choose the most effective methods for mitigating financial risks—risks primarily related to financing policy, the choice of equity and debt ratio strategy, refinancing, etc.

A significant contribution to the study of business risks was made by scientists such as Chang et al. (2018), Muriana and Vizzini (2017), and Wu et al. (2017). Chang et al. (2018) improved the classification of the enterprise's risks by the introduction of topological features. The topological features are as follows, which appear in the system of the company's activity: procedural (related to the operational activity), financial (financial activity), and technological (typical only to industrial companies).

Muriana and Vizzini (2017) constructed a system of managing the enterprise in the event of crisis, which is based on the attributive approach, which made it possible to identify the attributes of functional risks. The attributive approach distinguishes the primary risks, which emerge during the establishment of the company (foundation), and secondary risks, appearing when external risks (social, political, technological, and ecological) modify the primary risks or under the condition of the emergence of new risks at other stages of the company's life cycle.

Wu et al. (2017) used a matrix approach to justify managerial decisions in the risk management system, which allowed them to study the interconnection of risks. The matrix

method of tasks and authorities distribution is done through constructing a table, combining a list of structural units or positions that perform specific functions on risk management, and a list of functions, grouped upon the main areas of activity. The matrix method of tasks, powers, and responsibilities distribution is quite simple to implement and has the following advantages: it eliminates the absence of a certain risk management function and functions duplication as well; it helps to achieve the visibility of the preparation, decision-making, and implementation procedures on risk management; it concretizes the distribution of tasks, powers, and responsibilities in the risk management system; it eases the process of drafting regulations and positions based on the received results; and it eliminates overlaps and parallelism of the risk management system functioning at the enterprise.

The questions of identification the threats and tracking of their influence in the system of economic security of the enterprise are highlighted in the researches of Duceppe et al. (2017), Leva et al. (2017), and Munns et al. (2017).

Duceppe et al. (2017) studied the system of "security-insecurity" dichotomy and identified the risk levels in the enterprise. The risk levels at the enterprise correspond to Harrington's scale. Harrington's scale is a multi-interval discrete verbal-numerical scale, comprising five intervals of a unit segment, characterizing the degree of proximity to a specific ideal: very high (0.8–1.0); high (0.63–0.8); medium (0.37–0.63); low (0.2–0.37); and very low (0–0.2). For each risk level, one builds individual strategies on risks leveling. Thus, for medium risks, he builds a diversification strategy.

Leva et al. (2017) built the mechanism for interaction between economic security and economic risks. In the process of risk and security management, it is impossible to achieve the situation of absolute certainty and total absence of threats. As a result, under modern conditions, characterized by the disappearance of a certain part of threats and appearance of new hazards (primarily of technological nature), it is possible to suggest an extended statement that there is no risk- or threat-free behavior for entrepreneurs. The specialist's focus on only one aspect of the problem (risk/threats) contributes to the involuntary neglect of the other aspect (danger/risk). The result predominantly remains the same: one observes the losses in the business sphere and the loss of his own business.

Munns et al. (2017) used the program Matlab for building the forecasts of risks in the enterprise security system. It is worth mentioning that the authors took a huge retrospective sample—20 years—to build risk forecasts, in particular, for external risks. When calculating internal risks, it is sufficient to consider risks observed over 5 years, using the full range of company's reports, both financial and non-financial.

The approaches to solving a lot of theoretic and methodological aspects of anti-crisis management were described in the scientific papers by Boquist et al. (2017). These authors state that the establishment of an efficient risk management system requires the creation of the internal risk management mechanism, featuring all its components: an object, a subject, functions, principles, methods, tools, etc. One develops the interrelated stages of the mechanism. Thus, the final stage includes control and correction of the results of the implementation of the chosen strategy with consideration of new information. Control resides in obtaining information from managers about the losses that have occurred and the measures that were taken for their minimizing. It can manifest itself in the identification of new circumstances, changing the risk level, the transmission of this information to the insurance company, monitoring over the effectiveness of safety systems, etc. Every few years, one should take the review of data on the effectiveness of the used risk management measures with consideration of information about the losses that have occurred during this period.

Considering the existing opinions of the scholars and the authors' research, we offer the following qualitative signs of risk and threat differentiation:

(1) Conditions for emergence (a risk is a primary event, appearing in the case of making a decision under the condition of uncertainty, the availability of a conflict, and an alternative (Cohen et al. 2017): a threat is a derivative phenomenon that occurs in the case of the implementation of a risk event upon an unfavorable scenario (Kokangül et al. 2017);

(2) viability (a risk promotes extra benefits or losses, i.e., the variances from the planned figures, which do not affect the achievement of the objectives (Fan et al. 2017): significant losses, the enterprise downfall, or bankruptcy are the results of a threat implementation (Mehmood et al. 2019);

(3) the role in the development of the enterprise (a risk plays a driving role, while a threat—slows or destroys) (Javaria et al. 2020).

The conducted researches gave us the ground to make a conclusion that the separation of risks and threats at a qualitative level is relatively formal, which requires a solution to the issue related to their quantitative assessment.

Herewith, the question of identification and evaluation of the negative factors influence in the course of anti-crisis management has still been very poorly investigated. Since there are no unambiguous interpretations of risks and threats, as well as their clear division, this complicates the process of the negative factors influence diagnosing, as well as the tracking of their part in the managerial activity under conditions of crisis and its absence. The classification of risks of anti-crisis management and the technology of identifying the factors of negative influence under the conditions of reactive anti-crisis management of the enterprise leaves much to be improved. The works of the scientist do not provide the answer to the question regarding the structure of the model for quantitative evaluation of risks and identification of threats in the process of anti-crisis management of the enterprise. The need for finding solutions for these issues promotes the choice of the topic of the research and the determination of its goal and tasks.

The examination of literary sources and our own findings have shown that the onset of the crisis in an enterprise can be identified by a number of signs, i.e., the negative changes that take place in its financial and economic activity. The causes of those changes may come from both its internal and external environment and be of objective and subjective nature. The higher the level of uncertainty and conflict, the greater number of alternative variants in the decision-making process is available, the bigger the number of negative factors, and the stronger their influence on the enterprise; consequently, the enterprise will face the deeper destabilization of its financial and economic state. In this case, there is a higher probability that the risks may become threats. The impact of destructive factors should be considered when managing the enterprise for prevention of its crisis development.

## 3. Materials and Methods

### *3.1. General Characteristics Methods*

One used the following methods of scientific research to solve the set objectives: (1) comparison, generalization, concretization, and systematization—to clarify the conceptual framework and economic substance of a crisis, a threat, and a crisis for identification of their factors; to research the peculiarities of anti-crisis management, risk management, and the system of economic security of the enterprise and identification of the interplay between them; as well as for the study of the specificity of anti-crisis management in other companies; (2) methods of financial, economic, and statistical analysis—to evaluate the state and tendencies of the enterprises development; (3) a procession approach and methods of grouping and generalization—to determine the risks in the process of anti-crisis management of the company; (4) a theory of fuzzy sets—to form a model of quantitative evaluation of risks; and (5) a method of sensitivity analysis—to evaluate the level of sensibility of risks of anti-crisis managerial activity.

The scientific works of the authors on risk management serve as the theoretical background for our research. The empiric base of the study includes the financial reporting of the enterprise, materials of the Internet resources, and the authors' own investigations.

### *3.2. Research Construction*

Considering the process approach to the qualitative evaluation of factors of negative influence on the enterprise under the conditions of anti-crisis-management, we provide a generalized model of qualitative evaluation of integral risk, reflected in Figure 1.

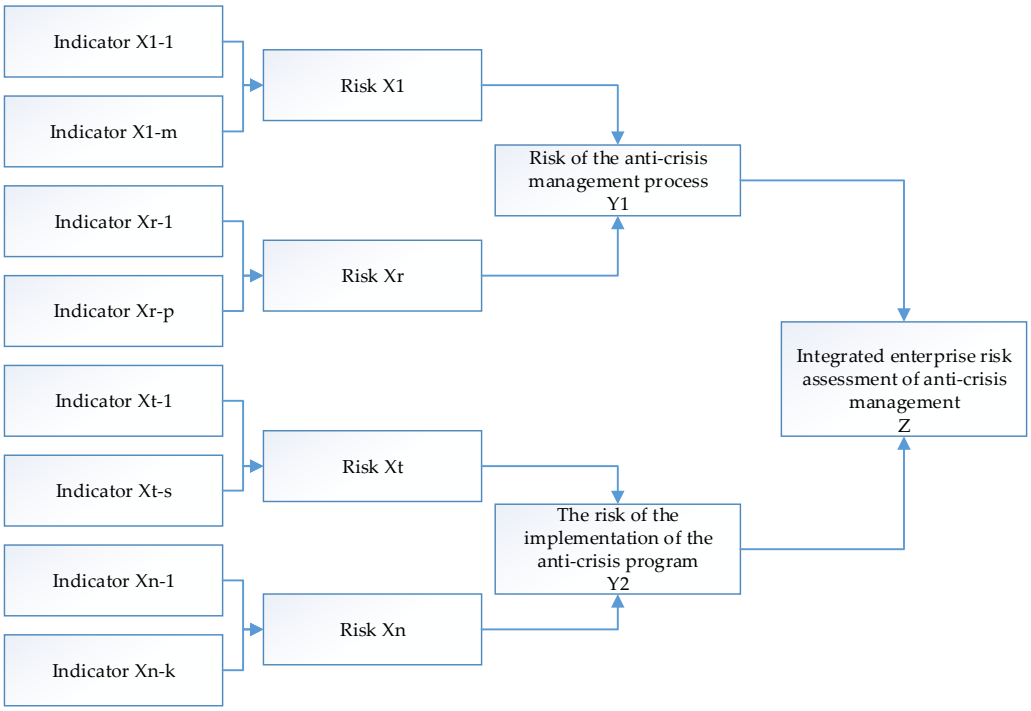


**Figure 1.** A generalized model of integral risk evaluation of the enterprise anti-crisis management (the authors' development). Note: $(x_{1-1}, \ldots, x_{r-p})$—process' risk indicators of the anti-crisis managerial activity; $(x_{t-1}, \ldots, x_{n-k})$—risk indicators of the process on anti-crisis program implementation; $(X_1, \ldots X_r)$—the risks of a process of anti-crisis managerial activity; $(X_t, \ldots X_n)$—the risks of a process of implementation of the program.

We hold the quantitative evaluation of risks for each process, considering the types of risks and their factors inherent to them, which will be evaluated using the indicators. The same kinds of risks, which were identified for the short and long terms, have specific differences. They can be traced in risk factors, factor impact levels, and a risk level (in the long term, the level of influence increases as uncertainty increases). We take into account differences in risk factors by introducing additional or other indicators for risks in the long run. The difference in the level of influence of the same risk factors and the same types of risks in different periods should be taken into account in the parameters of the mathematical model.

The developed concept of quantitative risk evaluation provides the ground for making a decision about the building of a fuzzy hierarchical model with the following components: terminal nodes—indicators of risks $(x_{1-1}, \ldots, x_{n-k})$; nonterminal nodes—specific risks, inherent to the processes $(X_1, \ldots X_n)$, and risks of each of the processes in general (Y1, Y2); the root of a tree—an integral risk of anti-crisis management (Z). It is efficient to use such type of a building the hierarchical fuzzy model, in which the fuzzy conclusions are generated for intermediate variables with the subsequent transfer of clear figures of these variables to fuzzy systems of the next level within the hierarchy.

The stages of the model development for evaluation of risks using the apparatus of the theory of fuzzy sets are given in Figure 2.

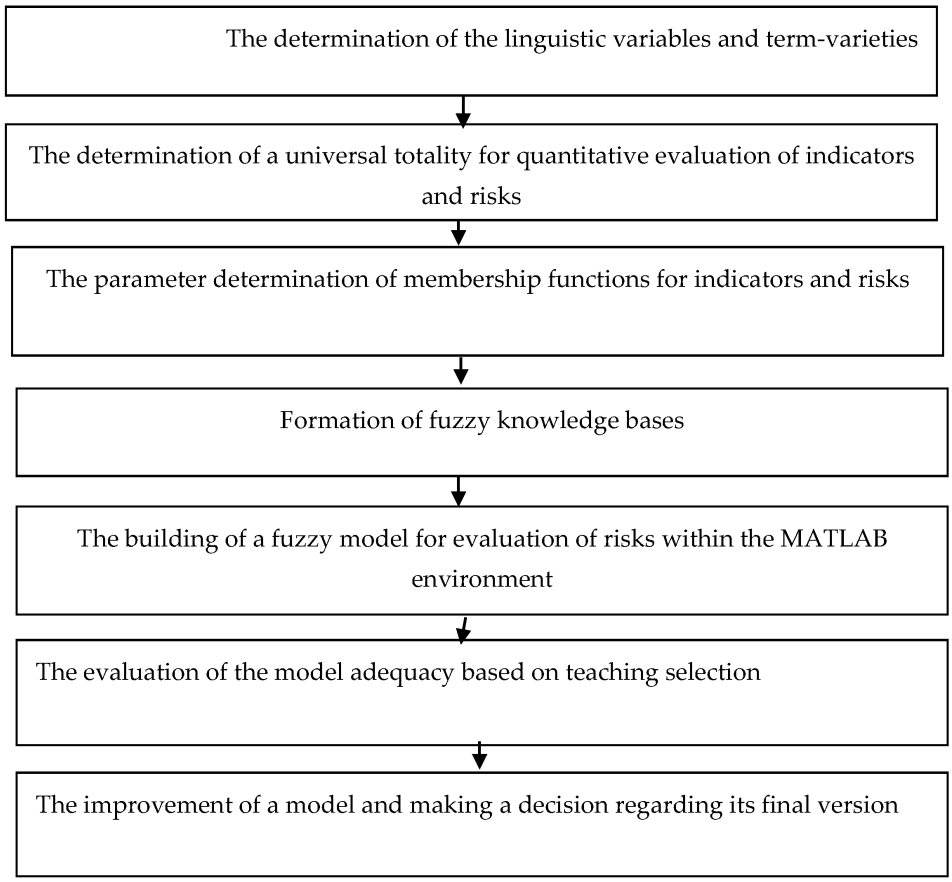


**Figure 2.** The stages of building a fuzzy set of risk evaluation of enterprise anti-crisis management. (the authors' development).

According to the 1st stage, the building of a fuzzy model involves the identification of linguistic variables and their corresponding figures.

## 4. Data

To evaluate the availability of a universal set from the elements [0;1] features of a fuzzy totality (for indicators: very low, low, intermediate, high, advanced; for risks: allowed, critical, catastrophe), the authors invited 14 experts: 3 anti-crisis managers, 4 researchers in the area of anti-crisis-management, 3 scientists from the field of risk management, and 4 managers with particular experience in the area. All the experts have high standards of knowledge, professional competence, and sufficient experience (over 15 years).

The experts had to express their opinion on the presence of the properties of a fuzzy set in all indicators and risks. However, such a large number of indicators and risks makes it difficult to interview all the experts and process the obtained survey results. Therefore, taking into account the most common types of membership functions, the characteristics of indicators and risks as objects of assessment and expert opinion, it has been established that it is advisable to choose trapezoid membership functions. In such a case, the construction of the membership function required only the setting of its parameters. The authors also decided that it would be more efficient to obtain expert estimates of the parameters of membership functions not via the traditional questioning of experts, but through the results of a brainstorming session. The brainstorming also has that type of advantages that provides the ability to quickly change the parameters of functions and adjust the model under the new conditions, which is significant for the provision of effective management, and, in particular, the crisis management of the enterprise.

The ability to overcome the influence of the external risks and threats significantly depends on the financial and economic state of each economic entity. Thus, diagnostics should become an attainable permanent part of anti-crisis management, aimed at timely detection of internal negative phenomena, their comprehensive study for making the most optimal managerial decisions on their elimination and prevention of the enterprise's financial and economic state deterioration, which will make it more resistant to negative external influences.

To identify the features of crisis development of the enterprise at an early stage, one should regularly conduct express-diagnostics, the informational basis of which is the data of the financial accounting.

The formation of the sample population for research results from the accessibility of financial data reporting of eight machinery manufacturing plants of Poland, which are joint-stock companies. The information basis is formed based on annual financial reporting of these enterprises during the period of 2016–2019. The indexes used in the authoring study are given in Appendix A.

## 5. Results

The performed research showed that the theory of fuzzy sets is appropriate to use for modeling of economic phenomena and processes, related to a high level of uncertainty. Such an approach provides the possibility to formalize both the peculiarities of the target of evaluation and the cognitive peculiarities of people, making decisions regarding this object within the framework of one model.

Using the fuzzy set apparatus mechanism, one can carry out the modeling of complicated systems in the light of conditions of insufficient information and random processes. The use of fuzzy mathematics is the tool for resolution of the tasks regarding aggregation of ambiguous, subjective, and inaccurate judgments of the experts about the state of a certain parameter or a risk indicator of the enterprise. It is quite difficult or even impossible at all to draw these figures to a common denominator. Furthermore, fuzzy sets can divide the data obtained by linguistic boundaries, which forms the basis for further decision-making processes. This approach provides an opportunity to set a model for getting quantitative estimates, in contrast to traditional qualitative evaluations of the experts.

By using the notion of a linguistic variable, we mean a variable, the meaning of which can be represented by words or phrases, used by people daily to evaluate different phenomena, processes, objects, and so on. The psychologists have found that almost all numerical information in the human brain is verbally transcoded and stored in the form of words. The set of all possible values of a linguistic variable is called the term set, while any element of a term set is regarded as a term.

To evaluate risk indicators, we integrated the linguistic variable "Risk indicator level." The term-totality of this linguistic variable consists of the following parameters: very low; low; intermediate; high; and advanced.

To evaluate the indicators of risks, we involved the linguistic variable "Risk level." The term-totality for this linguistic variable was determined considering the criteria of risk distribution upon the areas, given in Table 1.

**Table 1.** Areas of risk, based on the results of business operations (the authors' development).

| Areas of risk | Criteria for attribution to a specific area |
|---|---|
| Area of acceptable risk | Losses in the sum of estimated profit |
| Area of critical risk | Losses in the sum of estimated income; loss of working capital; the decrease of a range of activity |
| Area of catastrophe risk | Losses in the sum of own capital; structural damage of the capital |

Thus, the linguistic variable "Risk level" can take the following values: allowed; critical; and catastrophe. The catastrophe value will be considered to be a threat.

The list of linguistic variables and their possible meanings is generalized in Table 2.

**Table 2.** Linguistic variables and term-varieties (the author's development).

| Linguistic Variables | Terms |
|---|---|
| Risk indicator level | Very low |
| | Low |
| | Intermediate |
| | High |
| | Advanced |
| Risk level | Allowed |
| | Critical |
| | Catastrophe (threat) |

The next step is the determination of the universal set of numbers, the elements of which will be used as the quantitative estimates of indicators and risks. To assess the level of risks, it is advisable to choose numbers belonging to the interval [0;1]. The higher the number, the higher the risk level.

One distinguishes the qualitative and quantitative indicators. The qualitative indicators, like risks, use the universal set of real numbers within the interval [0;1]. The values of quantitative indicators are decimal fractions, which can also take values that are bigger than one. To choose a single universal set for a fuzzy model, the authors propose to estimate the indicators by percentage deviations of expected values from the normative or planned ones, transforming them into fractions of a unit. That is why the authors selected a universal set of real numbers on the interval [0;1] for both linguistic variables.

While building a knowledge base about the relationship between indicators and risks, one should pay into an account that the relationship between them can be either direct or inverse. Most indicators and risks are characterized by the following feedback: the higher the indicator value, the lower the risk level. Certain types of risks are characterized by a direct relationship with the indicator level is characteristic, for example, the following factors increase the risk: the level of limited time, the level of criminogenicity of the business environment, the level of financial and operational leverage, etc.

After the determination of term sets and a universal set, it is necessary to construct membership functions. It is the membership function that makes it possible to calculate the level of correspondence to a fuzzy set for any element of the universal set. As a rule, the membership functions are set on the basis of statistical processing of expert opinions about the presence of elements of a universal set of properties of a fuzzy set.

The analytical expression of the trapezoidal function has the following form (Formula (1)):

$$\mu(u) = \begin{cases} 0,\ u \le a \text{ or } u \ge d; \\ \dfrac{u-a}{b-a},\ a \le u \le b; \\ 1,\ b \le u \le c; \\ \dfrac{d-u}{d-c},\ c \le u \le d. \end{cases} \quad (1)$$

where $\mu(u)$ is the level of the correspondence of the components of the universal set [0;1] to the fuzzy set of parameters (for risks of the anti-crisis management of the enterprise: allowed, critical, and catastrophe; for the economic risk indicators: very low, low, intermediate, high, and advanced), the particles of a unit; (a;d) is the pessimistic estimation (the level of the experts' confidence that the properties of the fuzzy set in the elements belonging to the universal set are lower than (1)); [b;c] is the optimistic estimation (the level of the experts' confidence that the properties of the fuzzy set in the elements belonging to the universal set are equal to (1)).

For building the fuzzy model, the authors used the package Fuzzy Logic Toolbox in the MATLAB environment.

The parameters of the membership functions for the evaluation of the integral risk of anti-crisis management are provided in Table 3 below.

**Table 3.** Parameters of the membership functions for the evaluation of the integral risk of anti-crisis management (the authors' development).

| Risks | Membership Function Figures |
|---|---|
| Risk of the anti-crisis management process | Allowed:[0 0 0.25 0.35] |
| Risk of the anti-crisis program implementation process | Critical:[0.25 0.35 0.65 0.75] |
| Integral risk of the anti-crisis management process | Catastrophe:[0.65 0.75 1 1] |

The next step involves the formation of fuzzy knowledge bases. Considering the generalized risk assessment model (see Figure 3), one should establish the fuzzy rules (if any) for the following ratios:

(1) between indicators and risks:

$$(x_{1-1} = \widetilde{a}_{1j},\ x_{1-2} = \widetilde{a}_{2j}, \Theta_j \ldots \Theta_j, x_{n-k} = \widetilde{a}_{nj}) \Rightarrow X = d_j, j = (1, m); \quad (2)$$

where $\widetilde{a}_{ij}$ is a fuzzy term, evaluating the variable $x_i$ in the j-rule; $d_j$ is the conclusion of the $j$-rule; $m$ is the number of rules in the knowledge base; $\Theta_j$ is a logical operation, linking the fragments of the antecedent (it can be either a logical operation AND or OR); $\Rightarrow$ is a fuzzy implication;

(2) between the risks, inherent to a process, and the overall risk of this process:

$$(X_1 = \widetilde{a}_{1j}\, \Theta_j\ X_2 = \widetilde{a}_{2j}\ \Theta j \ldots \Theta_j\ X_n = \widetilde{a}_{nj}) \Rightarrow Y = d_j, j = (1, m); \quad (3)$$

(3) between the risks of processes and an integral risk of anti-crisis management:

$$(Y_1 = \widetilde{a}_{1j}\ \Theta_j\ Y_2 = \widetilde{a}_{2j}) \Rightarrow Z = d_j,\ j = (1, m). \quad (4)$$

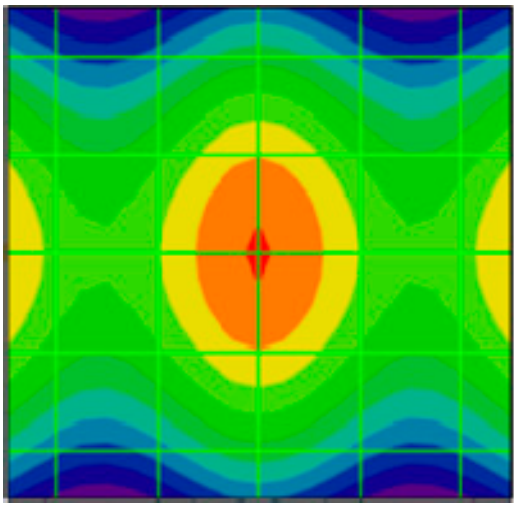

**Figure 3.** The dependence between the integral risk of anti-crisis management, the process of anti-crisis managerial activity, and the process of the anti-crisis process implementation. (Built by the authors within the MATLAB environment).

For the formation of fuzzy inference, we chose the Mamdani algorithm. After the formation of the rules, we evaluated the adequacy of the model based on the test set, the results of which are the corrections of its specific parameters.

The dependence between the integral risk of anti-crisis management, the process of anti-crisis managerial activity, and the process of the anti-crisis program implementation are graphically represented in Figure 3.

Based on the obtained figures, one can make a conclusion that the majority of risks, which are inherent to the process of anti-crisis management, lie within the manageable level. However, in view of the increased level of managerial and financial risks, the overall risk of anti-crisis managerial activity reaches the critical value, which requires urgent measures on its reduction.

The developed model can be used for both evaluations of risks upon the given parameters of indicators and for the study of risks sensibility to the change of the indicators' parameters. It is especially relevant under the conditions that are characterized by informative uncertainty and a high level of dynamics.

Moreover, the offered model can be easily adapted to new conditions, in particular, one can change the parameters of this model: a list of indicators and risks, a type of membership functions and their parameters, and logical rules, which determine the possibility of its use not only for the purposes of the enterprises.

## 6. Discussion

The authors have found that in conditions of stable activity of the enterprise, elimination or mitigation of the influence of destructive factors, it can be assigned to the economic security system of the enterprise. The functions of crisis management and risk management should be performed within the selected subsystem. The proposed approach will allow using specific techniques and tools of the economic security system, which are crucial for the enterprise to maintain stable development. In a state of crisis, the leading role should belong to the anti-crisis management. To prevent the occurrence of new risks and threats, which might intensify the crisis and the inability to implement the anti-crisis program, specific tasks and functions should be delegated to the economic security and risk management service.

The enterprise might influence the negative factors appearing within its internal environment or microenvironment. That is why risk management should develop certain risk management measures that can occur in the course of the development and implementation of the anti-crisis program. Such tasks and functions should be delegated by anti-crisis management.

In regard to the above-mentioned details, there is a need to determine the ways of minimization of the main negative factors, which might appear in the process of crisis management of an enterprise. Based on the studies, it was found that anti-crisis management activities are primarily associated with managerial risk. To reduce the negative impact of this risk, we offer the following measures:

advanced vocational training, knowledge and experience improvement of the employees in the area of anti-crisis management, which provides the possibility to timely identify the features of crisis events, evaluate their parameters properly, and develop and implement anti-crisis measures when it is needed; (Siraj and Fayek 2019)

the provision of the proper labor conditions, the use of motivational measures, and the formation of a friendly atmosphere within the enterprise team to improve the coherence of the work of both the anti-crisis team and all structural divisions, and the enterprise in general; (Mishra et al. 2019)

the conduction of a careful selection of specialists for the formation of an anti-crisis team, dedicated to the interests of the enterprise and the provision of the appropriate level of enterprise security, and avoiding deliberate bringing it to bankruptcy or raider seizure. (Brustbauer 2016)

We propose the following ways to minimize information and communication risk:

the improvement of the quality of the information through its profound check of the reliability of external sources; (Callahan and Soileau 2017)

the enhancement of methods, models, and application program packages, used in the process of diagnosing and decision-making; (Oliva 2016)

further development of information and communication technologies with the purpose of the information timely provision, and prevention of its loss or distortion; (Berry-Stölzle and Xu 2018)

the reduction of a level of professional risk of a public accountant is possible by means of the provision of free access to information; (Fraser and Simkins 2016)

the provision of valid data in the financial reporting; the use of services of adequate and reliable firms of auditors. (Lechner and Gatzert 2018)

For making timely and efficient anti-crisis managerial decisions, it is highly recommended to provide the appropriate financing of anti-crisis management activities to maintain the corresponding quality of all other resources, involved in the process (personnel, information and communication, and instrumental).

Having the purpose to increase the level of the legal protection of the enterprise in crisis, one should draw attention to the occupational attainment (in particular, on the knowledge of the law) and the responsibility of lawyers of the enterprise.

## 7. Conclusions

A hierarchical model has been constructed for the quantitative assessment of the risks of anti-crisis management of the machine-building enterprise, which, with the help of a fuzzy mathematical apparatus, makes it possible to evaluate the risk factors and the risks at each level of the hierarchy. The offered model provides the possibility to detect threats (risks of the catastrophic level) and also the most significant risk factors based on the use of a sensitivity analysis method, which is important for making managerial decisions under the conditions of uncertainty.

The authors improved the technology of the qualitative assessment of negative impact factors under the conditions of reactive anti-crisis management of the enterprise, which, in contrast to already existing ones, grounds on the process approach and makes it possible to identify factors, which can cause partial or complete non-achievement of the objective of each process.

The authors also improved the conceptual framework of managerial activity of the enterprise with consideration of its financial and economic state. Its difference from the current foundations resides in the following: under the absence of signs of crisis, one considers functioning of the economic security system as that which uses risk-management functions and anti-crisis management, under crisis conditions. Specifically, the introduction of anti-crisis management with the delegation of certain tasks and functions to the economic security system and risk management unit to prevent a deterioration of financial and economic state, as well as provision of conditions for efficient implementation of anti-crisis measures.

Considering the process approach to the identification of risks, we justified expedience of the construction of a hierarchical fuzzy model for quantitative estimation of the level of their influence. We determined the following elements for this model: terminal nodes—indicators (factors) of risks; nonterminal nodes—individual risks and process risks in general (anti-crisis managerial activity, anti-crisis program implementation); the root of a tree—the integral risk of anti-crisis management.

We included two linguistic variables into the model and determined the corresponding term-totalities: (1) the linguistic variable "Risk indicator level" with totality of parameters: very low; low; intermediate; high; and advanced; (2) the linguistic variable "Risk level," including term-totality: allowed; critical; and catastrophe (threat).

The set of real numbers in the range from 0 to 1 is a universal set for evaluation of indicators and linguistic variables. Based on private research and considering the experts'

opinions, the parameters of the trapezoidal membership functions were determined to assess indicators and risks. Fuzzy knowledge bases have been formed to highlight the relationships between: indicators and risks; the risks inherent to the process, and the overall risk of this process; process risks and integrated risk of anti-crisis management.

For our research, we selected the hierarchical fuzzy model for structure construction, in which the fuzzy conclusions are generated for intermediate variables with the subsequent transfer of clear figures of these variables to fuzzy systems of the next level within the hierarchy. Such an approach makes it possible to get the estimates of specific types of risks, process risks, and the integral risk of anti-crisis management.

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## Appendix A

**Table A1.** Indexes of financial firmness and independence of the enterprises.

| Enterprises | Years | Autonomy Ratio, Unit Fraction | Ratio of Short-Term Financial Obligations in an Aggregate Amount of Obligations, Unit Fraction | Ratio of Provision of Floating Assets with Equity Funds, Unit Fraction |
|---|---|---|---|---|
| Fabryka Samochodów Małolitrażowych | 2016 | 0.47 | 0.31 | 0.69 |
| | 2017 | 0.44 | 0.56 | 0.43 |
| | 2018 | −0.67 | 0.55 | −0.67 |
| | 2019 | −1.50 | 0.47 | −1.41 |
| Fabryka Samochodów Osobowych | 2016 | 0.53 | 1.00 | −0.11 |
| | 2017 | 0.49 | 1.00 | −0.22 |
| | 2018 | 0.50 | 1.00 | −0.10 |
| | 2019 | 0.58 | 1.00 | 0.16 |
| FSC Star | 2016 | −0.22 | 0.49 | −0.81 |
| | 2017 | −0.43 | 0.45 | −0.40 |
| | 2018 | 0.22 | 0.89 | −1.34 |
| | 2019 | 0.21 | 0.76 | −3.40 |
| Zabrzanskie Zaklady Mechaniczne S. A. | 2016 | 0.72 | 0.99 | 0.50 |
| | 2017 | 0.64 | 0.94 | 0.43 |
| | 2018 | 0.66 | 0.84 | 0.49 |
| | 2019 | 0.58 | 0.90 | 1.15 |
| Tauron Polska Energia | 2016 | 0.17 | 0.35 | 0.66 |
| | 2017 | 0.17 | 0.37 | 0.64 |
| | 2018 | 0.23 | 0.17 | 0.83 |
| | 2019 | 0.15 | 0.52 | 0.49 |

**Table A1.** *Cont.*

| Enterprises | Years | Autonomy Ratio, Unit Fraction | Ratio of Short-Term Financial Obligations in an Aggregate Amount of Obligations, Unit Fraction | Ratio of Provision of Floating Assets with Equity Funds, Unit Fraction |
|---|---|---|---|---|
| Nowy Styl | 2016 | 0.15 | 0.81 | −0.31 |
| | 2017 | 0.16 | 0.79 | −0.37 |
| | 2018 | 0.12 | 0.71 | 0.13 |
| | 2019 | 0.05 | 0.70 | 0.11 |
| Gdansk Shipyard | 2016 | 0.77 | 0.89 | 0.70 |
| | 2017 | 0.80 | 0.84 | 0.77 |
| | 2018 | 0.72 | 0.94 | 0.67 |
| | 2019 | 0.60 | 0.94 | 0.52 |
| Apator | 2016 | 0.05 | 0.49 | 0.47 |
| | 2017 | 0.001 | 0.48 | 0.32 |
| | 2018 | −0.11 | 0.46 | 0.25 |
| | 2019 | −0.16 | 1.00 | −0.69 |

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