# Optimal control in the problems of calculating the benefit/cost ratio in emergency response

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**A B S T R A C T**

*The optimal control problem in determining the benefit/cost ratio in emergency response is considered. A methodology is developed to assess the effectiveness of the development and use of an automated emergency management system.*

## 1. Introduction

It is virtually impossible to completely eliminate the risk of emergency situations. Therefore, the problem of reducing losses and costs in the context of possible and real emergencies consists in ensuring constant monitoring of all sources of increased risk, in the operational forecasting of the processes of manifestation of damaging effects and in a proactive response to danger by means of adequate counter-measures. This problem is directly related to improving the management of regional protection (RP) in emergencies, which is understood as an organized set of measures taken to prevent, localize and eliminate the consequences of emergencies. At the modern stage, a qualitative improvement in the management of organizational and technological processes is provided based on the integrated use of computer technology, automation and communication, as well as methods of mathematical modeling and optimization. With regard to emergencies, automatic monitoring and remote communication means provide timely identification and notification of the danger of manifestations of damaging effects, collection and transmission of data on the current situation, and receiving of orders for the implementation of necessary measures. Computer simulation methods make it possible to predict in advance the probable consequences of emergencies and to develop adequate RP decisions, to teach and train a wide range of people on rational actions in extreme conditions. Using these methods and tools, qualitatively new information management technologies are implemented in emergency situations, whose principal advantage is the integrated handling of heterogeneous, geographically distributed, multiconnected and dynamic factors of impact and protection. Automated information technologies can significantly increase the efficiency and validity

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of RP decisions, which opens up real opportunities for a proactive response to the danger of manifestation of damaging effects, in contrast to the traditional response to the consequences of their manifestations.

In this paper, we consider the optimal control problem in determining the benefit/cost ratio in emergency response, as well as a methodology for assessing the effectiveness of the development and use of an automated control system (ACS) in emergency situations, which is determined by the ratio between the costs associated with its development and the effect of its use.

The analysis of the benefit/cost ratio is carried out when modeling the environmental and economic situation in the region. The mathematical model of the region is given in [1, pp. 49-51; 2, p. 82-85, 142-144; 3, pp. 95-96]. We introduce the following functions: 1) "costs" caused by the migration of technological pollution beyond the borders of the region, determined by the presence of unrelated pollution within the region and the increased disease risk among the liquidators and victims of technological accidents:

$$L = l_z Z + l_1 I_Z + l_Q Q_Z,$$

where $Z$ is free pollution; $I_2$ is the flow of pollution to the outside; $Q_Z$ is the function that determines the level of disease risk in personnel engaged in the elimination of the consequences of a technological disaster; $l_Z, l_Z, l_Q$ are normalizing coefficients;

2) "benefit"

$$P = L - L_{opt} + V^+(1 - U_M - U_Z - U_V - U_T - U_Q - U_C),$$

where $L$ is the costs determined in the course of solving the dynamic modeling problem; $L_{opt}$ is the costs resulting from the solution of the optimal control problem; $V^+(1 - U_M - U_Z - U_V - U_T - U_Q - U_C)$ is the unused funds.

Suppose the given system of ordinary differential equations

$$\frac{dy_i(t)}{dt} = f_i(t, y_1, y_2, ..., y_N), \; i = 1....N.$$

The classical formula for the fourth-order Runge-Kutta method has the form

$$k_1 = hf(x_n, y_n),$$

$$k_2 = hf\left(x_n + \frac{h}{2}, y_n + \frac{k_1}{2})\right),$$

$$k_3 = hf\left(x_n + \frac{h}{2}, y_n + \frac{k_2}{2}\right),$$

$$k_4 = hf\left(x_n + \frac{h}{2}, y_n + k_3\right),$$

$$y_{n+1} = y_n + \frac{k_1}{6} + \frac{k_2}{3} + \frac{k_3}{3} + \frac{k_4}{6} + O(h^5),$$

where $h$ is the step-size of the method.

The optimal control problem was modified in order to find the optimal control, at which the benefit/cost ratio, which can be aimed at the following combination of sub-goals, reaches its maximum:

– minimizing the pollution level;
– minimizing the flow of pollution from the region;
– maximizing the assets;
– minimizing the losses;
– maximizing benefits;

– maximizing the function that defines the "quality of life".

The function $Q$ that determines the quality of life of personnel involved in the elimination of the consequences of a technological disaster was modified to take into account the following factors: levels of personnel safety; levels of social security; levels of conditions and remuneration.

Thus, the function $Q$ takes this form [4, p. 76-78]:

$$Q = Q_Z\left(\frac{Z_0}{Z}\right)Q_M\left(\frac{U_0}{U_Q}\right)Q_W\left(\frac{U_0}{U_W}\right)Q_S\left(\frac{U_0}{U_S}\right)Q_C\left(\frac{U_0}{U_C}\right),$$

where $Q_Z\left(\frac{Z_0}{Z}\right)$ is the tabular function that determines the level of disease risk in personnel involved in the elimination of the effects of a technological disaster; $Q_M\left(\frac{U_0}{U_Q}\right)$ is the reduction of the disease risk with an increase in the share of funds $U_Q$; $Q_W\left(\frac{U_0}{U_W}\right)$ is an increase in the level of labor safety with an increase in the share of funds $U_W$; $Q_S\left(\frac{U_0}{U_S}\right)$ is an increase in the level of social security of labor with an increase in the share of funds $U_S$; $Q_P\left(\frac{U_0}{U_P}\right)$ is an increase in the level of conditions and personnel remuneration with an increase in the share of funds $U_P$.

The following shares of funds are used as control actions, aimed at: restoration of resources $(U_R)$; elimination of pollution $(U_Z)$; reproduction of key assets $(U_V)$; preventing migration of pollution outside the borders of the region $(U_T)$; reduction of the disease risk of among liquidators and victims of technological accidents $(U_Q)$; development of the technology for the manufacture of useful products, technology for the disposal of waste and purification from pollution $(U_C)$; increasing the level of labor safety of personnel $(U_W)$; increasing social security $(U_S)$; raising the level of conditions and wages $(U_P)$.

With this in mind, the “benefit” function takes on this form:

$$P = L - L_{opt} + V^+(1 - U_M - U_Z - U_V - U_T - U_Q - U_C - U_W - U_S - U_P),$$

where $L$ is the costs determined in the course of solving the dynamic modeling problem; $L_{opt}$ is the is the costs resulting from the solution of the optimal control problem; $V^+(1 - U_M - U_Z - U_V - U_T - U_Q - U_C - U_W - U_S - U_P)$ is the unused funds.

It is easy to prove the following statements for a system of ordinary differential equations that describe a mathematical model.

***Assertion 1***. The given system of differential equations has a solution.

***Assertion 2***. The solution of the system of differential equations is not negative in the domain of existence of the solution and is bounded from above.

***Assertion 3***. The solution of the system continuously depends on the parameters in the right-hand side of the equations and on the initial values.

In the numerical solution of the system of ordinary differential equations, the fourth-order Runge-Kutta method was used. The key principles of this method are given further.

## 2. Problem statement

Let us give a mathematical formulation of the optimal control problem for a model designed for studying the environmental and economic situation in a region that has suffered as a result of a technological disaster.

Suppose the given system of differential equations, which describes the mathematical model of the region, is presented in the form:

$$\frac{d\vec{X}}{dt} = \vec{F}(\vec{X},\vec{U},t), \; t \in [t_0, t_k], \tag{1}$$

$$\vec{X}(t_0) = \vec{X}_0 \tag{2}$$

where $\vec{X}$ is the vector of variables of an $N$-dimensional model, $\vec{X}_0$ is the vector of the initial values of the variables at the initial instant $t_0$; $\vec{U} = \vec{U}(t)$ is the vector of control actions on the $M$-dimensional system; where $U_R$ is the part of the funds aimed at restoring resources; $U_Z$ is the part of the funds aimed at binding pollution; $U_V$ is the part of the funds for the reproduction of key assets; $U_T$ is the part of the funds to prevent the migration of pollution beyond the borders of the region; $U_Q$ is the part of the funds allocated to reduce the disease risk in liquidators and victims of technological accident; $U_C$ is the part of the funds allocated for the development of the technology for manufacturing useful products, technology for waste disposal and purification from pollution; $U_W$ is the part of the funds allocated to increase the level of personnel safety; $U_S$ is the part of the funds allocated to increase the level of social security of personnel; $U_P$ is the part of the funds allocated to increase the level of conditions and personnel remuneration; $t_k$ is the final value of the simulation interval. The right-hand side $\vec{F}(\vec{X},\vec{U},t)$ of system (1) is a continuous function of the argument X, the control vector U, and time t.

Each of the control actions is represented by a third degree polynomial:

$$U_i(t) = a_{i1} + a_{i2}\tau + a_{i3}(\tau - 1)\tau + a_{i4}(1-\tau)^2\tau, \text{ где } \tau = \frac{t - t_0}{t_k - t_0}$$

Thus, in the general case, it is necessary to find 4M coefficients of polynomials for which a functional of the following form is minimized:

$$q = \sum_{i=1}^{6} \beta_i F_i$$

where $\beta_i$ is weighting factors; $F_1 = \gamma_1 \int_{t_0}^{t_k} Z(t)dt + \gamma_2 \, Z(t_k)/Z(t_0)$ is the accounting for the level of pollution; $F_2 = \gamma_3 \int_{t_0}^{t_k} I_z(t)dt + \gamma_4 \, I_Z(t_k)/I_z(t_0)$ is the accounting for the level of the pollution flow; $F_3 = \dfrac{\gamma_5}{\int_{t_0}^{t_k} V_1(t)dt}$ is the accounting for the level of assets; $F_4 = \gamma_6 \int_{t_0}^{t_k} L(t)dt + \gamma_\tau \, L(t_k)/L(t_0)$ is the accounting for the losses; $F_5 = \dfrac{\gamma_8}{\gamma_9 \int_{t_o}^{t_k} P(t)dt + \gamma_{10} \, P(t_k)/P(t_0)}$ is the accounting for the benefit;

$F_6 = \dfrac{\gamma_{11}}{\gamma_{12}\int_{t_0}^{t_k} Q(t)dt + \gamma_{13} \, Q(t_k) / Q(t_0)}$ is the accounting for the level determining the "quality of life";

where $\gamma_j, j = \overline{1,13}$ is the normalizing factors; $Z$ is pollution; $I_Z$ is the flow of pollution from the region; $V_i$ is the money equivalent of funds in the region; $L$ is the money equivalent of the losses caused by technological pollution; $P$ is the money equivalent of the benefit resulting from the actions aimed at reducing the level of pollution; $Q$ is the integral index determining the "quality of life" - the risk of disease occurrence among liquidators and victims.

It should be noted that this optimal control problem, depending on the choice of control objectives, belongs to the class of minimax problems.

Suppose the goal of optimal control is to reduce the pollution level $Z$ and improve quality of life $Q$.

The permissible range of variation of the parameters of the model $\vec{X}(t) \in X$ and constraints on control actions $\vec{U} \in U$ is given, where $\vec{U} = (U_1,...,U_M)$. The value $\vec{X}_0 = \vec{X}(t_0)$ at the instant of time $t_0$ is given. It is necessary to find the value of the coefficients of polynomials $\alpha^*_{1i}, \alpha^*_{2i}, \alpha^*_{3i}, \alpha^*_{4i} (i = \overrightarrow{1,......,M})$ under which the following conditions are satisfied.

$$\gamma_1 \int_{t_0}^{t_k} Z(t, \vec{U}^*)dt + \gamma_2 \, Z(t_k, \vec{U}^*) / Z(t_0) = \min \gamma_1 \int_{t_0}^{t_k} Z(t, \vec{U})dt + \gamma_2 \, Z(t_k, \vec{U}) / Z(t_0),$$

$$\vec{X}(t) \in X,$$

$$\vec{U} \in U$$

$$\gamma_{12} Q(t, \vec{U}^*)dt + \gamma_{13} \, Q(t_k, \vec{U}^*) / Q(t_0) = \max \gamma_{12} \int_{t_0}^{t_k} Q(t, \vec{U})dt + \gamma_{13} \, Q(t_k, \vec{U}) / Q(t_0),$$

$$\vec{X}(t) \in X,$$

$$\vec{U} \in U$$

Then the problem comes down to finding the minimum of the functional:

$$q = \beta_1 \left( \gamma_1 \int_{t_0}^{t_k} Z(t)dt + \lambda_2 \, Z(t_k) / Z(t_0) \right) + \beta_6 \left( \frac{\gamma_{11}}{\gamma_{12} \int_{t_0}^{t_k} Q(t)dt + \gamma_{13} \, Q(t_k) / Q(t_0)} \right),$$

namely, to determining of the coefficients of the polynomials $\alpha^*_{1i}, \alpha^*_{2i}, \alpha^*_{3i}, \alpha^*_{4i} (i = \overrightarrow{1,......,M})$, at which the following holds true:

$$\beta_1\left(\gamma_1\int_{t_0}^{t_k} Z\left(t,\vec{U}^*\right)dt+\gamma_2 \frac{Z(t_k,\vec{U}^*)}{Z(t_0)}\right)+\beta_6\left(\frac{\gamma_{11}}{\gamma_{12}\int_{t_0}^{t_k} Q(t,\vec{U}^*)dt+\gamma_{13}\frac{Q(t_k,\vec{U}^*)}{Q(t_0)}}\right)=$$

$$=\min\ \beta_1\left(\gamma_1\int_{t_0}^{t_k} Z(t,\vec{U})dt+\gamma_2 \frac{Z(t_k,\vec{U})}{Z(t_0)}\right)+\beta_6\left(\frac{\gamma_{11}}{\gamma_{12}\int_{t_0}^{t^k} Q(t,\vec{U})dt+\gamma_{13}\frac{Q(t_k,\vec{U})}{Q(t_o)}}\right).$$

$$\vec{X}(t)\in X,$$
$$\vec{U}\in U$$

## 3. Methods of solution

The numerical method for solving the optimal control problem was modified by the random search method – the statistical gradient method. The algorithm of the random search method is as follows:

1) suppose $\vec{A}_0$, the initial vector, $q_0 = q(\vec{A}_0)$);

2) initialize $K$ vectors with random values $\vec{A}^i = \vec{A}_0 + \vec{R}^i$, $R_i = h_i(2r-1)$, where $r$ is a random variable uniformly distributed over the segment $[0,1]$, $i = 1,....,K$;

3) calculate the vector $\vec{q} = q(\vec{A}_1),....,\mathrm{q}(\vec{\mathrm{A}}_{\mathrm{N}})$;

4) suppose $q_{\min} = \min(q_i),;\quad i = 1,....,K$

5) when $q_0 \succ q_{\min}$, where $q_{\min} = q(\vec{A}_i)$, then $\vec{A}_0 = \vec{A}_i, q_0 = q_{\min}$ and proceed to Step 1, otherwise to Step 2.

To prevent the looping of the method, a constraint was introduced on the quantity of calculation of the objective function, and when the threshold is exceeded, the count is stopped.

A numerical estimate of the integral values of the model parameters for the simulation interval $[t_0, t_k]$ was carried out by the trapezoid method

$$\int_{t_1}^{t_2} f(t)dt = h\left(\frac{f_1}{2}+\frac{f_2}{2}\right)+O(h^3 f).$$

The calculation of the integral over the simulation interval comes down to finding the sum

$$\int_{t_{10}}^{t_k} f(t)dt = h\sum_{i=1}^{N}\left(\frac{f_{i-1}}{2}+\frac{f_i}{2}\right),$$

where $f_{i-1} = f(t_{i-1}),\ f_i = f(t_i), t_i = t_{i-1}+h.$

A numerical experiment determined the magnitude of the benefits and costs for fixed values of the control actions and for their dynamics found as a result of solving the optimal control problem, whose goal was to maximize the benefit/cost ratio and maximize the quality of life.

The problem solving was carried out with the following values of the input parameters:

– the level of funds $V_1$ is 700 million c.u., $V_1 \in \left[2*10^8,\ 9*10^8\right]$;

– the level of radioactive pollution $Z$ (unrelated) is 1000 million relative units (mln. r.u.), $Z \in [3*10^8, 2*10^9]$ (mln. r.u. corresponds to the total level of pollution);

– the resources $M$ is 10 000 mln. r.u., $M \in [0.5*10^{10}, 5*10^{10}]$;

– the flow of funds $V^+$ – 850 mln. c.u., $V^+ \in [2*10^8, 1.2*10^9]$;

– the period of decomposition of a unit of radioactive pollution $T_Z$ is assumed equal to 30 years, $T_Z \in [10, 60]$; cost of cleaning a pollution unit $C_Z = 10$, $C_Z \in [1, 25]$;

– the cost of preventing the migration of pollution units outside the zone $C_T = 2$, $C_T \in [1,6]$;

– costs per unit of pollution $l_Z = 1$, $l_Z \in [0.5, 2.5]$; costs per unit of pollution flow $l_I = 1.2$, $l_I \in [0.5, 2.5]$.

The model parameters were determined on the basis of analysis of real data as a result of solving identification problems [1, p. 52-53; 2, p. 214-221, 457-463]. Moreover, at this interval, we have an increase in the level of pollution, which is associated with a decrease in the part of the funds spent on eliminating the consequences of a technological disaster and an increase in the part of the funds spent on reducing the risk of diseases among the liquidators of the consequences of a technological disaster.

The effectiveness of the development and use of ACS in emergency situations is determined by the ratio between the costs associated with its development and the effect of its use.

The effect of the use of ACS should be manifested, first of all, in reducing regional losses $\Delta X$ in emergency situations by increasing the efficiency and soundness of decisions. Among the costs associated with the development of ACS, explicit and implicit costs are distinguished. The former represent the cost of resources $Z$ for the development and operation of the system. The latter are defined as lost profits $P$ due to underinvestment of resources $Z$ in the development of the production sphere.

Suppose that the above indicators can be reduced to some general measurement (e.g. in monetary terms). Then, the necessary condition for the effectiveness of ACS is the fulfillment of the ratio $Z < \Delta X > P$, and to assess the effectiveness $Э$ of the system, we can use the expression

$$Э = \frac{\Delta X - P}{Z}$$

The evaluation of the indicator $P$ is the subject of independent economic research. The quantity $\Delta X$ is directly dependent on the efficiency and soundness of decisions. The latter is determined by the structure and patterns of functioning of the ACS. The main constraints on an increase in the efficiency and soundness of decisions are the allowable costs $Z$ for the development and operation of the system.

The costs $Z$ are direct and indirect. The direct ones include the costs of resources $Z_P$ and time $Z_B$ for the development of the system, as well as the costs $Z_Э$ of its operation.

$Z_P$ include the cost of system design $Z_{P1}$, acquisition and installation of technical equipment $Z_{P2}$ uploading and updating the database $Z_{P3}$, development and debugging of software $Z_{P4}$. These costs are estimated as follows:

$$Z_{P1} = Z_1 \cdot N_1 \cdot \tau_1,$$

where $Z_1$ – average costs for a system designer (salary, cost of energy and materials consumed, overhead and other deductions); $N_1$ – number of system designers; $\tau_1$ – system design duration.

$$Z_{P2} = C_Ц + C_П + C_T + C_B ,$$

where $C_Ц$, $C_П$, $C_T$ – the cost of central, peripheral and telecommunication equipment, respectively; $C_B$ – the cost of installing and putting equipment into operation.

$$Z_{P3} = Z_3 \cdot \left( \frac{D}{d_3} + \frac{D}{d_3'} \right),$$

where $Z_3 -$ average database developer costs; $D-$ database size; $d_3,\ d_3'$ $-$ developer productivity in uploading and updating the database, respectively.

$$Z_{P4} = Z_4 \cdot \left( \frac{K}{k_4} + \frac{K}{k_4'} \right),$$

where $Z_4 -$ average cost per programmer; $K-$ number of teams in programs; $k_4,\ k_4'$ $-$ programmer's productivity in developing and debugging programs, respectively.

In determining $Z_B$, the following assumptions are used. The technical complex is formed from commercially available equipment, the installation and putting into operation of which does not exceed the duration of the system design and can proceed in parallel. Uploading and updating the database is usually a longer process than developing software tools. Therefore, programming time can be spent in parallel with creating a database. These assumptions and the introduced notation allow us to use the following expression in determining $Z_B$:

$$Z_B = \tau_1 + \frac{1}{N_3} \cdot \left( \frac{D}{d_3} + \frac{D}{d_3^{'}} \right) + \frac{K}{N_4 \cdot k_4'} + S \cdot \tau_2 \ ,$$

where $N_3 -$ number of database developers; $N_4 -$ number of programmers; $S-$ average number of failures in the development process; $\tau_2 -$ average recovery time in a failure situation.

The costs of operating $Z_{\text{Э}}$ include the salary of personnel $Z_{\text{Э1}}$, the cost of consumed energy and materials $Z_{\text{Э2}}$, depreciation and other deductions $Z_{\text{Э3}}$. The indicated costs substantially depend on the quantitative and qualitative composition of the instrumental part of the system. In the first approximation, they can be estimated through the cost of technical equipment $Z_{P2}$:

$$Z_{\text{Э1}} = F_1 \cdot Z_{P2} \cdot \tau_3 \ , \qquad Z_{\text{Э2}} = F_2 \cdot Z_{P2} \cdot \tau_3 \ , \qquad Z_{\text{Э1}} = F_3 \cdot Z_{P2} \cdot \tau_3 \ ,$$

where $F_1,\ F_2,\ F_3 -$ coefficients determining the dependencies of $Z_{\text{Э1}}$, $Z_{\text{Э2}}$ and $Z_{\text{Э3}}$, respectively, on $Z_{P2}$; $\tau_3 -$ duration of operation. This determines the total operating costs:

$$Z_{\text{Э}} = (F_1 + F_2 + F_3) \cdot Z_{P2} \cdot \tau_3$$

Indirect costs are associated with the training of service personnel $Z_{\text{П}}$, elimination of the consequences of false positives $Z_{\text{Л}}$, protection against misuse of information $Z_{\text{И}}$.

The effect of automation of control processes is determined in relation to traditional (non-automated) control technology under the conditions of the same targets and resource limitations. There are quantitative and qualitative indicators among the indicators $Q$ characterizing the indicated effect. The former include: increasing the efficiency of decision-making $Q_O$; a decrease in the duration of the management cycle $Q_{\text{Ц}}$; increasing the productivity of the governing body $Q_{\text{У}}$.

$Q_O$ is determined from the relation

$$Q_O = T_{OH} - T_{\text{OA}},$$

where $T_{OH}$ $-$ the time required to develop a solution with non-automated technology; $T_{\text{OA}}$ $-$ the same with automated technology. $T_{OH}$ is:

$$T_{OH} = \sum_{i=1}^{5} T_i \ ,$$

where $T_1 -$ time for familiarization with the received information; $T_2 -$ time for searching and using the necessary data for the preparation of solution options; $T_3 -$ time for preparing solution options;

$T_4-$ time for making a rational decision; $T_5-$ time for executing the order to implement the decision.

With automated technology, time is spent mainly on the familiarization with the received information ($T_1$) and making a rational decision ($T_4$), since the rest of the operations are performed in a negligible time. Thus,

$$T_{OA}=T_1+T_4\,.$$

Similarly, the reduction in the duration of the management cycle is determined:

$$Q_{Ц}=T_{ЦН}+T_{ЦА},$$

where $T_{ЦН}$ – cycle time with non-automated technology; $T_{ЦА}$ – the same with automated technology.

$$T_{ЦН}=\sum_{j=1}^{5}T_j$$

where $T_1-$ time of registration and collection of primary data; $T_2-$ time of data transmission and reception; $T_3-$ pre-processing and data accumulation time; $T_4-$ decision making time; $T_5-$ time for issuing the relevant order.

With the automation of these processes, time is reduced, mainly due to increased efficiency in developing solutions. Hence:

$$T_{ЦА}=T_{ЦН}-Q_O$$

Due to the rapidly and significantly changing situation in emergency situations, it is necessary to regularly monitor and adjust the progress of the implementation of previously made decisions. For this, cycles of calculations are periodically carried out in the operational control loops. The number of calculation cycles that the governing body can perform in a limited time interval $T$ characterizes its performance. The increase in this productivity when replacing a non-automated technology with an automated one is determined from the relation:

$$Q_{У}=\frac{T}{T_{цА}}-\frac{T}{T_{цН}}$$

## 5. Conclusion

Some optimal control problems related to the minimax class have been solved — minimization of the level of pollution and the pollution flow from the region leads to a decrease in the pollution flow from the region to the outside resulting in its accumulation inside, maximization of the level of production and quality of life leads to a competition between these two goals for the amount of available resources – an increase in the level of production leads to an increase in the level of pollution and the risk of diseases, which reduce the quality of life. The redistribution of funds allows improving the quality of life and the benefit/cost ratio in the interval from 2020 to 2030. At the same interval, we have an increase in the level of pollution, which is associated with a decrease in the part of funds that are used to eliminate the consequences of a technological disaster and an increase in the part of funds that are used to reduce the disease risk among liquidators of the consequences of a technological disaster.

Qualitative indicators of the effect of developing and using ACS in emergency situations are manifested in streamlining and reducing managerial document workflow $Q_Д$, improving the organizational and technological process of interaction in the general hierarchical structure of management $Q_C$, increasing the validity of the decision on the use of labor, material and financial resources for protective measures $Q_K$. The variability of user requests requires an assessment of the considered indicators at each stage of the life cycle of the system.

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