

# Economic mechanisms for environmental risk management

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**Abstract.** In this paper, to reduce risk of occurrence of an emergency environmental situation, quite a large number of economic mechanisms have been designed that are understood as complexes of interrelated evidence-based policies, procedures, and methodological solutions that provide optimal economic forms of regulation in the field of safety management and risk management at the federal, regional and facility levels.

## 1 Introduction

Growing problem of human safety is one of the technical progress consequences in our modern society. In a broad sense, safety means security of a person, object or environment. Interfering in nature humanity has formed a very complex system that laws of development are not sufficiently studied. The destructive potential of the major technological disasters is now equal to the military and political threats [1-4].

Serious consequences after the major technological accidents and natural disasters of the recent years indicate that the existing safety system requires a radical overhaul. The probability of the occurrence of a natural disaster or technological accident significantly increases with the emergence of megacities, with the growth of economic activity, with the concentration of large industrial facilities, with the increase of complexity of production and technological cycles [5,6].

The aim of safety management is to preserve human life and health, to maintain infrastructure to ensure the required standard of living. Therefore, to implement the safety management it is necessary to ensure the optimal balance between the quality of life and the risk level in the region (the concept of acceptable risk) [7,8].

The implementation of these objectives is achieved by the application of the appropriate economic, legal and organizational measures that are necessary, on the one hand, to solve the issues of maintaining a certain safety level and, on the other, not to block the output of the required amount of goods and services. It should be noted that the acceptable safety level to a large extent depends on the level of society development. And it is this level of development that limits the possibilities of application of economic and organizational mechanisms. Indeed, the effective application of the mechanisms directly depends on the

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price that society is ready to pay for its safety. The higher the price of an emergency risk, the greater the economic effect of the elimination of the possibility of an accident is [9,10].

The presence of such bilateral restrictions makes serious demands on the system of economic mechanisms, understood as a set of interrelated evidence-based policies, procedures and methodological solutions that provide optimal economic forms of regulation in the field of safety management and risk management at the federal, regional and facility levels [11].

It actually requires implementing the optimal strategy of deliberate influence on the social system as a whole and on its individual components [12]. At the same time, science provides us with new knowledge about the nature of risks, suggests us ways and means of the necessary technical and technological development. The role of economics and law is to transfer vital activity to the established by state standards and requirements, methods and forms of management collectively representing the state policy implemented by public authorities for safety regulations [13,14].

## 2 Management model description

Analysis of the experience in the field of development and application of the economic mechanisms for disaster management have shown that there is a sufficient number of economic mechanisms directed onto the risk level reduction of the occurrence of an emergency situation (ES). There is a natural division of all of these mechanisms into homogeneous groups. They are different only in some modifications within each group. Assume that the structure of the economic mechanism system is a two-level one. The upper level is a body of managing safety level – environmental authority, local or central government. In addition, there can be one or several insurance companies at the upper level. Facilities that activity is a potential threat of emergencies are the lower level of the system.

Let's choose the main economic mechanisms for managing safety level.

### *Economic responsibility mechanisms.*

This group of mechanisms includes the system of standards (norms, regulations and quotas), any deviation from them lead to the certain economic sanctions – from penalties to a stop of production or to a ban of the construction, etc. Relevant standards first and foremost relate to the applied production technologies or construction, technical and organizational measures to ensure production safety, limitations on maximum permissible concentration, emissions or dumps. They also include the mechanisms of expertise of projects and enterprises when the safety level assessment (risk level assessment) is conducted by the expert commission and depending on the results estimate the economic responsibility is defined.

### *Risk redistribution mechanisms.*

It's mostly the insurance mechanisms (public insurance, independent insurance and mutual insurance). The main problem in the development of the insurance mechanisms is to determine the insurance premiums.

Mechanisms for generation and usage of budgetary and extra-budgetary funds

Allocation of funds is the weakest link here. The effective mechanisms for the allocation of funds should be based on the integrated assessment of the regional safety level.

### *Incentive mechanisms for the enhanced safety level.*

This includes the concessional tax mechanism and also the mechanism of concessional lending of measures to reduce risk level.

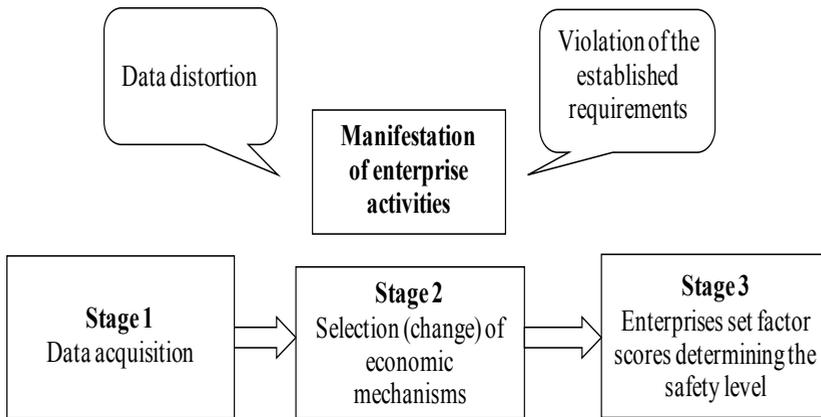
### *Reservation mechanisms in case of emergencies.*

This group includes formation of the reservation mechanisms for labor resources: firefighters, rescuers, etc., material resources: food, raw materials, medical supplies,

transport, etc., capacities for the fast production organization necessary for disaster management or reduction of disaster losses.

Stagnation of economic mechanisms related to an adaptation period determines the importance of a preliminary estimate of their efficiency based on the prediction of the behavior of active system elements under a given set of economic arrangements. The reliability and accuracy of the prediction is largely determined by the accuracy description of the element motivation system. Take the dominant motivation of such economic category as a company's profit after-tax, penalties, pollution charges, emissions, dumps, etc. with the addition of subsidies and other financial resources received from centralized, public and other funds. Let's call it the residual profit and take the pursuit of its maximization as the main goal of a business organization.

Let's consider the operation stages of the safety level management system (Fig.1).



**Fig. 1.** Safety level management system.

#### *Stage 1. Data acquisition.*

At this stage, management body (MB) collects and processes information necessary to determine the parameters of the system of economic mechanisms. This information, primarily, related to the estimate of the regional safety level and the expenditures of economic organizations in reducing their negative impact at this level. It is important to note that the source of such kind of information is a company itself, i.e. a source of potential danger. Due to their own economic interests, the company can distort submitted information that leads to errors in choosing a type and parameters of economic mechanisms.

#### *Stage 2. Selection (change) of economic mechanisms.*

At this stage, there is a change in the system of economic mechanisms that may include both the significant change in the type of the applied mechanisms and the change of the mechanism parameters without its type changing.

#### *Stage 3. Functioning of the region in the system of economic mechanisms.*

Based on its economic interests at the stage of operation, enterprises choose a particular strategy of action. Reasonable choice of the economic mechanisms system leads enterprises to focus at the enhanced level of production security, reducing its harmful impact on the regional safety level and as a result the aim to provide the required regional safety level provided that the high economic efficiency is achieved.

Let's consider a class of costs compensation mechanism.

Costs compensation mechanism for risk level reduction

Let's continue to assume that each enterprise provides the Central body with the information on estimate  $s_i$  of parameter  $r_i$  costs function  $\phi_i(y_i, r_i)$  and thereby estimates  $\tilde{\phi}_i(y_i) = \phi_i(y_i, s_i)$  its costs functions. Based on this information, the Central body solves the problem of total costs minimizing  $\Phi = \sum_{i=1}^n \phi_i(y_i, s_i)$  if  $\sum_{i=1}^n y_i \geq Y$ .

As a target enterprise function let's take the difference between the received and spent financial resources  $f_i(y_i, s_i, r_i) = \phi_i(y_i, s_i) - \phi_i(y_i, r_i)$ .

Conduct a study of the compensation mechanism for costs functions as  $\phi_i = r_i \phi \left( \frac{y_i}{r_i} \right)$

and the hypothesis of weak influence. Given that in the optimal solution

$$y_i = \frac{s_i}{S} Y, \quad i = \overline{1, n},$$

where

$$S = \sum_{i=1}^n s_i,$$

we obtain optimal conditions

$$\phi \left( \frac{Y}{S} \right) = \frac{Y}{S} \phi' \left( \frac{s_i}{r_i} \times \frac{Y}{S} \right)$$

or

$$\frac{s_i}{r_i} \times \frac{Y}{S} = \xi \left[ \frac{S}{Y} \phi \left( \frac{Y}{S} \right) \right], \quad i = \overline{1, n},$$

and obtain

$$s_i = r_i \frac{S}{Y} \xi \left[ \frac{S}{Y} \phi \left( \frac{Y}{S} \right) \right], \quad i = \overline{1, n}.$$

Summing the result for all enterprises we have

$$S \phi \left( \frac{Y}{S} \right) = Y \phi' \left( \frac{Y}{\sum_{i=1}^n r_i} \right). \quad (1)$$

The left part of this equality is equal to the amount of funds paid to the enterprises in case of the compensation mechanism and the right part, it is easy to see, is equal to the amount of funds paid to the enterprises in case of the incentive mechanism. Thus, we get the following output: The costs compensation mechanism is the equivalent to the incentive

mechanism in the sense that in both cases the Central body shall pay to enterprises the same amount of funds.

From (1) we obtain

$$s_i = r_i \frac{S}{\sum_{i=1}^n r_i}, \quad i = \overline{1, n}.$$

Example. Let  $\varphi = z^\alpha$ . In this case, equation (1) takes the form of

$$S \left( \frac{Y}{S} \right)^\alpha = \alpha Y \left( \frac{Y}{\sum_{i=1}^n r_i} \right)^{\alpha-1},$$

solving it with the respect to  $S$ , we get

$$S = \left( \frac{1}{\alpha} \right)^{\frac{1}{\alpha-1}} \sum_{i=1}^n r_i = K(\alpha) \sum_{i=1}^n r_i.$$

Note that  $\lim_{\alpha \rightarrow 0} K(\alpha) = \frac{1}{e}$ ,  $\lim_{\alpha \rightarrow \infty} K(\alpha) = 1$ .

Concessional tax mechanism

Target enterprise function is equal to

$$f_i(y_i) = (1 - \mu_i)[P_{0i} - \phi_i(y_i, r_i)],$$

where  $\mu_i$  is a tax rate on profit and  $P_{0i}$  is an enterprise profit excluding costs to increase the safety level. Enterprise will try to maximize this function.

Mechanism 1. Let for all enterprises in the region the Central body establishes a single regulatory safety level  $q$  reaching or exceeding which the enterprise receives a tax benefit  $\mu_i = \mu_0 - \beta_i$ ,  $i = \overline{1, n}$ , different for each enterprise, i.e.

$$\begin{cases} \mu_i = \mu_0, & \text{if } y_i < q \\ \mu_i = \mu_0 - \beta_i, & \text{if } y_i > q \end{cases}$$

The enterprise will invest to improve safety level and use the provided tax benefit if the profit will be greater than in case of its absence and invest to maintain the minimum safety level

$$(1 - \mu_0 + \beta_i)[P_{0i} - \phi_i(q, s_i)] \geq (1 - \mu_0)[P_{0i} - \phi_i(y_{i_{\min}}, s_i)]. \quad (2)$$

Assume that the company has the option not to allocate funds to maintain the minimum safety level, then  $\phi_i(y_{i_{\min}}, s_i) = 0$ .

From (2) we obtain

$$(1 - \mu_0 + \beta_i)[P_{0i} - \phi_i(q, s_i)] = (1 - \mu_0)P_{0i}, \quad (3)$$

where we get tax benefits  $\beta_i$  for each enterprise

$$\begin{aligned} \beta_i P_{0i} - (1 - \mu_0 + \beta_i)\phi_i(q, s_i) &= 0; \\ (1 - \mu_0)\phi_i(q, s_i) &= \beta_i [P_{0i} - \phi_i(q, s_i)]; \\ \beta_i &= \frac{(1 - \mu_0)\phi_i(q, s_i)}{P_{0i} - \phi_i(q, s_i)}. \end{aligned} \quad (4)$$

Received tax benefits  $\beta_i$  will encourage each enterprise to increase its safety level to level  $q$ . Then the regional safety level will be  $Y = nq$ .

Therefore, from the planned regional safety level  $Y$  the Central body gets value  $q$  and then solves problem (4) to find each enterprise tax benefit which should lead to the planned regional safety level.

Mechanism 2. Its difference from Mechanism 1 is that the Central body for all enterprises in the region sets a single tax benefit  $\beta$ , but various normative safety levels  $q_i$  required to obtain this benefit

$$\begin{cases} \mu_i = \mu_0, & \text{if } y_i < q_i \\ \mu_i = \mu_0 - \beta, & \text{if } y_i > q_i \end{cases}$$

Let's also assume that enterprise may not allocate funds to maintain the minimum safety level, then follow equality (3) from Mechanism 1

$$(1 - \mu_0 + \beta)[P_{0i} - \phi_i(q, s_i)] = (1 - \mu_0)P_{0i},$$

where regulatory safety levels  $q_i$  for each enterprise are

$$\begin{aligned} \beta P_{0i} - \beta \phi_i(q_i, s_i) &= (1 - \mu_0)\phi_i(q_i, s_i); \\ (1 - \mu_0 + \beta)\phi_i(q_i, s_i) &= \beta P_{0i}; \\ \phi_i(q_i, s_i) &= \frac{\beta P_{0i}}{1 - \mu_0 + \beta}; \\ q_i &= \xi_i \left( s_i, \frac{\beta P_{0i}}{1 - \mu_0 + \beta} \right). \end{aligned} \quad (5)$$

Received tax benefit  $\beta$  will encourage each enterprise to increase its safety level to level  $q_i$ . Then the regional safety level will be

$$Y = \sum_{i=1}^n q_i = \sum_{i=1}^n \xi_i \left( s_i, \frac{\beta P_{0i}}{1 - \mu_0 + \beta} \right).$$

Therefore, from the planned regional safety level  $Y$  the Central body gets value  $\beta$  and then solves problem (5) to find each enterprise tax benefit which should lead to the planned regional safety level.

Let's compare the efficiency of Mechanism 1 and the efficiency of linear incentive mechanism:

$$\phi_i(q_i, s_i) = \frac{q_i^2}{2s_i};$$

$$S_{M_1} = \sum_{i=1}^n \beta_i [P_{0i} - \phi_i(q_i, s_i)] = \sum_{i=1}^n (1 - \mu_0) \phi_i(q_i, s_i) = \sum_{i=1}^n (1 - \mu_0) \frac{Y^2}{2n^2 s_i} = (1 - \mu_0) \frac{Y^2}{2n^2} \sum_{i=1}^n \frac{1}{s_i}$$

$$S_{LIM} = \sum_{i=1}^n \lambda y_i = \sum_{i=1}^n \frac{Y}{\sum_{i=1}^n s_i} y_i = \frac{Y}{\sum_{i=1}^n s_i} \sum_{i=1}^n y_i = \frac{Y^2}{\sum_{i=1}^n s_i}.$$

Mechanism 1 requires less financial resources if  $S_{M_1} > S_{LIM}$ :

$$(1 - \mu_0) \frac{Y^2}{2n^2} \sum_{i=1}^n \frac{1}{s_i} > \frac{Y^2}{\sum_{i=1}^n s_i};$$

$$\frac{(1 - \mu_0)}{2n^2} \sum_{i=1}^n \frac{1}{s_i} > \frac{1}{\sum_{i=1}^n s_i}.$$

### 3 Conclusion

Achievement of the safety objectives involves considerable financial expenditures, and, in the context of the limited resources, it is possible only through the evidence-based development and implementation of the complex interrelated legal, economic and political measures.

The transition from the concept of "absolute" safety to the concept of "acceptable" risk determines the appearance of a fundamentally new approach to the society development management consisting in the fact that satisfaction of material and spiritual needs of population should be carried out with the respect to a mandatory requirement on safety of the person and his/her environment.

In this paper, we've tried to define some ways to create a system for safety management and risk management at the federal, regional and facility levels with the description of its basic mechanisms.

The theory of economic mechanisms for safety management, allowing evaluating and regulating programs to reduce risk in complex technical systems and in the regions, creating a reliable system of economic mechanisms for the implementation of these programs, has been developed.

The paper shows the management model and emphasizes the major economic mechanisms for managing safety level.

## References

1. A. Abbasi, N. Kapucu, *Computational and Mathematical Organization Theory* **22**, 47–70 (2016)
2. P. Chitakornkijasil, *International Journal of Organizational Innovation* **3(2)**, 309–337 (2010)
3. Y-S. Chen, Y-H. Lin, Y-L. Hsu, Y-L. Lu, *Int. Journal of Organizational Innovation* **8(3)**, 326–35 (2016)
4. A. Faas, R. Barrios, *Human Organization* **74(4)**, 287– 295 (2015)
5. C. Huggel, D. Stone, H. Eicken, G. Hansen, *Climatic Change* **133**, 453–467 (2015)
6. N. Kapucu, M-E. Augustin, V. Garayev, *Public Administration Review* **69(2)**, 297–313 (2016)
7. A. Henderson, E. Charbonneau, *Public Affairs Quarterly* **40(3)**, 559–588 (2016)
8. J. Rocha, PhD Thesis (Florida International University, 2011)
9. J. Loebbaka, PhD Thesis (Alliant International University, 2008)
10. S. Prabhakar, A. Srinivasan, R. Shaw, *Mitigation and Adaptation Strategies for Global Change* **14**, 7–33 (2009)
11. N. Nirupama, D. Etkin, *Disaster Prevention and Management* **21(5)**, 599–607 (2012)
12. S. Ray, *The Journal Contemporary Management Research* **2(2)**, 1–17 (2008)
13. S. Somers, J. Svava, *Public Administration Review* **69(2)**, 181–193 (2009)
14. J-J. Wang, *Disaster Prevention and Management* **21(1)**, 110–123 (2012)