ASSESSMENT OF TERRITORIAL MAN-CAUSED RISKS IN THE ARCTIC TERRITORIES USING PROBABILISTIC-GRAPHIC MODELS

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Abstract

As a result of the work carried out, the main factors influencing on the formation of the technogenic load in the Arctic territories of the Krasnoyarsk Region were considered, taking into account natural and climatic features. On the basis of Bayesian networks, a methodology has been developed for assessing the probability of the occurrence of man-made hazards, followed by an assessment of the complex risk using the official statistics of the Russian Emergencies Ministry for the period 1996-2020. The obtained quantitative estimates made it possible to identify the main factors influencing on the formation of the man-made load in the Arctic territories.

Keywords: technogenic safety, territorial risk, Arctic territories, Bayesian networks

I. Introduction

The problem of the risks of catastrophic processes is particularly acute for Siberia and the Arcti territories, where there is a wide range of threats of various nature, and, at the same time, the main points of growth Russian economic potential are outlined. Under these conditions, the issues of social, natural and technogenic safety are of paramount importance, since they determine the prospects for the territories development. This gives unconditional relevance to research in the field of risks, methods for their assessment and mitigation of negative consequences.

The specificity of territorial development management is characterized, on the one hand, by a large amount of infrastructural, environmental, economic and social information, and on the other hand, by the lack of effective methods for its processing and a unified structured information space in the monitoring field. In addition, the amount and content of information required for sound scientific support of decisions is changing rapidly.

The technological development of Siberian territories and the growth of industry have a negative impact on environmental and social security and form a number of problems that may affect the region and the development of the country as a whole. The Krasnoyarsk Region is the largest industrial entity in the Siberian Federal District, the Arctic zone of which includes all the territories of the Taimyr Dolgano-Nenetsky municipal district, the northern parts of the Turukhansky district (where the city of Igarka is located), the Evenki municipal district, and the

urban district of Norilsk [1]. Despite the uniqueness of the Arctic zone of the Krasnoyarsk Territory and the harsh natural and climatic conditions, objects that are sources of high technogenic load are operated: fire and explosion hazardous objects, radiation hazardous objects, hydrodynamic hazardous objects, transport routes, public utility systems, chemically hazardous objects, etc.

For the effective management of the Arctic territories and the analysis of integrated security, it is proposed to use methods and risk criteria. Quantitative values of risks characterizing the formation and implementation of hazardous processes and events are proposed as safety criteria.

II. Methods

To establish cause-and-effect relationships of technogenic risk factors, it is advisable to use the apparatus of Bayesian trust networks.

Bayesian networks are graphical models of events and processes based on the combination of the mathematical apparatus of probability theory and graph theory [2-4]. Bayesian networks are a convenient tool for describing fairly complex processes and events with uncertainties. The main idea of building a graphical model is associated with the concept of modularity, that is, the decomposition of a complex system into simple elements. Such a graph-theoretical approach to building a model makes it possible to take into account processes with many interacting variables, as well as to create data structures for the subsequent development of effective algorithms for their evaluation and decision making.

The Bayesian belief network is a directed acyclic graph. The graph is written as a set of independence conditions: each variable is independent of its main event, under such conditions the probability of a vertex event will be calculated using the total probability formula (1). If event A can occur only when one of the events B_1, B_2 ... B_n, which form a complete group of incompatible events, occurs, then the probability of event A is calculated by formula (1):

$$P(A) = P(B_1) \cdot P(A \mid B_1) + P(B_2) \cdot P(A \mid B_2) + \cdots + P(B_n) \cdot P(A \mid B_n) \quad (1)$$

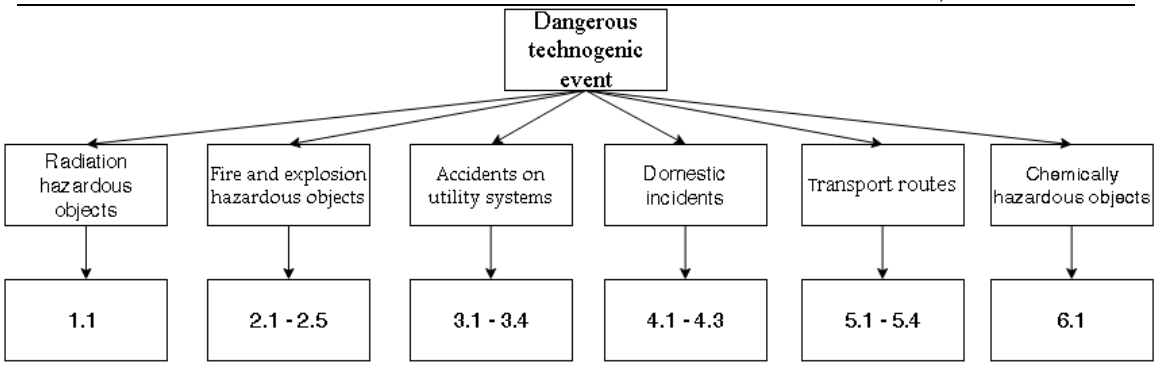
In the case if the distribution goes from the child vertex to the main vertex, the Bayes formula (2) will be used. Let H_1, H_2… be a complete group of events, and A be some event whose probability is positive. Then the conditional probability that the event H_k took place, if the event A was observed as a result of the experiment, can be calculated using the Bayes formula (2):

$$P(H_k \mid A) = \frac{P(H_k) \cdot P(A \mid H_k)}{\sum_{i=1}^{k} P(H_i) \cdot P(A \mid H_i)} \quad (2)$$

III. Results

As mentioned above, Bayesian network risk assessment begins with the construction of a graph. Figure 1 shows an acyclic directed graph of the occurrence of a technogenic risk.

The column considers 6 groups of factors of technogenic hazardous events due to the peculiarities of economic activity in the Arctic zone of the Krasnoyarsk Region. The main peak is represented directly by a dangerous man-made event. Child vertices represent groups of factors that are the cause of this event. Each group, in turn, contains a specific version of the development of an event. The results of calculating the probabilities of hazardous events are presented in Table 1.



1.1	Accident with the release of radioactive substances
1.2	Radioisotope thermoelectric generator accidents
2.1	Fire at objects with mass stay of people
2.2	Explosion industrial
2.3	Accident at an industrial facility
2.4	Industrial fire
2.5	Collapse of technical structures
3.1	Water supply disruption
3.2	Disruption of gas supply
3.3	Heat supply disruption
3.4	Power failure
4.1	Household collapse
4.2	Household explosion
4.3	Household fire
5.1	Railway accident
5.2	Air transport accident
5.3	Car accident
5.4	Water transport accident
6.1	Accident with the release of hazardous chemicals

Figure 1: *Bayesian network model*

Table 1: *The results of calculating the probability of the dangerous implementation man-made events for the Arctic territories of the Krasnoyarsk Territory*

Name of the main factors	Name of child factors	Probability of realization of a dangerous event	Probability of realization of a group of events
Transport routes	Railway accident	0,0062112	0,23913
	Air transport accident	0,136646	
	Car accident	0,04347826	
	Water transport accident	0,052795	
Radiation hazardous objects	Accident with the release of radioactive substances	0,0031	0,0031
Chemically hazardous objects	Accident with the release of hazardous chemicals	0,0217391	0,0217391
Fire and explosion hazardous objects	Fire at objects with mass stay of people	0,267080745	0,363354035
	Explosion industrial	0,01863354	
	Accident at an industrial facility	0,01863354	
	Industrial fire	0,04347826	
	Collapse of technical structures	0,01552795	
Accidents on utility systems	Water supply disruption	0,0217391	0,07452295
	Disruption of gas supply	0,0031	
	Heat supply disruption	0,0031	
	Power failure	0,04658385	
Domestic incidents	Household collapse	0,0031	0,288808696
	Household explosion	0,0031	
	Household fire	0,282608696	

Table 2 shows that the greatest contribution to the occurrence of a technogenic hazardous event is made by fire and explosion hazardous objects, especially household fires and at facilities with a mass stay of people.

In order to detail the indicators of the occurrence of man-made emergencies in the territory of the Arctic zone in the Krasnoyarsk Region, the probability of a hazardous event occurring is calculated for each territorial entity (Table 2).

Table 2: *The results of calculating the probability of the implementation of dangerous man-made events for each territorial entity of the Arctic zone in the Krasnoyarsk Region*

Name of the main factors	Name of child factors	Probability of realization of a dangerous event			
		Taimyr Dolgano-Nenetsky municipal district	Evenki municipal district	Turukhansky municipal district	Norilsk
Transport routes	Railway accident	-	0,00307	-	0,00307
	Air transport accident	0,015337	0,015337	0,030675	0,0552147
	Car accident	0,015337	0,006135	-	0,0214724
	Water transport accident	0,018405	0,027907	0,006135	0,00307
Radiation hazardous objects	Accident with the release of radioactive substances	-	-	-	0,00307
Chemically hazardous objects	Accident with the release of hazardous chemicals	-	0,0092	0,00307	0,0092
Fire and explosion hazardous objects	Fire objects with mass stay of people	0,0122699	0,06135	0,027907	0,171779
	Explosion industrial	-	0,0092	-	0,0092
	Accident at an industrial facility	0,00307	0,006135	-	0,0092
	Industrial fire	0,00307	0,0092	0,0092	0,0214724
	Collapse of technical structures	-	0,00307		0,01227
Accidents on utility systems	Water supply disruption	-	-	-	0,0214724
	Disruption of gas supply	-	-	-	0,00307
	Heat supply disruption	-	0,00307	-	-
	Power failure	0,0122699	0,0122699	-	0,0214724
Domestic incidents	Household collapse	-	-	-	0,00307
	Household explosion	-	-	-	0,00307
	Household fire	0,027607	0,082822	0,03681	0,128834

On the basis of the obtained results of assessing the probabilities of hazardous man-made events in the Arctic territory, we will calculate the complex man-made risk (3):

$$R_t^c = \sum_{i=1}^{n} P_i \cdot U_i \quad (3)$$

where P_i is the probability of occurrence of a certain risk factor; U_i is damage from a certain risk factor, million rubles (data obtained from the official database of the EMERCOM of Russia).

For the Arctic territories, a complex risk is determined for each technogenic factor (table 3). The main risk is associated with domestic fires and accidents in transport (air and river).

Table 3: *The results of the calculation of the technogenic risk of the Arctic zone in the Krasnoyarsk Region*

Name of the risk factor	Risk
Railway accident	0,00025
Air transport accident	7,99
Car accident	0,4
Water transport accident	1,9
Accident with the release of radioactive substances	0
Accident with the release of hazardous chemicals	0,144
Fire objects with mass stay of people	3,31
Explosion industrial	0,38
Accident at an industrial facility	0,26
Industrial fire	0,1
Collapse of technical structures	0,02
Water supply disruption	0,2
Disruption of gas supply	0,00005
Heat supply disruption	0,000003
Power failure	0,1
Household collapse	0,0001
Household explosion	0,0017
Household fire	9,33

IV. Discussion

The management of a territorial entity should be based on an assessment of the complex technogenic risk and the identification of the most dangerous factors that require special attention and control.

The development of urbanized territories requires new approaches to management tasks. The problems of increasing risks both for the life and health of the population and for the state of the environment are associated with an increase in anthropogenic impact. In both cases, qualitative and quantitative assessments of the risk of adverse situations and impacts become a key task, the solution of which determines the quality and effectiveness of the development and implementation of management decisions to protect the population and the environment.

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