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Multiparameter models in the management of the development of territories, taking into account the influence of hydrometeorological factors

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Abstract: The article considers the geoinformation management of the territory as a way to manage the organizational and technical systems and territories distributed in space. The article describes the main factors for the development and implementation of management decisions, requirements for the territorial management system and the structure of knowledge and data. Mathematical one-parameter and multiparameter models of risk assessment of management decisions applied to the natural and climatic potential of the development of the territory were considered.

Content management as a focused type of human activity from a methodological point of view involves the use of certain approaches [1]. Known approaches in management are system, program-target, project, marketing and others. At the same time, modern socio-economic systems are complex spatially distributed systems and territories. This indicates the need to develop and apply a geo-information approach to management.

The phenomenon of geoinformation management in modern conditions leads to the need to consider and implement the object management system as a multidimensional spatial phenomenon that includes spatially distributed factors, resources and conditions. Space in this case should be regarded as a form that serves as a medium for the existence of other forms and objects. Objects as constructions of space are points characterized by a set of properties.

Dependence of the process of development and implementation of management decisions on the scale of systems and territories allows us to consider the problem of managing sustainable development of the latter as a strategic target for the socio-economic development of systems and territories of various levels and scales [1, 2]. The development strategy of the territory is based on:

Objective factors - resource-spatial and natural-climatic potential of the territory, infrastructure and labor opportunities for locating objects of economic and economic activity;

Subjective factors - the current level of scientific and methodological management, organizational decisions of the subjects of management, as well as the readiness of leading cadres to the complex processes of developing and implementing effective strategic solutions.

The territory as a control object includes several subsystems [3]:

Population as a subject and object of management in terms of democratic governance principles;

Natural resource subsystem;

Production subsystem - realizing the supply of a tangible product: industry, construction, agriculture and forestry etc.;

Non-productive subsystem - rendering of market and non-market services: transport and communication, markets, science and education, health, art, etc.

At the heart of the management principles of any system are two main system properties:

- purposefulness: compliance of the purpose of territory management with the objectives of subjects of management of the objects of the territory;
- sustainability: it presupposes the ability of the territory to resist the process of destroying the foundations of its functioning and to maintain the chosen mode of activity for a certain time.

In accordance with these principles, the organization of management of the development of organizational and technical systems and territory should be:

- applicable to various situations, including emergency situations, when communication with subjects and management objects may be lost for some time;
- flexible, which implies a change in the forms of management depending on the situation and changes in long-term trends;
- operational and continuous in time, i.e. Capable of timely responding to changes in the external and internal environment;
- effective, which means the ability of elected management decisions and the entire management process to ensure the achievement of the goal at a certain level of performance criteria (economic, social, etc.).

Space at the level of perception is intuitively understood as a place, volume or territory in which motion is possible, different positions and mutual locations of objects, as well as characterizing the diversity of objects from each other. It can be characterized by relations of proximity-range, the concept of direction, as an arena of events and actions, universally containing all places and accommodating objects and structures, sometimes as a specific place that largely determines the essence of events occurring in it.

With reference to the problems of geoinformation management, it is worth noting the content, coordinate and structural features of components of organizational and technical systems, in accordance with which it will be possible to isolate and explore the corresponding types of spaces: geographic: two- and three-dimensional, event space and object existence space or attribute space. Spatial factors in their content, specificity of the components of the territory can be divided into compliance with certain characteristics: natural-resource, institutional, socio-demographic, economic, managerial, geographical (coordinate), etc.

The analysis of the characteristics of the territory is a basic stage in the development of strategy development [4-7]. Methodically, this stage involves identifying entities that form an attractive competitive image of the territory, its natural-resource and economic potential, as well as entities and objects that impede the positive dynamics of development. Allowing to assess the advantages and weaknesses of the territory, the results of the analysis can be used as a basis for strategic management of the development of the territory.

Attributes of the basic components of the territory allow:

Assess the impact of the elements (territories) of the territory considered on the development prospects in accordance with the chosen system of criteria;

Assess existing limitations;

To build a decision tree as the basis for a management strategy for the development of the territory.

To solve these problems, it is possible to propose a typical structure of knowledge and data characterizing the territory presented in the table 1.

Natural, technogenic and social processes of territory development unfold in time and in space and are characterized by a set of random parameters. We will show the possibility of formalizing the characteristics of the territory using the example of the natural and climatic potential [8-11].

The components of the natural and climatic potential are random non-stationary processes, the study of the regularities of which leads to the necessity of forming, based on the measurement results, multifactorial models. An example is the model for assessing the risk of flooding, when the meteorological parameters such as the direction and force (speed) of the wind are acting as factors,

and finding them within certain limits (in the tolerance zone) can lead to a rise in the water level above the established level, which is regarded as a flood. Different approaches can be applied to the solution of this problem. On the one hand, having a series of observations of the water level, one can construct a one-dimensional model, treating the level as a random process (a random function of time). On the other hand, one can consider the influence of meteorological factors that lead to a change in the water level. In this case we are dealing with a two-parameter model. In the end, both models describe one event - a flood. For the management of the territories, the knowledge of the occurrence of a flood is important, but not enough. It is necessary to take into account not only the fact of flooding, but also be able to predict the likely damage from flooding (risk).One-parameter models of risk assessment are well described and can be used for different cases [3, 8, 9]. However, more interesting are two-parameter and multi-parameter models, which can describe more complex processes.

Table 1. Typical structure of knowledge and data for the analysis of the territory.

Knowledge	***Data***	***Indicators***
Characteristics of the economic environment of the territory	The volume of production in the base and current periods	The level of gross domestic product (GDP)
	The price of the "market basket" in the reporting year and the base period	The rate of inflation
	The number of employed / unemployed, the number of economically active population, the total population	Employment level
	The amount of resources in the current period by types of resources, Production volumes	Resources, including energy resources
	Volume of exports and imports in cash	Trade balance (positive / negative)
	The number and size of firms on the market, barriers to entry, uniqueness of the supply chain, the status and significance of buyers and others	Level of competition
Characteristics of the political environment of the territory	Changes in laws, regulations affecting the operation of facilities	Current legislation and its possible changes
	Methods of regulating local markets: administrative, economic	Forms of state regulation and control over the sectoral markets
	City twin-cities, agreements and agreements on cooperation and so on, organizations operating in the foreign market	International Relations and Relations
	Territorial / state management system	State (political arrangement)
Characteristics of the social environment of the territory	Number of population, number of working population, unemployed, economically active population, number of employees on the territory and outside it	Demography
	Statistical data on the size and structure of household incomes	Structure of incomes and expenditures of the population
	Elements of culture	Traditions and habits Ethnic and religious characteristics
Characteristics of technological development of the territory	The amount of advanced technology used, the amount of R & D costs, the volume of production in monetary terms, the number of patent applications, the average life of fixed assets and the average life of their operation	Indicators of available and implemented technologies
	Total number of enterprises, number of enterprises using the Internet	Development of information technologies, communications

Knowledge	***Data***	***Indicators***
	Total distance of all roads, communication lines	Level of development of transport and communications
Spatial characteristics of the territory	Geographic coordinates of the boundaries of the territory	Regulations on climatic and meteorological zones
	Geographical coordinates of the boundaries of the territory and the coordinates of development centers, industrial zones and other	Regulations on development centers
	Geographical coordinates of the boundaries of the territory, neighboring territorial units	Regulations on other regions, territories
	Geographical coordinates of the boundaries of the territory and the coordinates of hazardous objects and areas of their influence	The situation regarding the dangerous zones and high-risk factors of neighboring territories
Characteristics of a territory management system	Geographical coordinates of the largest enterprises within the territory, special economic zones (industrial, zones of economic development, etc.)	Scheme of location of especially significant objects in the territory and conditions of their functioning
	Data on public services, administrative units, job descriptions, provisions for departments, communications between subjects of public administration	Organization of the management of the territorial system
	Job descriptions, regulations on departments of administrations of municipalities	Organization and implementation of strategic and operational management
Characteristics of the territory in the external environment	Weighted average estimates of economic, political factors, social, technological	Investment climate Image of the territory competitive advantages Opportunities for development Threats of development

Formulation of the problem:

1. The critical level of the characteristic of an extreme natural phenomenon is determined by two main factors and can be considered as a two-dimensional stochastic process.
2. We assume that we can monitor (regularly measure) the characteristics of an extreme natural phenomenon, and present the dependence as a one-dimensional random process $h(t)$.
3. It is necessary to determine (predict) the waiting time for the onset of an extreme natural phenomenon, provided that the values of the characteristics of the main factors at the time of the forecast are known. Determine the mathematical expectation of the non-occurrence of a two-dimensional random process over a specified tolerance field. We need to estimate a functional of the form $T(x_1, x_2)$.

In this formulation, the problem acquires a classical form, for the solution of which it will be necessary to adopt a number of restrictions related to the type of random processes.

Let there be given a vector random process $X_t = (X_{t1}, X_{t2})$. We assume that each of the one-dimensional stochastic processes is described by a stochastic differential equation of the form:

$$dX_{ti} = b_i(t)dt + a_i(t)d\eta_t, \quad (1)$$

In this formulation, the problem has a solution under the following conditions of unique solutions:

$$\frac{\varphi_2(u_2)-x_2}{u_2}-\rho\frac{\varphi_1(u_1)-x_1}{u_1}\geq c_*$$
$$\frac{\varphi_1(u_1)-x_1}{u_1}-\rho\frac{\varphi_2(u_2)-x_2}{u_2}\geq c_* \qquad (2)$$

where: $x_i \equiv M_{\Psi i}(t)$, $u_i(t) \equiv \sqrt[2]{\int_0^t a_1^2(t)dt} \leq \beta_i(t)$, $\varphi_i(u_i)$ – the auxiliary function for finding the extremum, $\rho\ (t) = \rho$ is a cross-correlation function.

In the end, we obtain estimates for the desired functional $T(x_1, x_2)$ - the mathematical expectation of the time of the process in the given region - the waiting time of the event.

Suppose that a two-dimensional random process can be described as a normal process, then, when condition (2) is satisfied, and known values of the mathematical expectation and variance, solving problem (1) we obtain a lower bound for the desired functional:

$$T_*(x_1, x_2) = \int_0^\infty P_2(\mathrm{t})\Phi(Z)\,dt \qquad (3)$$

where: Φ (·) is the Laplace function,

$$\Phi(Z) = \Phi\left(\frac{\Phi^{-1}\,(P_1(t))\cdot\left(u_1^2+\sigma_1^2\right)^{1/2}+m_1-x_1-\rho\cdot P_1}{\sqrt{1-\rho^2}}\right)dt,$$

$$P_i(\mathrm{t}) = \Phi\left(\frac{\varphi_i(u_i,t)-m_i}{\sqrt{u_i^2(t)-\sigma_i^2}}\right),\ i=1,2.$$

In solving many problems, an upper bound is required for the given functional, which can be obtained and the problem has a solution.

This method allows, for a different class of tasks, to obtain estimates of the waiting time for an event to occur in an explicit form.

From here follows the management, which is formulated for the solution of each specific problem.

Application of the proposed model requires isolation of extreme natural phenomena and corresponding pairs of basic hydrometeorological factors. The transition from two-parameter to multi-parametric models is possible by combining pairs of main factors in accordance with their significance for the process of development of the natural phenomenon.

Conclusion

The analysis of natural, technogenic and social processes of territory development demonstrates the need to develop multi-parameter models of risk assessment. The proposed model is based on the approximation of complex multiparametric estimations by forming paired characteristics of unfolding in time and space. As a random factor, the characteristics of the territory can be proposed. To clarify the forecast solutions, it is necessary to construct a parametric description of specific events and development processes of the territory. The proposed approach to risk assessment has been tested based on the results of the evaluation of flooding in St. Petersburg and the forecast of emergency situations in the management system of housing and communal services.

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