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RISK OPTIMIZATION OF INDUSTRIAL ENTERPRISE

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Abstract. Industrial enterprise risk management must take into account the conditions of the activities that are carried out and the goals that are set out under these conditions. To solve this problem, a scientific and methodological approach to targeted risk optimization of an industrial enterprise was developed based on a set of models of comparing the goals of the enterprise under operation conditions, matching the available resources with the needs and choosing the methods of risk management according to the limitations by goals and resources. The use of the developed scientific and methodological approach enables the enterprise to choose the most effective methods of risk management.

Keywords: industrial enterprise, risk management, development, model, optimization, operation conditions

JEL Classification: C44, D81

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1. Introduction

When managing the risks of an industrial enterprise, it should be borne in mind that under different conditions the approaches to optimize risks and the tolerable magnitudes and probabilities of these risks may differ. Risk that is unacceptable in the ordinary course of business of an industrial enterprise, may well be tolerated under crisis management environment, where the enterprise must agree with risky strategies and choose between bad and very bad.

Therefore, the risk management of an industrial enterprise must take into account the current operating conditions and be based on the goals set by the owners and managers of the enterprise. In addition, different operating conditions of an industrial enterprise set different goals. Therefore, the risk optimization of an industrial enterprise should be targeted.

2. Literature review

Risk management is the identification, evaluation, and prioritization of risks (defined in ISO 31000 as the effect of uncertainty on objectives) followed by coordinated and economical application of resources to minimize, monitor, and control the probability or impact of unfortunate events or to maximize the realization of opportunities. Certain aspects of many of the risk management standards have come under criticism for having no measurable improvement on risk; whereas the confidence in estimates and decisions seem to increase. (Hubbard & Douglas, 2009).

(Chernenko, 2014) reviewed the main current directions of risk management. He identified the types of risk minimization, such as avoidance, reduction, conservation and transfer. In addition, Chernenko considers separating the transformation and financing of risk, understood as either minimizing risk or creating reserves to secure it. The proposed classifications are relevant in view of the further improvement of industrial enterprise risk management methods.

In turn, (Sifumba et al., 2017) states that risk management is one of the most important issues being the key for business success, but can negatively affect the profitability if not realized properly.

(Klimenko, 2013) believes that industrial enterprise risk management should be implemented by using a cumulative approach based on the bifurcation nature of industrial development. The risk-taking strategy of the enterprise is based on the assumption at every phase of life cycle, and the enterprise aims to maximize potential.

(Stepanova & Volkov, 2017) offered a hierarchical classification of risks based on their probabilities, which allows managing the levels of information risk of the enterprise. Despite the prospect of the study, it should be noted that the management of an industrial enterprise needs to take into account not only information but other types of risks.

According to the standard ISO 31000 "Risk management is the principles and guidelines on implementation" ISO (2009), the process of risk management consists of several steps as follows:

- the social scope of risk management;
- the identity and objectives of stakeholders;
- the basis upon which risks will be evaluated, constraints;
- defining a framework for the activity and an agenda for identification;
- developing an analysis of risks involved in the process;
- mitigation or solution of risks using available technological, human and organizational resources.

Common risk identification methods are:

- objectives-based risk identification;
- scenario-based risk identification;
- taxonomy-based risk identification – the taxonomy in taxonomy-based risk identification is a breakdown of possible risk sources. Based on the taxonomy and knowledge of best practices, a questionnaire is compiled. The answers to the questions reveal risks (Carr et al., 1993);
- common-risk checking – in several industries, lists with known risks are available;
- each risk in the list can be checked for application to a particular situation;
- risk charting (Crockford & Neil, 1986) – this method combines the above approaches by listing resources at risk, threats to those resources, modifying factors which may increase or decrease the risk and consequences an enterprise wishes to avoid.

Once risks have been identified and assessed, all techniques to manage the risk fall into one or more of these four major categories (Dorfman & Mark, 2007):

- avoidance (eliminate, withdraw from or not become involved);
- reduction (optimize – mitigate);
- sharing (transfer – outsource or insure);
- retention (accept and budget).

Planning how risk will be managed in the particular project (Virine & Trumper, 2007):

- assigning a risk officer;
- maintaining live project risk database;
- creating an anonymous risk reporting channel;
- preparing mitigation plans for risks that are chosen to be mitigated;
- summarizing planned and faced risks, effectiveness of mitigation activities, and effort spent for the risk management (Simon & Hillson, 2012).

(Vihlyaeva & Fedya, 2013) consider that the main cause of risks is lack of information, therefore, in order to optimize the risks of an industrial enterprise it is necessary to intensify the work of collecting and processing information, to provide diagnostics of the problem, formulation of restrictions, identification of alternatives, the choice of solutions. Despite the logic and validity of the proposed measures, the main obstacle to the practical application of this approach is the lack of formalized methods for determining the optimization criteria and quantitative characteristics of decisions made.

In addition, the contribution to solving the risk optimization problem by such scientists should be noted (Bajgoric, 2011; Better et al., 2008; Bonaccolto & Caporin, 2016; Dźwigoł, 2018; Dźwigoł & Dźwigoł-Barosz, 2018; Dźwigoł & Wolniak, 2018; Dzwigoł et al., 2019; Eskandari & Fuschi & Tvaronavičienė, 2016; Rabelo, 2007; Fukushima, 2006; Hroznyi et al., 2018; Kamińska, 2018; Karpenko et al., 2018; Kouvelis & Yu, 1997; Kelly, 2002; Kuzmak et al., 2018; Kvilinskyi & Kravchenko, 2016; Kwilinski, 2017, 2018a, 2018b, 2018c, 2019; Kwilinski et al., 2019a, 2019b; Mackevičius et al., 2018; Okoli et al., 2016; Paulusch, 2017; Ramalingama, 2018; Savchenko et al., 2019; Tarasova, 2018; Tkachenko et al., 2019; Zeng & Skibniewski, 2013; Zhou et al., 2016).

The essence of the optimization system lies in pre-planned measures aimed at identifying possible adverse situations and reducing the degree of their possible impact on the project to an acceptable level. At the same time, risk optimization includes such targeted actions as planning, identification, assessment, processing, control and documentation of risks (Kaminska, 2018).

In situations where uncertainty is at the core of the problem — as it is in risk management — a different strategy is required. In the field of optimization, there are various approaches designed to cope with uncertainty (Fukushima, 2006; Eskandari & Rabelo, 2007). In this context, the exact values of the parameters (e.g. the data) of the optimization problem are not known with absolute certainty, but may vary to a larger or lesser extent depending on the nature of the factors they represent.

Robust optimization may be used when the parameters of the optimization problem are known only within a finite set of values. In order to measure the robustness of a given solution, different criteria may be used. (Kouvelis & Yu, 1997) identify three criteria:

1) absolute robustness;
2) robust deviation;
3) relative robustness.

Practically every real-world situation involves uncertainty and risk, creating a need for optimization methods that can handle uncertainty in model data and input parameters.

(Better et al., 2008) described two popular methods, scenario optimization and robust optimization, that seek to overcome limitations of classical optimization approaches for dealing with uncertainty and that undertake to find high-quality solutions that are feasible under as many scenarios as possible.

(Opalenko, 2015) proposes to optimize the risks of a manufacturing enterprise based on four main types of risks (internal, which are divided into financial and non-financial, as well as external, which are market and regulatory) and four main activities of the manufacturing

enterprise (production, sales, management and financial activities). For each activity, the risk weight, the necessary costs and the maximum risk reduction are established; the purpose of optimization is to minimize the total necessary costs. The main disadvantage of this approach is the lack of attention of how it is proposed to reduce individual risks and to ignore the variety of generally accepted risk management methods.
As a whole, it can be concluded that the majority of researchers did not take into account the current conditions of operation of an industrial enterprise and its objectives when developing risk optimization methods, which have an impact on the methods of risk management that can be used.

3. Methods

When managing the risks of an industrial enterprise based on the principles of goal-oriented optimization, it is necessary to take into account the list of possible goals for each type of enterprise functioning and dependence on the current capabilities of the enterprise. It is the current capabilities that determine the goals of an industrial enterprise in risk management, because, for example, if an enterprise lacks resources, it has limited capacity to exert influence on risky situations. At the same time, depending on the operating conditions, these restrictions may be extended, for example, in times of crisis, when an enterprise is already in danger of bankruptcy, it may be advisable to take greater risks than is reasonably practicable.

The industrial enterprise risk optimization system receives the necessary input from the risk assessment system and the targeting system which is shown in *Fig. 1*. The risk assessment system provides risk mapping and formulation of the operating conditions for risk map is being developed. In turn, the industrial targeting system provides its strategic goals and objectives that must be addressed in order to achieve goals.

Risk optimization is performed by using three models of primary data processing that provide formalized processing and validation of conclusions regarding risk optimization measures:
- model for comparing the goals of the enterprise under operating conditions and typical risks for these conditions;
- model for matching existing resources with the needs and outcomes of tasks;
- model for choosing risk management methods.

The goal-setting model under operating conditions and the typical risks for these conditions provide for the formalization of the strategic goals of the industrial enterprise and for determining how those goals coincide with the specific risks inherent in the existing operating conditions. The model is based on the use of fuzzy set theory and enables the intersection of the goals and objectives of the enterprise with the goals of risk management, which are conditioned by the operating conditions.

For each purpose of an industrial enterprise it is determined that negative deviation of the planned indicators is inadmissible. For this purpose, a set of membership functions is constructed for fuzzy sets corresponding to the linguistic variable ”tolerance.” The

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membership function argument uses a metric that reflects the goal. For each type of operation of an industrial enterprise, its goal achievement indicators, or several such indicators, are established, and a function is built that relates indicator to the net profit and total sales of the industrial enterprise.

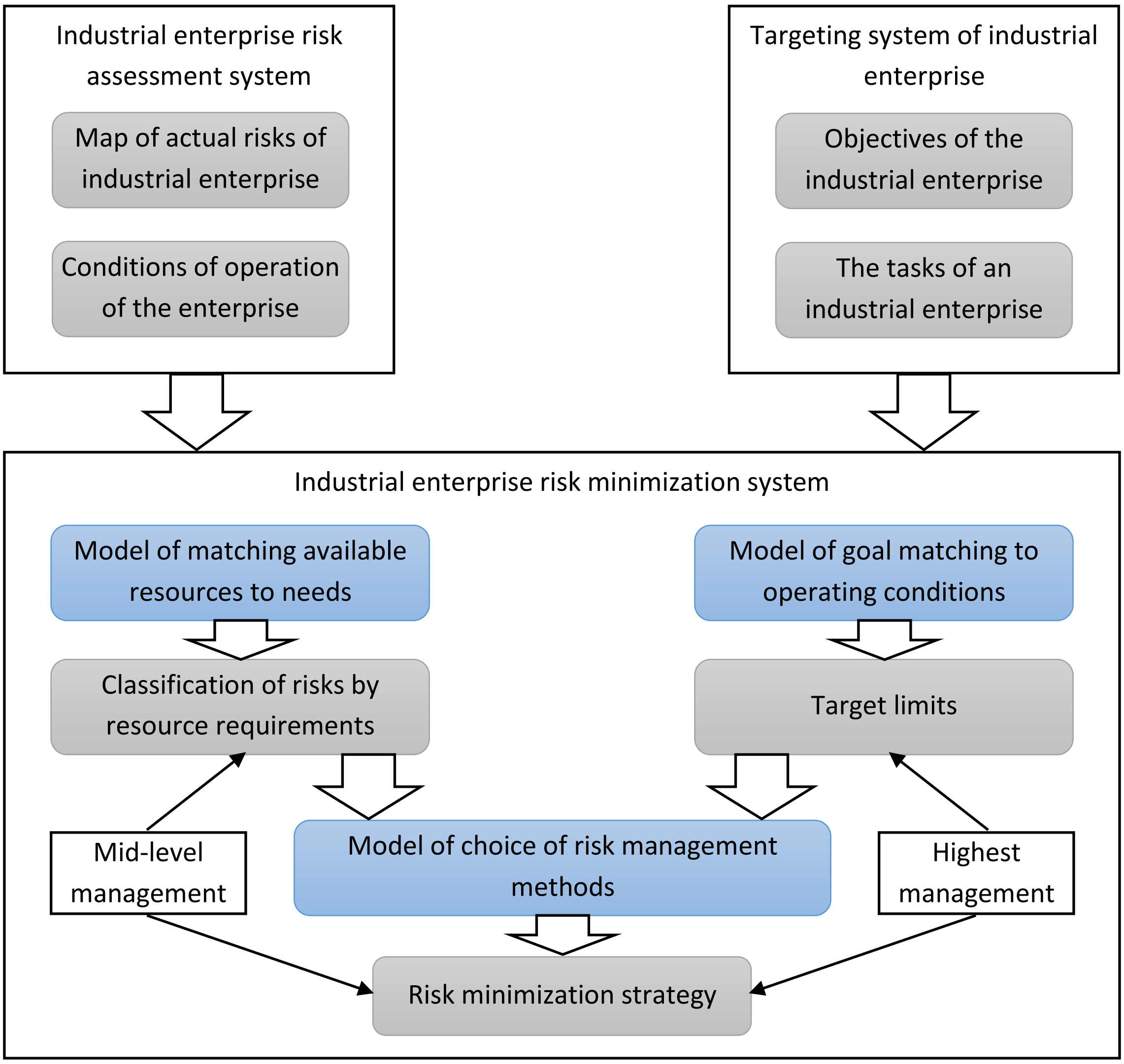

Figure 1. The structure of risk management of an industrial enterprise under various operating conditions
Source: own research.

The membership function has a sigmoidal appearance, since all values of deviation less than a certain limit are admissible, all values above another limit are invalid, and those between them depend on the personal view of the leader and are therefore described by fuzzy sets:

$$\mu^G(x,a,b) = \begin{cases} 0,\ if\ x \le a \\ \dfrac{2(x\text{-}a)^2}{(b\text{-}a)^2},\ if\ a \le x < \dfrac{a+b}{2} \\ 1\text{-}\dfrac{2(b-x)^2}{(b\text{-}a)^2},\ if\ \dfrac{a+b}{2} \le x < b \\ 1, if\ x \ge b \end{cases} \quad (1)$$

$$x = f^x(P,V) \quad (2)$$

where: $\mu^G(x,a,b)$ – the function of belonging to the linguistic variable "tolerance";

x – deviation of actual target from the planned one;

$f^x(P,V)$ – a function that connects the deviation of the actual target from the planned profit and sales volume of the industrial enterprise;

a,b – parameters of the sigmoidal membership function;

P – net profit of an industrial enterprise;

V – volume of industrial enterprise sales.

Similarly, the fuzzy set membership function can be constructed for each industrial enterprise task, if the depth of analysis requires it.

Depending on the conditions of operation of an industrial enterprise, different criteria are set when constructing the function of belonging to a fuzzy set, which characterizes the inadmissibility of deviations when reaching the goal. For normal operating activities, the main thing is to maintain profitability of the enterprise. Therefore, the criterion is a change in profitability.

When operating in an industrial manufacturing business, they end up trying to increase the volume of work to capture most of the market and need to use in the market that exists but needs to be kept clean. Thus, to create the functionality of accessory in the production of an industrial enterprise is a pure existing or a separate place with a possible coefficient.

Finally, the functioning of an industrial enterprise under crisis conditions is of paramount value to solvency. Therefore, given the management under crisis and generalized indicators with the goals of crisis management structure of the service, there are accessories that arbitrarily chose to worsen the current number of opportunities. Therefore, depending on the operating conditions, the function of belonging to the linguistic variable ”tolerance” has different targets.

In turn, for each risk identified in the assessment process, the expected losses in the event of a negative event or several adverse events in the case of complex risk are identified. These losses can also be seen as a reduction in net income. For industrial enterprise risk, a membership function is formed that describes the linguistic variable ”tolerable risk” and which has a z-shaped form (Kelly, 2002):

$$\mu^R(y,c,d) = \begin{cases} 1,\ if\ y \le c \\ 1 - \frac{2(y\text{-}c)^2}{(d\text{-}c)^2},\ if\ c \le y < \frac{c+d}{2} \\ \frac{2(d\text{-}y)^2}{(d\text{-}c)^2},\ if\ \frac{c+d}{2} \le y < d \\ 0, if\ y \ge d \end{cases} \quad (3)$$

$$y = f^{y}(P - \overline{R}, V) \quad (4)$$

where: $\mu^R(y,c,d)$ – the function of belonging to the linguistic variable "acceptable risk";

y – the impact of the risk on the deviation of the actual target from the planned;

$f^{y}(P+\overline{R},V)$ – a function relates the deviation of the actual target from the projected profit and risk-based sales volume;

c,d – parameters of z-membership function;

P – net profit of an industrial enterprise;

$\overline{R}$ – expected loss from risk;

V – volume of industrial enterprise sales.

As a result of the intersection of fuzzy sets of ”tolerance” and ”acceptable risk,” you can get a fuzzy set that reflects constraints on the goals. For each type of functioning of an industrial enterprise, intersection is carried out. Thus, the goal-setting model under operating conditions and the typical risks for these conditions is:

$$\Omega^O = \Omega^R \cap \Omega^G, \quad (5)$$

$$\mu^O = \min(\mu^R, \mu^G) \quad (6)$$

$$\mu^R = \mu^R(y,c,d) \quad (7)$$

$$\mu^G = \mu^G(x,a,b) \quad (8)$$

where: Ω^O – a fuzzy set that limits the scope of possible goals and risks;

Ω^R – a fuzzy set of ”acceptable risk”;

Ω^G – a fuzzy set of “inadmissible deviation”;

y – the impact of the risk on the deviation of the actual target from the planned ;

x – deviation of the actual target from the planned, where profitability is the target for normal development, profit or sales volume for development conditions, current liquidity for crisis conditions ;

$\mu^G(x,a,b)$ – the function of belonging to a linguistic variable of ”inadmissible deviation”;

$\mu^R(y,c,d)$ - the function of belonging to the linguistic variable of "acceptable risk."

For many risks and goals, the fuzzy sets Ω^G and Ω^R can have several variables that meet different goals and different risks. A graphical representation of the intersection of fuzzy sets with one risk and one goal. The shaded area is the area of feasible solutions in risk management in different operating conditions of an industrial enterprise.

Thus, the goal-setting model under operating conditions and the typical risks for these conditions makes it possible to identify the constraints and management decisions have too high risks or are unacceptable in view of achieving the global goals of an industrial enterprise.

The needs matching model provides a classification of risks according to the resources needed to optimize them and the magnitude of the losses from those risks. The model based on the assumption that any task of industrial enterprise has to perform may have negative implementation scenarios that carry the risk of direct monetary losses or the cost overruns of the various types of resources required to complete the task.

To identify resource constraints, it is suggested that each task of an industrial enterprise be compared with many characteristics that reflect the effect of the tasks, the cost of resources to accomplish the tasks, and the assessment of the associated risks.

As a result, many of the tasks of an industrial enterprise are:

$$Q = \{Q_1, ..., Q_m, ..., Q_M\}, \tag{9}$$

$$Q_m = \left(F_m, S_m, S_m^{\max}, R_m, \overline{R}_m\right), m \in M \tag{10}$$

where: Q – a set of tasks of an industrial enterprise;

$\left(F_m, S_m, S_m^{\max}, R_m, \overline{R}_m\right)$ – characteristics of m-th task of an industrial enterprise;

F_m – the economic effect of the m-th task of an industrial enterprise;

S_m – the amount of expenses that are planned for the m-th task of an industrial enterprise;

$S_m^{\max}$ – the maximum amount of costs that can be spent to fulfill the m-th task of an industrial enterprise;

R_m – the ratio of the consequences of negative and positive scenarios for the task;

$\overline{R}_m$ – mathematical expectation of the consequences of risks for the m-th task of an industrial enterprise;

M – a set of tasks that are planned at an industrial enterprise.

As a result of the analysis of tasks, resources and risks, the whole set of risks can be classified into several groups:

- risks that result in greater losses than the effect of the task;

- risks that are personally critical to resources;
- risks that, together with others, are resource-critical;
- risks for which the loss / benefit ratio is worse than the corresponding effect and cost estimate for an industrial enterprise.

The risks, the losses of which are greater than the effect of the task, are a set of Ψ^1, for which the condition is fulfilled:

$$\begin{gathered} \overline{R}_{m^1} \geq F_{m^1} \\ m^1 \in M^1 \\ M^1 \subset M \end{gathered} \tag{13}$$

Risks that are personally resource-critical have the expectation of a waste of resources, which more than the enterprise has for a single task, are a set of Ψ^2, for which the condition is fulfilled:

$$\begin{gathered} \overline{R}_{m^2} > S_{m^2} \\ m^2 \in M^2 \\ M^2 \subset M \end{gathered} \tag{14}$$

Risks that, along with others, are resource-critical, are a set of Ψ^3, for which the condition is fulfilled:

$$\begin{gathered} \sum_{m^3} \overline{R}_{m^3} > \sum_{m^3} S_{m^3} \\ m^3 \in M^3 \\ M^3 \subset M \end{gathered} \tag{15}$$

The risks to which the loss-benefit ratio is worse than the corresponding impact-cost estimate for an industrial enterprise are a set of Ψ^4, for which the condition is fulfilled:

$$\begin{gathered} R_{m^4} \leq \frac{F_{m^4}}{S_{m^4}} \\ m^4 \in M^4 \\ M^4 \subset M \end{gathered} \tag{16}$$

Thus, the classification of risks according to their relevance to the tasks of the industrial enterprise, the resources required for these tasks, indicators of utility tasks and risks, etc. Each risk can belong to several groups at the same time.

The model of choice of methods of risk management based on the established restrictions on the purposes and classification of risks according to resource needs gives an opportunity to choose one of the possible methods of risk management. Traditionally, the following risk management methods are distinguished (Dorfman, 2012):

- evasion when an enterprise abandons risky projects, counterparties, products, etc.;
- diversification, where an enterprise carries out several activities or releases several products in a bypass that only one or more of them will result in losses and others will compensate for those losses;
- localization when the company creates individual projects or units with a limited budget, which allows to limit the risk to the maximum size and to better control its occurrence;
- compensation when an entity creates reserves (insurance or simply financial reserves) to cover risk losses in the event of adverse events.

The task of risk optimization at an industrial enterprise is to determine which management method is the most appropriate, taking into account the current conditions of operation of the enterprise goals and available resources. For this purpose, optimization is performed by the criterion of maximizing the effect of achieving the goals of an industrial enterprise, while limiting the size of the risks and the types of the risks that the enterprise can handle. Maximizing the effect of achieving the goals is in the context of tasks that decipher the goals of the industrial enterprise. To do this, use the target function:

$$\sum_{m \in M} \left(F_m - \sum_{u=1}^{4} \left(b_{u,m} \cdot L_{u,m} \right) \right) \to \max \qquad (17)$$

where: F_m – the economic effect of the m-th task of an industrial enterprise;

$b_{u,m}$ – a logical variable that takes a value of 0 or 1, depending on whether it is appropriate to use the u-type of risk management for the m-th task;

$L_{u,m}$ – the cost of implementing the u-th type of risk management for the m-th task;

u – the type of risk management index, where 1-evasion, 2-diversification, 3-localization, 4-compensation.

No more than one risk management method may be used for each risk, otherwise the risk could be decomposed into components. Therefore, there is a limitation that only one or no risk management method is used:

$$\sum_{u=1}^{4} b_{u,m} \le 1 \qquad (18)$$

Possible risk management methods are identified for each risk group, which is classified by using a model of matching available resources.

Risks that result in greater losses than the effect of the task cannot be minimized through compensation and localization, so they are subject to the following limitations:

$$b_{3,m} = 0, if\ m \in M^1 \tag{19}$$

$$b_{4,m} = 0, if\ m \in M^1 \tag{20}$$

Risks that are personally critical to resources cannot be minimized by ways other than evasion, so they are subject to the following limitations:

$$b_{1,m} = 1, if\ m \in M^2 \tag{21}$$

Risks that, together with others, are resource-critical, need to be eliminated from the highest risk of the same type of risk:

$$b_{1,m} = 1, if\ \bar{R}_m = max\,(\bar{R}_{m\prime})\ and\, m, m' \in M^3 \tag{22}$$

Risks in which the loss/benefit ratio is worse than the corresponding effect and cost estimate for an industrial enterprise's task are not appropriate to minimize through localization or compensation:

$$b_{3,m} = 0, if\ m \in M^4 \tag{23}$$

In addition to the ratio of risks to specific resource groups, consideration should be given to identifying risks in the area of possible solutions for risk tolerance and non-tolerance for each target. If the risk solution is not in the area of acceptable solutions Ω^O, then it must necessarily use risk management techniques, otherwise the enterprise may take that risk. That is, if the risk solution does not belong to the set Ω^O, an additional limitation is:

$$\sum_{u=1}^{4} b_{u,m} > 0 \tag{24}$$

Thus, the use of the proposed model of selection of risk management methods based on the established limits on the objectives and the classification of risks according to resource requirements allows to select the most favorable risk management program for the industrial enterprise in achieving goals.

The developed set of models for comparing the goals of the enterprise under operation conditions and resources forms the based on scientific and methodological approach to targeted risk, the optimization of an industrial enterprise, through which the enterprise can be adapted to different operating conditions and improve efficiency by minimizing losses from negative events.

4. Results and Discussion

When testing the developed scientific-methodical approach of risk-oriented optimization of industrial enterprise risks at the Kerammash, a selection of the most expedient methods for managing the risks of reducing profitability in the ordinary course of business was made. The main risks for PJSC "Kerammash" are the exceedance of the defect rate, excess of the equipment downtime due to breakdowns, excess of the downtime when changing the production program, decrease of the market volume, decrease of competitive prices for products. Selected, using the developed scientific and methodological approach, targeted risk optimization of industrial enterprise risk management methods are shown in *Table 1*.

Table 1. Selected risk management methods for PJSC "Kerammash"

Risk indicators	The risk management method chosen	Selected events
Exceeding rate of spoiled goods	Avoidance	Improvement of the defect detection system in the initial stages of production to reduce the cost of repairing the defect
Breakdown of equipment downtime due to breakdowns	Avoidance	Optimization of equipment prevention schedule
Exceeding rate of downtime when changing production program	Avoidance	Improvement of the scheduling system to prevent downtime
Decrease in market volume by 10% or more percent	Diversification	Development of production of related products
5% reduction in competitive prices for products	Compensation	Conclusion of long-term contracts with consumers

Source: own research.

Most of these risk management measures do not require additional costs, but only developing the production of related products. At the same time, they can significantly reduce the risk of losses. The estimated results of the implementation of the risk management measures of PJSC "Kerammash" are shown in *Table 2*.

Table 2. Results of implementation of risk management measures of PJSC "Kerammash"

Selected events	Cost of implementation, thousand UAH	Reduction of possible losses, thousand UAH
Improvement of the defect detection system in the initial stages of production to reduce the cost of repairing the defect	0	19
Optimization of equipment prevention schedule	0	28
Improvement of the scheduling system to prevent downtime	0	66
Development of production of related products	283	1688
Conclusion of long-term contracts with consumers	0	32

Source: own research.

The total cost of risk management of PJSC "Kerammash" is UAH 283 thousand and the total saving is UAH 1834 thousand. Thus, the total economic effect equals UAH 1,551 thousand.

5. Conclusions

It is established that the risk management capabilities of an industrial enterprise differ depending on the operation conditions and the goals set. Depending on the objectives set, the targets differ and the risk management system must therefore consider which deviations are acceptable.

An analysis of industrial enterprise risk management approaches has revealed that most researchers have not taken into account the current operating conditions of an industrial enterprise and objectives, which have implications for risk management methods that are available for using when developing risk optimization methods.

It is proposed to carry out the optimization of risks of an industrial enterprise using three models of processing of initial data that provide formalized processing and justification of conclusions about measures for optimization of risks: a model of comparison of the goals of the enterprise with the conditions of operation and typical risks for these conditions; model of matching available resources with needs; a model for choosing risk management methods.

It is substantiated that the task of risk optimization at an industrial enterprise is to determine which management method is most appropriate taking into account the current conditions of operation of the enterprise, goals and available resources. For this purpose, optimization is performed by the criterion of maximizing the effect of achieving the goals of an industrial enterprise, while limiting the size of the risks and the types of risks that the enterprise can handle. Maximizing the effect of achieving the goals is in the context of tasks that decipher the goals of the industrial enterprise.

The complex of models of comparing the goals of the enterprise under the operation conditions and resources has been developed, forms based on a scientific and methodological approach to the purposeful optimization of risks of an industrial enterprise.

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