Geoecological Risk Assessment Methods of Anthropogenic Risks Occurrence in Aridic Territories

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Abstract. Problems of the territory ecological state monitoring, prediction and mapping constantly remain relevant in conditions of modern urbanization. The space extension of built-up areas, traffic load increase, different types of industrial fields development, manufactures and service industries at the cups of XX-XXI centuries form positive environment for technogenic accidents initiation, consequently, increase technogenic risk level. It leads to the necessity of technogenic influence comprehensive study on natural system components and adversity reveal on the territories. Geoecologic risk assessment method of anthropogenic risks occurrence on the Astrakhan region territory is proposed in this work. Proposed results have a great meaning for management decision-making, directed on the territory safety protection and mitigation from technogenic influence.

1. Introduction

Arid territories characteristic feature is fragility and their landscape instability and the whole ecological balance, their susceptibility to the process of further degradation towards desertification. Complex of anthropogenic impact sources changes all components of its natural geosystems on the process of arid territory transformation [4]. It leads to the necessity of technogenic influence comprehensive study on natural system components and adversity reveal on the territories. Special meaning has making of scientific-based approaches to these territories environment geoecologic monitoring system creation with the use of geoinformational technologies and theme geoecologic mapping as important instruments of territory planning and sustainable environment development providing [7-9].

Existing methods of geoecologic territory assessment are developed insufficiently, as far as separate their aspects exist separately (the main research objects are separate subsystems or their elements: residential, agricultural, forestry, industrial, transport, mine technical, recreational, conservational) and it is difficult to make a complex assessment of the territory state. It is necessary to solve this task using complex approach, directed to the geoecologic analysis of natural, social and industrial territory subsystems interaction, based on use either traditional geographic and ecological methods, or methods of math-statistical modelling with the use of geoinformational technologies [2].

2. Results and discussions

Nowadays the majority of tasks in different science fields are solved with the use of system approach. General system theory in its current state is considered as complex of different types system description models and ways. First of all qualitative system concepts are distinguished among them. Their common side consists in selection and fixation of “system reality” in its initial differentiation(fig. 1).

System theory all ow stop resent ideas and concepts about research object (objects) in short but significant form, which gives possibilityes to process and analyze research objects with the help of computer technologies [1, 3].
The advantage of the system approach is that very often information about research systems is insufficient to make their detailed math models, even if the main cause and effect relations, defining these systems functioning are known. Nevertheless, it is sometimes possible to make models on the language of the general system theory, which can be a strong basis for further study and more detailed analysis of investigated systems behavior [5].

Secondly, the system description difficulty with great amount of variables can be connected with the way in which these variables and interrelations among them are described. In this case, it is possible to raise system behavior analysis efficiency significantly or just make this analysis possible by developing less structured model, based on key factors (set-theoretic or algebraic type) [10].

Thirdly, more important step in the model development is in the choice of interested system model structure, as far as structural images play major role both under analyses and different types system synthesis. In such case, modelling should be started with the development of principal scheme to reveal general system structure to work simplification according to its further structuring and analytical model development [6].

Fourthly, general system theory, due to its strictness, eliminate the possibility of fundamental system definitions variant reading, that allows considering it as the base for any system definitions formalization. In this way, general system theory makes a foundation for system approach use practically to any situation [8].

It is meaningful to use all existing modelling methods fuzzy set theory of complex systems functioning prediction (state), which allows to take in consideration influence of several values simultaneously (multivariate distribution) [1].

Geoeconomic risk assessment method of anthropogenic risks occurrence in arid territories is a complex of consistently carried out logical operations (stages), allowing to describe the state of considered complex system, taking into account risk criteria, peculiar to considered territory (fig. 2). Data according to the investigated territory are collected to analyze natural and anthropogenic influences, source analysis is carried out, which support technogenic risks on the territory, and geoinformation risk data is formed on the first stage of work according to the geoeconomic assessment “Risk identification”.

Geoeconomic assessment values are defined, reflecting physiographic and social-economic specific features of considered territory for further characteristic modelling of their influence on the environment on the second stage “Risk factors defining”.

Geoeconomic system criteria explanation for characteristic modelling of arid territories technogenic risks is made on the basis of probabilistic-statistical analysis of the territory (regional) factors role in the territory technogenic risk level formation. Physiographic (location, hydrology, climate, landscape, natural resources) and social-economic (territory urbanization, industry branches development and production, environment support systems deterioration, traffic infrastructure etc.) territory specific features are considered in this work [3-5].
Selected values ranking is carried out, also investigated territory zoning according to the technogenic risk occurrence and is mapping modelling to the technogenic risk degree on the third stage “Risk assessment”.

The main factor (alternatives), which characterize territory technogenic risk are distinguished on the basis of complete analysis and choice of criteria for arid territory technogenic risk parameters.

To such factor belong:
1) climate;
2) hydrology;
3) territory urbanization;
4) natural resources;
5) fuel and energy complex;
6) manufacture and production;
7) housing and public utilities system;
8) traffic infrastructure;
9) hydrotechnical constructions.

Figure 2 – Geoeconomic risk assessment method of anthropogenic risks occurrence in arid territories
5) fuel and energy complex;
6) manufacture and production;
7) housing and public utilities system;
8) traffic infrastructure;
9) hydrotechnical constructions.

Ranking model of arid territories technogenic risks values is presented in the form of objective function \( Z \) priority defining, having relative importance or element preferability of made hierarchical structure, with the help of pairwise comparison procedure:

\[
Z = A_i \cdot x_i
\]  

(1)

Where \( x_i \) istechnogenicriskindicatorvalues, \( A_i \) iscoefficients, characterizing importance degree of that or other value.

Weight coefficients \( A_i \)eachofvaluesdefinedbyanalythicierarchy process method, which allows by using pairwise comparison to rank chosen alternatives according to their significance level. Conductedanalysisshowedthathierarchywillconsistoftwolevels (fig. 3), where on the first (the highest) hierarchy level, general purpose is presented, but on the second hierarchy level alternatives are placed:

- \( A_1 \) –climate forcing influence;
- \( A_2 \) – territory hydrological characteristic;
- \( A_3 \) – territory urbanization degree;
- \( A_4 \) – natural resources stock;
- \( A_5 \) – fuel and energy complex;
- \( A_6 \) – industries and production fields development;
- \( A_7 \) – housing and public utilities system objects state and people’s life support system;
- \( A_8 \) – traffic infrastructure system;
- \( A_9 \) – hydrotechnical constructions existence and state.

Pairwise comparison matrix for the 2 level hierarchy is made up according to the comparison results of proposed technogenic risk values with each other, but also technogenic risk weight coefficient values are calculated.

Astrakhan region technogenic risk values ranking model has the type (2) taking into account reported technogenic risk weight coefficients values:

\[
Z = 0.346 \cdot x_1 + 0.052 \cdot x_2 + 11.42 \cdot x_3 + 0.237 \cdot x_4 + 4.083 \cdot x_5 + 2.006 \cdot x_6 + 4.787 \cdot x_7 + 7.246 \cdot x_8 + 0.073 \cdot x_9
\]  

(2)

![Figure 3 – Arid territories technogenic risk values hierarchy](image)

Arid territory zoning algorithm according to the degree of technogenic influence on the environment was conducted by using applied scale “territory technogenic risk degree”, with the help of
which it is possible to make assessment of the territory technogenic risk degree according to the obtained objective function value $Z(2)$. Linguistic variable “Technogenic risk” was made for this, which is characterized by the set

$$\{\beta, T(\beta), X, K, M\},$$

where: $\beta$ is a linguistic variable name;

$T(\beta)$ is a term variety of linguistic variable $\beta$, so variety of linguistic (verbal) variable values, where each of these values is fuzzy variable with the define area $X$;

$K$ is a syntax rule (having usual grammar form), given name $a \in T(\beta)$ of linguistic variable $\beta$ verbal meaning;

$M$ is a semantic rule, which put in correspondence with every fuzzy variable $a \in T(\beta)$ is a fuzzy variety, $C(a)$ is a sense of fuzzy variable $[2, 7]$.

As a result, arid territory technogenic risk assessment degree scale will have a form shown on the fig.4.

![Figure 4 – Astrakhan region technogenic risk assessment degree scale](image)

Figure 4 – Astrakhan region technogenic risk assessment degree scale

Territory zoning according to the technogenic risk degree was carried out by defining objective function $Z(2)$ values and comparison of these values with the risk scale (fig. 4).

Astrakhan region technogenic risk map development is the result of the territory technogenic risk geocological assessment (fig. 5), the base of which is geoinformational modelling of obtained technogenic risk degree values, where the colour is a numeric expression of the territory risk assessable factors (intensity) $[5]$.

![Figure 5 – Astrakhan region technogenic risk map](image)
Making development predictions of this and other situations, recommendations formulation for risk decrease, prevention measures execution etc are conducted on the fourth stage “Risk management”.

Territory technogenic risk decrease achieved by preliminary complex activities carrying out (interconnected according to the place, time, purpose and resources), directed to prediction, prevention and arising risks elimination. Certain prevention measures, directed to risk acceptance and risk decrease are the basis of measures to prevent possible risks and loss decrease and harm upon incurrence [8].

3. Conclusion

Thus, developed method allows to define territory technogenic risk level keeping in mind threat criteria, peculiar to the territory (physiographic conditions and social-economic specific features) and carry out territory mapping modeling according to the technogenic risk degree. Special actuality has the use of developed models when reasoned the risk of investment into the development of this or other territory, economic and social territory development strategy, for rational production powers andtechnogenic safety location distribution.

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