# THE MANAGEMENT OF HYDROMETEOROLOGICAL RISKS IN SOCIO-ECONOMIC SYSTEMS OF COASTAL AREAS

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**The article considers the problems of functioning and development of complex socio-economic systems of coastal areas in unstable weather-climatic conditions. It is known that the characteristics of the spatial organization of economy of coastal zones are defined industrial and trade specialization and tourism potential of the area It is shown that socio-economic systems are subject to a number of factors, including weather and climatic conditions, which can have both positive and negative effects on economic potential. development of the coastal areas. The density distribution and the economic activities should be considered. The classification of risks of socio - economic systems of coastal areas, due to the influence of hydrometeorological conditions are described. The need to incorporate the tasks of risk management function and the development of spatial distributed systems in the concept of integrated coastal zone management is justified. The model of management of hydrometeorological risks in the system "territory - economy - natural environment" in the space-time dimension is developed. Proposed methods of solving the problems of functioning and development of complex socio-economic systems are based on complex research carried out by the authors.**

*Key words: GIS, risk-management.*

Functioning and development of socio-economic systems of coastal areas are characterized by features associated with the spatial organization of economy of coastal zones, high population density and the need to ensure optimal management.

The coastal areas are stressed by industrial and commercial activities. Considers tourist space, determining the existence of a number of social, environmental, traffic and other problems as a consequence of the conflict of interests of participants of economic activities.

Integrated Complex Zone Management (ICZM) is developed in the framework of the concept of sustainable development. World experience of implementation of ICZM shows that the main emphasis in management policy are made for the protection of the marine environment, scientific research of ecosystems, the sustainable use of fishery stocks, biodiversity conservation, tourism development in coastal areas. At the same time, there is the problem of coordination of the countries in the coastal zone between individual activities, determining the desire for sovereign control of the industry, which increases the risks for the functioning and development of the coastal areas.

Risk assessment of the functioning of the coastal areas should contain not only the impact of socio-economic systems on the environment, which is defined as the restriction of economic activity, but effects of natural, including hydrometeorological environment on various components of socio-economic systems of coastal areas.

Hydrometeorological environment can have both positive and negative effects on the economic system: weather-climatic conditions are defined as natural resources in agricultural production, energy; at the same time unfavorable and hazardous hydro-meteorological conditions and phenomena of weather may be causing economic and social losses that should be investigated in the space-time dimension. The integral effect of the meteorological environment should be considered when assessing the economic development potential of the region. When this essential condition are the variability of weather-climatic conditions, density and types of economic activity in the territory.

At the present time hydro-meteorological information is widely used in the research, development and use of the space and resources of the oceans, seas and coastal areas. In the framework of the Federal target program "World ocean" has developed the unified state information system about the situation in the World ocean (ESIMO). ESIMO is an interdepartmental information system designed for the formation and maintenance of a common information space in the field of Maritime activities, providing comprehensive information about the situation in the oceans the bodies of state power of the Russian Federation and to persons engaged in Maritime activities, as well as information interaction with international systems. GIS systems allow for interactive assessment of hydrometeorological conditions of water areas of the seas and coastal areas, provide operational information on ice conditions, dangerous weather phenomena combined with information about location transport and fishing vessels, permits calculation of the distribution of contaminants in the areas of oil and gas platforms [1]. At the same time, the instability of weather-climatic conditions, in recent decades, and is characterized not only by the variability of calculated values of meteorological characteristics, but also the increase in the frequency of hazards and to adverse meteorological conditions, causes the growth of uncertainty of the results of weather-dependent economic activity that should also be reflected in the systems of decision support.

Because the negative impacts the uncertainty of economic performance is characterized by the notion of risk, we will use the term "hydrometeorological risk" to refer to the probabilistic characteristics of the costs of the entity associated with the uncertainty of the implementation of the weather conditions.

Considering the negative impact of the metocean environment on the economic activity socio-economic systems spatially distributed in coastal areas, we propose to distinguish the following groups of risks of economic systems, due to the influence of weather and climate [2]:

1. Current hydro-meteorological risks - risks from daily fluctuations in weather conditions that influence the activities of industrial facilities. Current risks exposed to all weather-dependent facilities located in coastal areas. When the deviation of weather conditions from the most favourable for the implementation of this type of economic activity, business entities there are additional economic costs.

2. Catastrophic hydrometeorological risks - risks from extreme manifestations of weather and climate, influencing the functioning of the region as a whole. Catastrophic risks cause the problem of sustainability of socio-economic systems to the effects of hydrometeorological environment.

Risks of both types should be considered as strategic planning of territory development and operational management of the region. First of all, the analysis aimed at identifying in the economic system of the subjects of risk - modulating elements of the economy and the definition of these types of potential damage, and also risk identification (determination of threshold values of meteorological variables and weather conditions, the implementation of which may lead to a risk for the subject risk). Note that any socio-economic system has such characteristics as exposure and vulnerability to the negative impacts of hydro-meteorological environment[3].

Exposure is determined by features affecting the phenomenon or condition of the weather depends on the magnitude of the economic objects located in a given area, and their density. It is necessary to develop quantitative and qualitative characteristics of the exposure region, and the zoning on this criterion with consideration of peculiarities of economic activity. Note that in general, coastal areas will always have high exposure to negative manifestations of weather and climate. Exposure is a necessary but not sufficient determinant of hydrometeorological risk. Exposure characterizes the possible influence of weather conditions on economic activity and should be considered during development of strategic plans for development of the territory.

Actual the impact of the metocean environment on the socio-economic system characterizes the vulnerability of socio-economic system. Vulnerability is seen as the susceptibility of the subject to the impact of hydrometeorological elements of the system to adverse effects (economic and social losses from the dangerous manifestations of weather and climate). The degree of vulnerability is determined by the capabilities of this element of the socio-economic system to protect from the effects of adverse meteorological conditions.

Assessment of hydrometeorological risk assessment boils down to two components – risk assessment (probability of occurrence to adverse meteorological conditions) and vulnerability assessment (estimates of potential damages under the unfavorable meteorological conditions). Therefore, as noted above, is especially important to take into account the possible range of exposure to adverse meteorological conditions at the stage of making strategic decisions in the planning of development of territories. The distribution of values of hydrometeorological characteristics in coastal areas studied by several authors, for example [4], given in climatic handbooks, the increasing instability of the climate system is seen as a factor leading to the increase of risk in socio-economic systems.

Spatially distributed socio-economic system and its individual elements (production facilities, infrastructure, etc.) must implement continuous management process hydro-meteorological risks. This needs to be defined:

a) meteorological factors affecting the functioning of the socio-economic system;

b) values of meteorological factors leading to impaired functioning socio-economic system;

b) the economic impact of hydrometeorological conditions with varying degrees of intensity, expressed in monetary terms.

Exploring the dependence of economic performance and the influencing meteorological factors $X$, we assume that the damage $U$ possible, if the realized value of $X$ is greater than a preset threshold $X_{nop}$ determined by the specifics of economic activity ($X>X_{nop}\rightarrow U>0$). Damage is a function of the value of meteorological factor of $U=U(X)$ depends on the intensity and duration of adverse meteorological conditions. The realization of $X$ at time t is a random event, and the change in $X$ in time is a random process $X(t)$, as shown in figure 1.

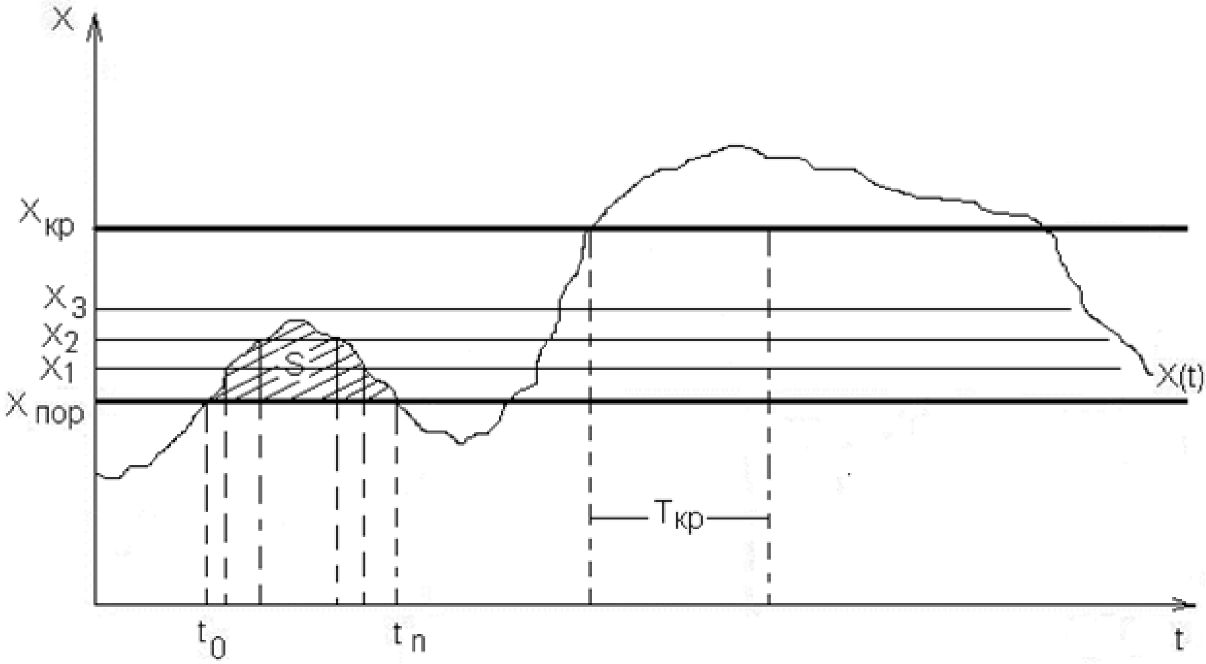


Fig. 1. Implementation of meteorological factor in time

Obviously, the damage can be seen as a process that will depend on the duration of the period of time $t_1$-$t_n$ in which the condition $X>X_{пор}$ and the total gross positive deviations $\Delta X=X-X_{пор}$ affecting meteorological factor, i.e. the square *S*:

$$S = \int_{t_0}^{t_n} \left[X(t) - X_{пор}\right] dt \,. \qquad (1)$$

Then the damage assessment is described by the following expression:

$$U(X) = K \cdot A \cdot S \,, \qquad (2)$$

where: *K* – coefficient of proportionality, is set empirically; *A* is the parameter determined by the adaptive capacity of socio-economic systems to the effects of adverse meteorological factors, $A \in [0, 1]$. Values of *A* will vary for different levels of $X_i$ and the length of time values of meteorological factor is higher than a predetermined intensity.

If socio-economic system takes no action to reduce damage (*A*=1), then there is possible damage $U_{max}(X)$:

$$U_{max}(X) = K \cdot S \qquad (3)$$

If the system has a cardinal measure of protection against adverse weather influences, damage is determined only by the cost of implementation of protection measures ($A \to 0$).

We assume that extreme weather can lead to disturbances in the stability of the economic system, if the damage from their manifestations $U(X)$ beyond a certain level of $U_{кр}(X)$.

It is assumed that at *A*=1 catastrophic damage is possible if meteorological factor *X* exceeds a critical value $X_{кр}$ at the period of time *t* is not less than $T_{кр}$. The application of measures of protection (*A*<1) enables to prevent an increase in the interval of the $T_{кр}$.

Exploring the possible realization of the random process *X(t)* in a given territory for a sufficient period of time, you can determine the most typical scenario of the process. Climate change will lead to deviations from the standard scenario and would require improvement measures.

Baseline risk assessment *R* may be given on the basis of accumulated information about the possible realizations of the random process and their economic consequences:

$$R = Q\left(X(t) > X_{пор}\right) \cdot U_{max}(X), \qquad (4)$$

where: $Q\left(X(t) > X_{пор}\right)$ - the probability of exceeding the threshold value of meteorological factor $X_{пор}$ random function *X(t)* describing the behavior of this factor in time.

Under the condition of stationarity of the studied process in the time interval τ as risk assessment $Q\left(X(t_k) > X_{пор}\right)$ at the time $t_k$, can be used for prognostic evaluation [5]:

$$Q\left(X(t_k) > X_{пор}\right) = \left(1 - \Phi\left\{\frac{X_{пор} - m_X - r_X(\tau)\cdot\left[X_i - m_X\right]}{\sigma_X\sqrt{1 - r_X^2(\tau)}}\right\}\right) \qquad (5)$$

where: $\Phi\{...\}$ – Laplace function, $m_X$ – the expectation of a random process X(t), $r_X(\tau)$ – autocorrelation function, $\sigma_X$ – standard deviation, $X_i$ – the current (actual) value of meteorological factors at the time $t_i$, $X(t_k)$ – meteorological factors expected value at time $t_k$, $\tau$ – the width of the time interval

$$\tau = t_k - t_i, \qquad (6)$$

where i<k .

In general, hydrometeorological risks are associated not only with adverse weather conditions, but also with their expectation. The use of weather forecasts reduces the risk of damage by hydro-meteorological causes regarding climate assessments by reducing the uncertainty of the value of meteorological factor on a given time interval and the use of protective measures, but not avoiding it completely - there are risks management, which are caused by the problem of choosing the optimal management decisions in accordance with the principle of maximizing expected utility, taking into account the uncertainty of the realization of the forecast of the hydrometeorological state of the environment.

The management of hydrometeorological risks are managed in the system "territory - economy - natural environment" [6], an important role is played by the process of adaptation (adaptation) of economic activity possible negative manifestations of the hydrometeorological environment. In the process of adaptation is classified into the following stages:

- the stage of development of protective measures, differentiated depending on the intensities I (I ~ΔX) and the duration T of the influencing meteorological factors;
- the stage of implementation of protective measures in anticipation of inclement weather.

The task of operational management of risk of loss from adverse meteorological conditions is a cyclically repeating the process of making decisions on the basis of information about the expected state of weather. The solution to this problem is the development of algorithm of actions of decision-makers, management process of adaptation to the adverse weather conditions, aimed at mitigating the damage by hydrometeorological causes, and includes the following successive steps:

- determining the level of impact of meteorological factor X at a given time $t_k$: if it is expected that the value of meteorological factor exceeds the threshold ($X(t_k) > X_{пор}$), then define the processes aimed at reducing the consequences of exposure to a predetermined (minimum) level $U_{min}(X)$ is a selection control function;
- implementation of management functions - the implementation of the planned activities aimed at reducing the effects of adverse weather. Implementation of protective measures requires a lead time, at the time of the adverse weather $t_k$ protection measures should be implemented;
- at the moment of time gathering information $t_k$ about the actual condition of meteorological parameters and monitoring results obtained during the implementation of protective measures on the basis of quantitative indicators; identification and analysis of deviations of actual from expected results, determination of causes of deviations;
- the adoption of measures to eliminate the causes of deviations, change in planning and allocating resources for the next time $t_{k+1}$ of the actual weather forecast and the adjusted forecast.

For effective management of hydrometeorological risks necessary to create information systems to support decision making, comprising:

- database correlation of predicted and actual weather over time and space;
- information about the possible economic consequences of management decisions, due to the influence of weather in their respective areas.

This approach to risk management will allow to optimize the process of selecting solutions that satisfy the objective function - the reduction of economic loss caused by adverse meteorological conditions in the study area, and will contribute to the achievement of sustainable results of financial and economic activity of the region.

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