Remote assessment of an integrated emergency risk index

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Abstract: The article deals with the formation and remote assessment of the integrated emergency risk index for the constituent entities of the Russian Federation based on the three components of the risk index - an indicator of natural and human-induced hazards, vulnerability (population, objects and territories) and countermeasures (forces and means of warning, response and emergency response, the system of territories engineering protection from natural hazardous processes). This approach can be useful to decision-makers when developing measures to improve the protection of the population and territories from natural hazardous processes and man-made accidents, as well as to identify the most protected and less protected areas on the territory of the Russian Federation from natural and man-made threats.

1. Introduction
Assessment of the risk of natural and human-induced emergencies is a necessary step in the prevention and mitigation of emergencies. Emergency risk assessment approaches are usually based on statistics of emergencies. Recently, the usage of risk index methods has also become widespread1. In this regard, it is advisable to use the method implemented in the international INFORM tools [1]. The essence of this method is that the risk index is formed from the indices of danger, vulnerability and potential, as for combating hazards. Each of indices is calculated on the basis of the developed system of indicators characterizing the components of the integral emergency risk index. The idea of this method was used in the development of the methodology and technology for remote assessment of the integrated index of emergencies risk [2].

2. Methods
The main idea of the remote assessment of the integrated index of emergency risk is that the source data obtained from open databases, or requested and processed without the involvement of experts. Methodology for the remote assessment of the integrated emergency risk index developed in the framework of this paper, also three components of the integral emergency risk index are taken as the basis: hazard index, vulnerability index and response potential index [1-3].

Vulnerability is understood as conditions determined by physical, social, economic and environmental factors or processes that increase the exposure of an object or community to hazards2. By countering potential, it means the ability of a system, community or society exposed to threats to

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1 IEC 31010:2019 Risk management — Risk assessment techniques
2 Sendai Disaster Risk Reduction Framework 2015–2030. A / RES / 69/283
withstand the consequences of a threat, transfer them, adapt to them and also timely and effective recover, including preserving and restoring fundamental structures and functions.

When performing the technology of the integrated emergency risk index's remote assessment, open data were used from the portals of the following federal executive bodies: Federal State Statistics Service; Ministry of Natural Resources of Russia; Federal Service for Environmental, Technological and Nuclear Supervision; executive authorities of the constituent entities of the Russian Federation; local executive authorities of municipalities [3,4].

The main open data of the Russian Federation are posted on the open data portal of the Russian Federation [3]. The Open Data Portal of the Russian Federation is one of the key tools for implementing state policy in the field of open data, which plays the role of a system-forming element, the core of the open data ecosystem of the Russian Federation [4,5].

As the main dangers for the constituent entities of the Russian Federation are considered: floods and surge phenomena [4]; seismic activity; landslides, mudflows, avalanches; natural fires; hurricanes, tornadoes, strong winds; flooding; human induced emergencies at potentially hazardous facilities (radiation, chemical, fire and explosion hazard, hydraulic constructures); human induced emergencies in transport communications; technogenic emergencies in transport [6-8].

Indicators are characterizing the vulnerability of the population, including indicators reflecting vulnerable groups of the population (disabled people, children, etc.); indicators reflecting the vulnerability of potentially dangerous objects (depreciation of building structures, depreciation of equipment systems, etc.); indicators reflecting the vulnerability of utilities (deterioration of drainage systems, heat supply, and other systems); indicators reflecting the vulnerability of the territory (for example, the lack of engineering protection systems for the territory from dangerous natural processes) [9,10,11,12,13,14]. As indicators of the potential combating natural and technological hazards, considered indicators characterizing the degree of equipment of the constituent entities of the Russian Federation (municipalities) with warning and information systems, systems of hazards responding, engineering protection systems, as well as the volume of reserves of material and financial resources, individual means protection, etc.

In addition to these indicators, the integrated emergency risk index uses indicators characterizing the socio-economic development of the subject and municipalities, since these parameters largely determine the preparedness of the subject and the municipality for hazards [15-20].

The proposed approach is based on the methodology of the risk-oriented method INFORM (index for risk management). The integrated INFORM index of risk includes about 50 different indicators for measuring the dangers and impact on them, vulnerability indicators and determining the necessary resources for stopping hazards and is defined as the geometric mean by the formula3:

\[
R = \sqrt[3]{H \times V \times L}
\]

where \( H \) - indicator of danger and threats; \( V \) - the indicator of vulnerability; \( L \) - an indicator of the insufficiency of the potential for counteraction of danger.

In accordance with the proposed structure of the integrated risk index, the indicators are divided into three dimensions (hazard, vulnerability and inadequate capacity to counteract hazards and threats), in each of the three dimensions, the corresponding indicator is assessed on a 10-point interval scale. To obtain the integral risk index, the "counteraction potential" index is used instead of the index - the "lack of counteraction potential" index. This method allows using in the calculations of the integral risk index both averaged formulas (geometric mean, arithmetic mean, etc.) and linear combinations [1,2].

The indicators and specific indicators are described in more detail in the monography [2]. All indicators are normalized and take values from 0 to 10. The closer the value of the indicator to zero, the more favorable the situation in the area that is measured by the corresponding indicator.

3 www.inform-index.org
The flood hazard index is calculated by the formula:

\[ I_f = a_1 \frac{S^*}{S} + a_2 \frac{N^*}{N} \]  

(2)

where \( a_1, a_2 \) are non-negative weighting factors not exceeding 1 in total.

\( S^* \) – the area with 1% security, the area subject to flooding, km\(^2\); \( S \) – total area of the territory of the municipalities, km\(^2\); \( N^* \) - the population affected by the flood, thousand people.

The vulnerability index of the population is calculated on the basis of information on the population (age composition, mobility), the deterioration of critical infrastructure, the deterioration of housing stock and the presence of dilapidated housing. The index of the counteraction potential shows the presence of the forces and facilities of the municipalities for informing, alerting the population, as well as the availability of necessary equipment for responding to emergencies and evacuating the population.

3. Results

The Krasnodar region was chosen as a subject for developing the methodology and technology for remote assessment of the integrated emergency risk index. Figure 1 shows the results of calculating the integrated emergency risk index for municipalities of the Krasnodar region [21,22].

![Cartogram of the integrated emergency risk index for municipalities of the Krasnodar region.](image-url)
Figure 2 shows on a map the histograms about calculating results of emergency risk situations integrated index.

![Histograms displaying the results of the emergency risk index calculation: the indicator of danger and threats (light), the indicator of vulnerability (dark).](image)

These calculations allow ranking municipalities according to their degree of preparedness for natural and human induced hazards. In the course of the paper, the following results were obtained based on:

- the analysis of regional statistics on the specific spectrum of emergencies, hazards for the Krasnodar region, were ranked and calculation models were selected to determine the hazard index and its components, the composition of representative parameters of sources of natural, human induced and complex natural-technogenic hazards subject to mandatory monitoring was determined;
- an analysis of the Russian Federation’s open data in the field of security for the region was carried out, and calculated dependencies were created for the vulnerability index and its components, as well as for the index of emergency response potential;
- indicators characterizing hazard, vulnerability, and emergency response capabilities have been developed;
- a methodology for obtaining an integrated emergency risk index for the subjects of the Russian Federation and municipalities using the method of risk indices has been developed;
- software technology of remote emergency risk assessment for the constituent entities of the Russian Federation and municipalities, which using open data, was developed.
4. Conclusion
As a result of the work, a risk-based approach was implemented in the field of developing a methodology and technology for remote risk assessment, brought to implementation in the form of a WEB application for visualizing the results.

The results of this work can be claimed both at the level of individual municipalities, entities, and generally at the federal level for objective information on the state of population protection against natural and human induced hazards, to identify the most vulnerable entities, individual municipalities to emergency risks.

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