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ОЦЕНКА И РЕГУЛИРОВАНИЕ ЭКОЛОГИЧЕСКОГО РИСКА ПРИ ПРОЕКТИРОВАНИИ МОРСКИХ ПОРТОВ

DESIGNING OF MARITIME PORTS: ENVIRONMENTAL RISK ASSESSMENT AND CONTROL

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Abstract. The possibilities of use of the risk-analysis while estimating, forecasting and choosing the environmental hazard control activities of port construction are studied herein. It is shown that it is more reasonable to estimate the environmental risk in probabilistic and cost terms: the sum of expectation values of the damage from implementation of alternative scenarios of ecologically harmful developments. The proposed method application is demonstrated on the example of preliminary assessment of the environmental impact of Avantports of the Big Port of Saint-Petersburg. One of the most advantageous aspects of such approach is the possibility of strictly justified decision making concerning project and management issues that proceeds from the interrelation of values of the prevented environmental risk and expenses required therefore.

Key words: Estimation and control of the environmental risk, ecological damage, development of seaports, aquatic ecosystems

The role of maritime transport in contemporary Russia increases inevitably and will increase in foreseeable future. The total cargo turn-over of Russian terminals has already exceeded the cargo turn-over of the Soviet Union and continues linearly increasing *(fig. 1).*

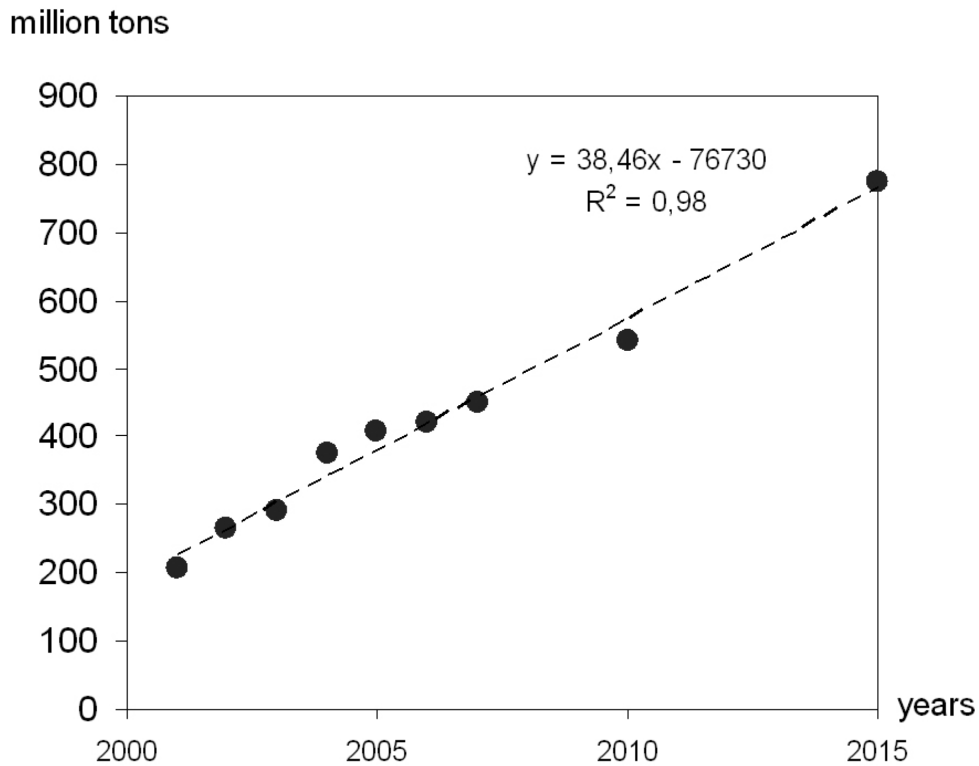


Fig. 1. Dynamics of the aggregate cargo turn-over of the Russian ports.

The intensity of national port construction increases correspondingly. The example of the dynamics of construction of ports and their aggregate cargo turn-over in the eastern part of the Gulf of Finland is highly illustrative (*fig. 2*). In addition, the volume of dredging and formation of new territories increases exponentially as well (*fig. 3*).

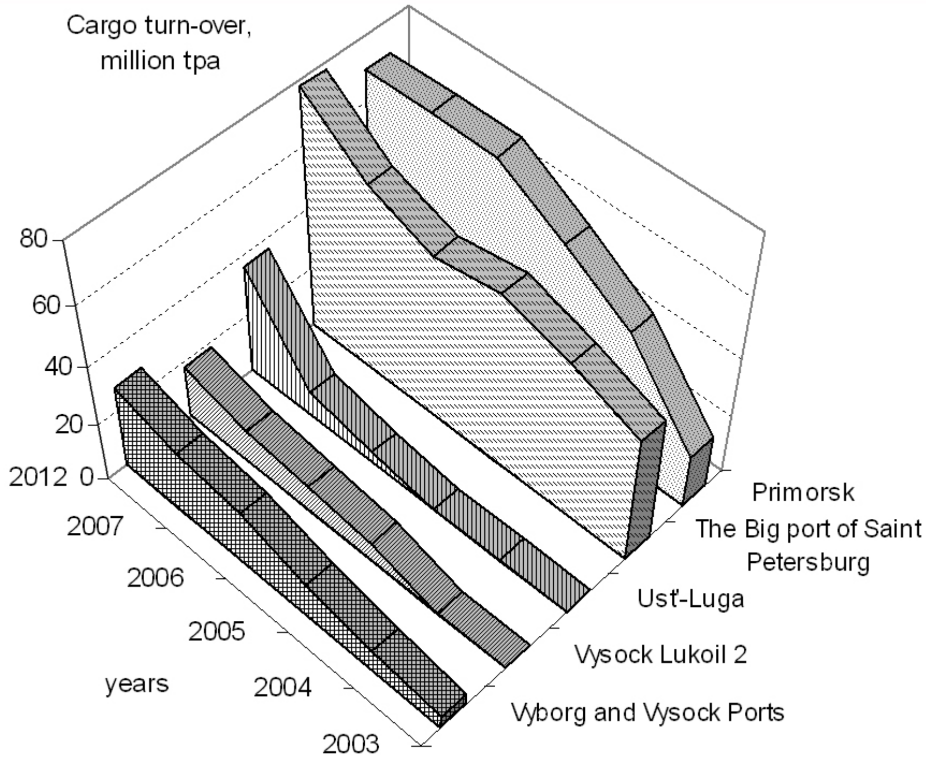


Fig. 2. Dynamics of cargo turn-over of the Russian ports in the eastern part of the Gulf of Finland.

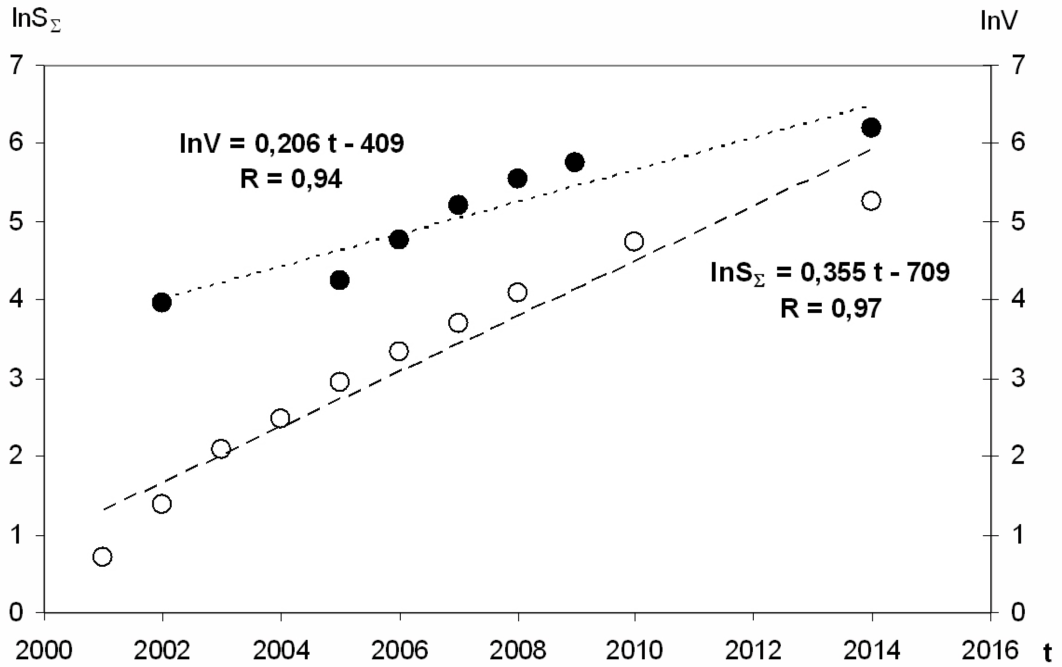


Fig. 3. Dynamics of formation of new territories (alleviation) (area - summarily, on an accrual basis S_Σ (ha^2)) and volume of dredging (V, million tons per annum) at the port construction in the Gulf of Finland.

At the same time, it is essential to preserve the marine ecosystems being used, to ensure the ecological safety of port construction. These two interrelated issues must be resolved systematically and in strategic integration. Such objective can't be achieved within the framework of the current environment-oriented regulatory and methodical base. In particular, one of its principal disadvantages is that only the simplified scenario of ecologically destructive developments is under consideration traditionally. Some conventional, the only possible value of the man-triggered damage is estimated as if determined by the impact. What actually happens is that the ecologically destructive developments cannot be strictly determined and are of probabilistic nature. Therefore, the active elaboration and implementation of methodology and methods of the environmental risk quantity analysis is essential in order to forecast and minimize the environmental implication of the developing system of maritime transport on the whole and its individual elements in particular. This approach will help to regulate reasonably the environmental hazard of port construction and prevent from excessive impact on aquatic ecosystems already at the stage of adoption of pre-design and design solutions. While choosing the risk level one must take into consideration that only the cost equivalent of caused changes -environmental damage may be considered as the unified quantity indicator of various negative consequences of the impact on different environment components. Thus, the assessment of the man impact on the ecological environment must have probabilistic and cost character: both the ***possibility of realization*** of negative consequences and the ***degree of their gravity*** shall be taken into account.

The notion of "environmental risk" is popular and mentioned quite often in scientific and semi-popular publications. However, such papers deals with the phenomena and features not related directly or even indirectly to the risk-analysis. Sometimes they estimate the so-called "risk" simply according to the scope of damage that is forecasted if not already inflicted to a natural object. In other cases, the environmental hazard of an impact source is estimated by the area sector or volume of the natural object of impact already suffered someone or other noticeable changes. The sector indicator of the object change substitutes the probabilistic measure of environmental risk, but has nothing in common with this measure except for the dimension. The developments where the used measure of environmental risk includes both the probabilistic and cost estimates of environmental risk are extremely rare.

Thus, for example, it is necessary to estimate the accident rate of a linear object in the course of the analysis of environmental risk of cross-country gas pipelines (CCGP) operation. It emerged that the average number of accidents per unit length of the route in a unite time (X, average number of accidents per a kilometer of the estimable part of the CCGP route per annum in the assessment period of time) is considered to be an adequate measure of the frequency of ecologically destructive event realization.

Judging by the results of the performed analysis of statistical data on the accidents happened in 84 simulative sectors of CCGP on the territory of the Russian Federation, the hystogram of values of the accident risk index is well approximated by the logarithmically normal distribution (*fig. 4*):

$$f = \frac{N \times c}{s \times \sqrt{2p}} \times e^{-0.5 \times \left(\frac{\lg X - \overline{\lg X}}{s} \right)^2}$$

where *f* - realization frequency of the values of X index of corresponding classes, N -amount of sampling (number of simulative sectors), C - class interval ($\overline{LgX}$ = -3.11; N = 84, σ = 0.452, C = 0.5). The Kolmogorov criterion K_λ=0.08, the explained dispersion portion of empirical frequencies - 99.9 %.

Therefore, the mathematical expectation of economical and environmental damage from accidents per unit length of the route in a unite time (per a kilometer per annum) is defined with the multiplication of index X and average value of the respective type of damage from one accident for the same period in the given sector.

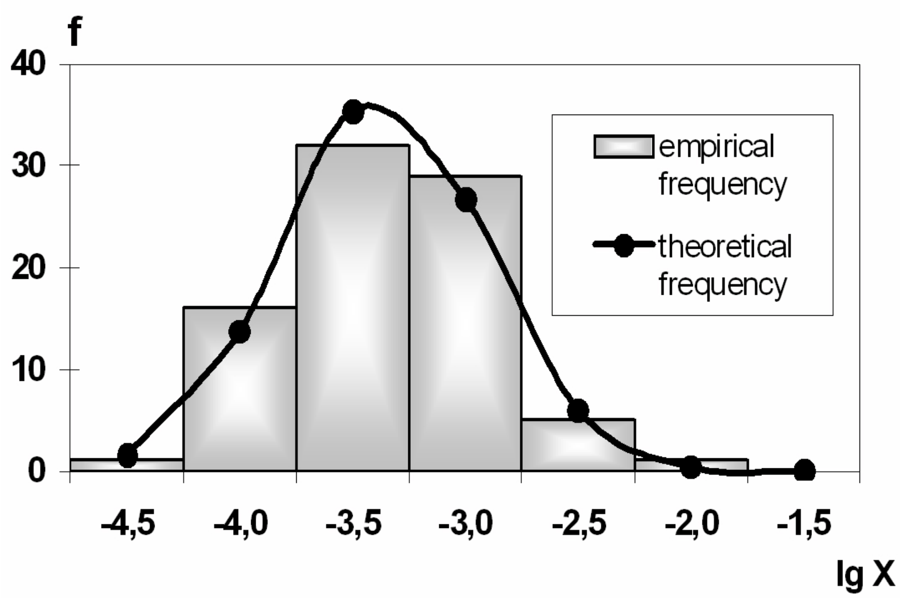


Fig. 4. The hystogram of values of the accident risk index in model sectors of CCGP (X – number of accidents per 1 km of the CCGP route per annum) (the data on the accidence of the CCGP of the Russian Federation, data base of «Gasprom Transgas Saint-Petersburg» LLC were used).

In other cases, depending on the features of the impact source and its natural object, these indexes may be correspondingly transformed. Thus, for area sources and (or) objects of impact the indexes of quantity per unit area, suffered the negative impact etc. may be more effective measure of the frequency of ecologically destructive events [1].

However, the most adequate approach of environmental hazard estimation seems to be the quantitative probabilistic and cost approach, already universally accepted for estimation of technological hazards [2]. With that, the value of man-triggered environmental risk (R), resulting from an ecologically destructive development, is interpreted as the mathematical expectation of environmental damage (U):

$$R = p \times U \qquad (1),$$

where p - probability of developments leading to the endamagement U.

When the extraction and quantity analysis of various scenarios of ecologically destructive developments are possible, their tree may be built. The probability and complete values of damage to the impact recipients in cost terms (U) must be taken into account for every possible alternative event (or scenario - sequence of events). The probability of realization of each *i* independent scenario of ecologically destructive events from *n* of potentially possible scenarios (p_i) is determined multiplicatively:

$$p_i = \prod_{j=1}^{k} p_{ij} \;, \qquad (2)$$

where p_{ij} - probability of the *i* scenario at every alternative situation of further event development giving *k* of variants.

The expected damage R in cost terms is determined as the sum of mathematical expectation of the damage from realization of alternative scenarios of ecologically destructive developments, according to the equation:

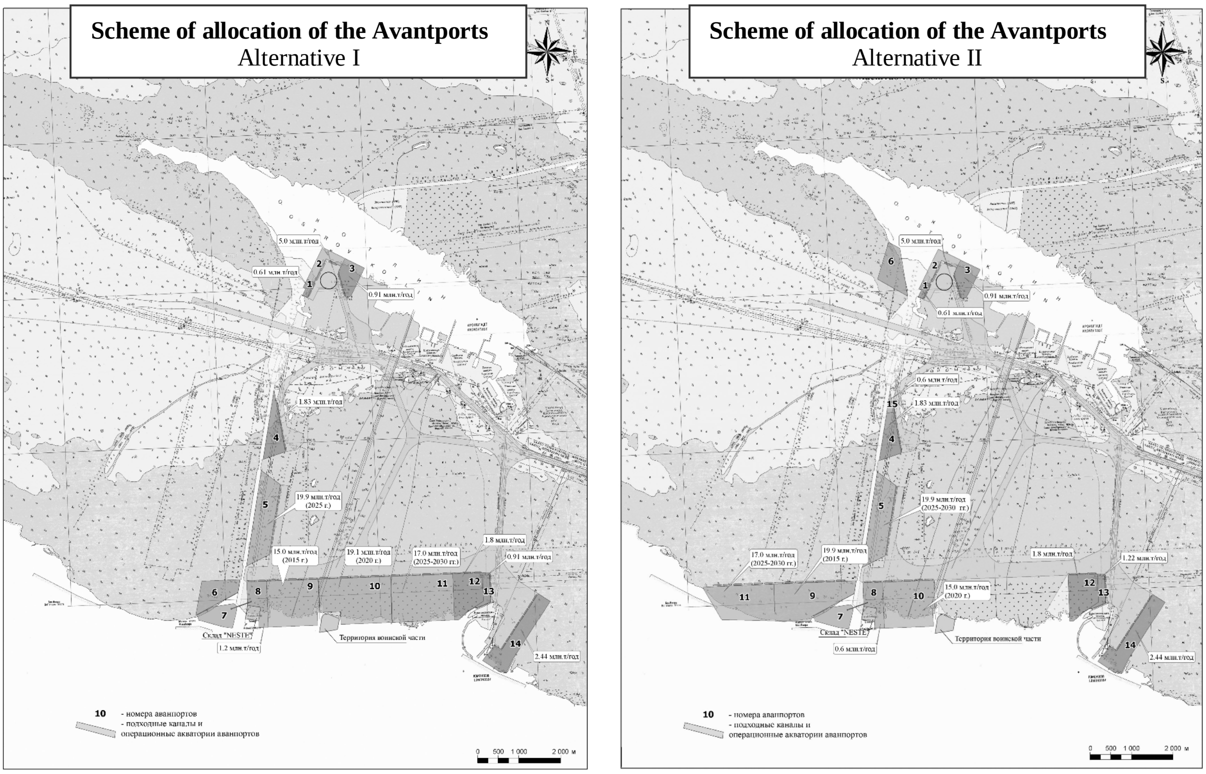
$$R = \sum_{i=1}^{n} R_i = \sum_{i=1}^{n} (U_i \times p_i) = \sum_{i=1}^{n} \left(U_i \times \prod_{j=1}^{k} p_{ij} \right), \qquad (3)$$

where: *n* - number of analyzed alternative scenarios of ecologically destructive developments caused by the object impact; R_i - probable environmental damage from the *i* scenario realization in cost terms; U_i - complete values of environmental damage in physical terms.

There are publications where we used this approach for the estimation and regulation of environmental risk of the man-triggered impacts on freshwater streams [1,3]. These materials have been presented within the preceding editions of the School "Modeling and Analysis of Safety and Risk in Complex Systems".

Unfortunately, the sole example of such approach application in regulatory and methodical documents is the Temporary Guidance Concerning the Environmental Risk Assessment of Petroleum-Storage Depots Activity [4], approved by the State Committee for Environmental Protection in 1999 for the three-year period and therefore ceased to be in force.

As an example of using such approach in engineering of ports may serve the Preliminary Assessment of the Environmental Impact of the Avantports of the Big Port of Saint-Petersburg performed by the "Eco-Express-Service" LTD in 2008 [5]. According to the design specifications there were considered two alternatives of allocation of the Avantports (***Fig. 5***).



a b

Fig. 5. Alternative allocation of Avantports (a: alternative I-14 objects; b: alternative II -15 objects).

In the both cases the Avantport system will take much territory; its certain objects cover the southern part of the Protective structures complex, the coastal strip on the east and in the other alternative on the west of the Protective structures complex, southern part of the Kotlin island.

An overall comparative assessment of the expected impact of the Avantport system on the environment has been carried out concerning the both comparable alternatives of port allocation with the elements of risk-analysis. As is known, the basic components of the combined value of environmental damage from the hydro-construction arise from contamination and spreading of sediments in water and concomitant reduction of aquatic biological resources. As a theoretical basis of computational studies of the expected dynamics of the cloud of excessive turbidity served the syntesized system consisting of two mathematical models - the adapted three-dimensional thermohydrodynamic model and the model of spreading of sediments of the Princeton University, USA [6] (Example on the fig. 6).

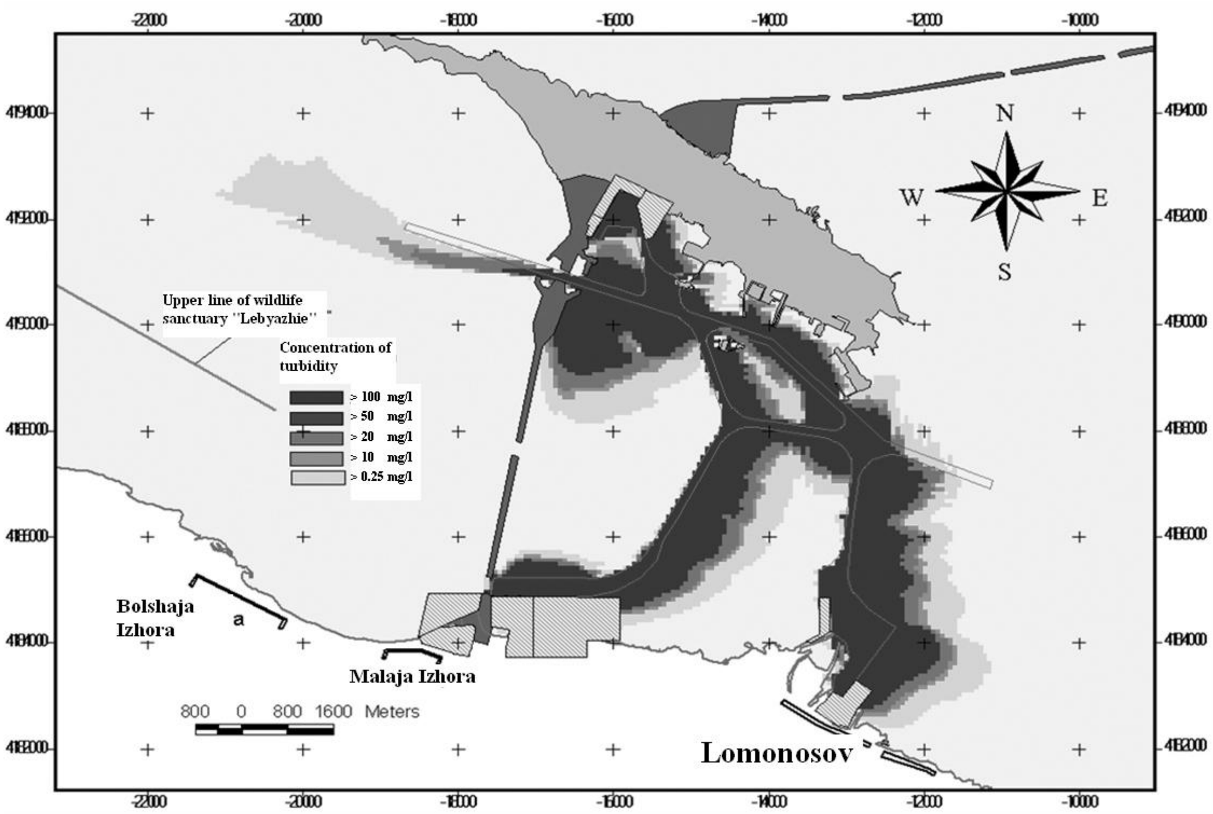


Fig. 6. Example of assessment of the zone of expected roiling of the water area as a result of dredging operations for construction of Avantports in one of the alternatives under consideration concerning possible hydrometeorological conditions. [5].

Generally the expected damage to the components of aquatic environment from rolling and contamination of water is assessed by the results of just one alternative of simulation thereof. Whereby, a number of simulative conditions for calculation are being selected a -bit subjectively which leads to considerable devaluation of the results. But at elaboration of the present Preliminary Assessment of the Environmental Impact it was carried out simulation of rolling of water for different alternatives of possible hydrometeorological conditions in the period of conducting the construction operations taking into consideration the probability of the each of them. Accordingly, based on the results of analysis of these alternative scenarios of environmentally hazardous developments the resulting assessment of the damage to the components of the aquatic environment has been carried out through an equation (3). As a result, the environmental risk cost caused by rolling and chemical contamination of water made 505 in the first alternative of allocation of the objects and 501 million rubles in the second. The environmental risk cost for the fishery resources amounted 523 and 497 million rubles respectively.

The results of the overall comparative assessment of the environmental risk with regard to the said alternatives of allocation allowed to recommend reasonably the second alternative with partial removal of the objects to the west of the Protective structures complex. It will allow to preserve the group of planned wildlife sanctuaries between the "Bronka" port and the City of Lomonosov, and at the same time not to fall outside the limits of the admissible impact on the Special Protected Natural Areas such as the wildlife sanctuary "Lebyazhie".

Therefore, the suggested approach of estimation and regulation of the environmental risk connected with the port construction demonstrates distinct advantages as compared to the traditional "one-scenario" estimation. The calculation of so-called unique value, determined by the impact of future damage is changed for the tree analysis of possible ecologically destructive developments with due account for the probability and cost of consequences of each scenario. This method is more adequate, realistic and enables to reach quantitatively reasonable project and management decisions.

Along with the risk assessment of projected activities, the mapping of environmental risk spacial distribution in cost terms is also possible within the framework of this method. Involving several alternative design solutions, it is reasonable to determine the total values of environmental risk of the object construction and operation for each of them. The preferred solution is the one associated with:

- the least environmental risk,
- the more prevented environmental risk (which may be estimated as the difference of risk values in compared situations),
- and the least costs of risk aversion.

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К ОПРЕДЕЛЕНИЮ ПРЕДЕЛЬНЫХ НАГРУЗОК, ПРИВОДЯЩИХ К АВАРИЯМ ТЕХНИЧЕСКИХ СИСТЕМ

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Аннотация. В данной работе излагается один из возможных подходов к прогнозированию аварий технических систем, использующий современный математический аппарат теории катастроф. Градиентная система описывается потенциальной функцией параметров управления и состояния системы. На устойчивость и неустойчивость исследуются только те критические точки, в которых гессиан потенциальной энергии близок к нулю. Рассмотрен пример применения данной методики исследования на устойчивость.

Ключевые слова: Параметр управления, параметр состояния, устойчивое, неустойчивое положение равновесия, катастрофа, гессиан потенциальной энергии, двухосное растяжение.

Решение основных проблем безопасности для объектов техносферы опирается на фундаментальные результаты, полученные в таких дисциплинах, как сопротивление материалов, теория упругости, теория пластичности, теория ползучести, механика разрушения и других разделах механики деформируемого твёрдого тела. Эта теоретическая база положена в