Support technologies for management of the land flood protection

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Abstract. The problems of management for the safety of territories are considered as well as their application with the landfloods as an example. Model of organization of the informational resources is proposed. Models of decision-making in the conditions of uncertainty are described as well as the architecture of information-analytical systems allowing integration of the new technologies for digitization of economics.

1. Introduction
Development of the efficient ways in the struggle with the negative effects of landfloods is actual practically for all regions of Russian Federation [1–3]. Increase of the number and scale of emergency conditions (EC) is stipulated not only by the changes of climate but also by transfer to another model of economics at the beginning of 90-th years. In addition, as a result of undue repairs the accidents became more frequent at the unattended hydraulic structures (HS) accumulating water for the needs of agriculture [4]. Uncontrolled forest exploitation at the upper parts of the river basins decreased moisture-retaining power capability of a soil increased the probability of the catastrophic summer floods [5]. Collapse of the industry in small settlements, outflow of able-bodied population increased vulnerability to the natural disasters.

Adoption of the new technologies of digital economics into management system allows organizing efficient interaction of population, rescue services, bodies of power at the different levels of management when preparing to the possible floods and easing of their negative consequences. Communication means provide an operative delivery of the required information to decision makers in the form of warnings, forecasts of the situations development, recommendations, information on the protection systems, etc. This information represents the results of deep data processing concerned with the operative complex monitoring and situational simulation. With solution of the problems connected with the floodplain management as an example the application of end-to-end technologies for support of the decision making is considered. Business-processes in solution of different problems are described in brief. The model for organization of the information resources is presented and the results of its practical realization are shown on the example of Voronezh region.

2. Formalization of the management problems for a territorial safety
According to [6], protection of the population and territories from emergency situations (ES), providing of acquisition, processing, exchange and issuing of the information for warning and elimination of ES are determined as the basic tasks for the Uniform State System of warning and elimination of emergency conditions RSES. The difficulty of the management processes for the natural-anthropogenic safety consists in the need of the information exchange and coordination of power and means under conditions of severe limitations in time and resources and the lack of adequate information. Large amount of data in the form of
reports, messages, instructions is used in the processes of decision making while their form of presentation and their structure admits ambiguous interpretation thus facilitating the growth of amount of non-formalized data. Non-formalized type of the characteristics describing the objects and events, previously accepted decisions and their results complicates automation of the informational support of the management for providing natural-anthropogenic safety of the territories and reduces efficiency of RSES operations.

In order to formalize the processes for support of the safety management of the territories with the use of information technologies a system model was developed [7]. Variety of the tasks providing the safety it seems reasonable to demonstrate it by designations of the model elements. Let us present the management tasks T as crossings of the elements G and L, where G are the processes (modes) of RSES operations, L – are management levels (Table 1).

\[ G = \{g_1, g_2, g_3\}, \quad \text{where } g_1 \text{ is an everyday management of ES; } g_2 \text{ is an operative control; } g_3 \text{ – planning of strategic measures for diminishing of the risks.} \]

\[ L = \{l_1, l_2, l_3\}, \quad \text{where } l_1 \text{ – is a subject (regional) level, } l_2 \text{ – municipal level, } l_3 \text{ – is a settlement or protected object.} \]

**Table 1. Tasks of management of the territories safety.**

| Modes of operation | Management levels | Subject of RF, \(l_1\) | Municipality, \(l_2\) |
|--------------------|------------------|-------------------|-----------------|
| **Daily, \(g_1\)** | Acquisition, processing of the monitoring data. Identification of the dangers. Warning | Response to the threats and forecasts | |
| | Formation of the information resources by inter-agency exchange | Formation of the informational resources through the system of data acquisition | |
| **ES mode, \(g_2\)** | Situational modelling for the adjustment of situation | Realization of scenario responses. Verification of computer solutions in certain situations | |
| **Strategic management, \(g_3\)** | Situational modelling of the possible ES consequences | Formation of scenario responses | |
| | Conversion of the plans of actions into the knowledge base | Verification of computer solutions in the process of exercises and trainings | |
| | Analytical modelling. Risks validation. Substantiation of the preventive measures | Realization of preventive measures. Acquisition of the data on results of risks reduction | |

The accepted decisions realized at \(l_1\) level. Unlike of \(l_1\) and \(l_2\) levels decisions are, as a rule, accepted alone. Informational exchange with the upper management levels in \(g_2\) should be comprised in the form of requests for refinement of the situation or the use of additional reserves. In the other modes every management level updates informational resources according to the regulations.

Informational processes in support for the decision making include successive execution of the functions on the acquisition, consolidation, storage of the data, analytical and situational modelling, formation of solutions. In this cases IT technologies are enabled, \(IT = \{i_{t_1}, i_{t_2}, \ldots, i_{t_5}\}\), where \(i_{t_1}\) – are technologies of data storage; \(i_{t_2}\) – technologies of the analytical data processing; \(i_{t_3}\) – geoinformation technologies; \(i_{t_4}\) – web-technologies, \(i_{t_5}\) – intellectual technologies. Their multiple number demonstrates variety of technologies aiding to realize the functions of data processing. For example, when forming of solutions basing on the simulation of maximal water levels expert systems, neural networks and other technologies of the artificial intellect (AI) can be enabled [8, 9].

Hierarchy of design of the management system for the safety of territories stipulates the requirements to the presentation of results of the data processing. Not numerous specialists at \(l_1\) are able to develop technologies of the situation simulation with a detailed validation of the flood consequences and variation of the responses. At the municipal level there are no degrees of freedom while choosing solutions. At \(l_1\) level, a compact information is required for support of management taking up several display windows of smart-phone.
3. Monitoring of environment using BigData

Prediction of the probability of ES occurrence at hydraulic objects is formed on the basis of meteorological data, observations for water regime, analysis of characteristics of the sources of danger (water streams, hydraulic facilities, stream crossings). Methodology of hydrological forecasts has been actively developed from the middle of the past century. In the short-term calculations of hydrographers some empirical coefficients are, as a rule, applied which are unique ones for every river site [10]. Integration of the distant sounding of Earth and BigData makes it possible to extend the application of forecasts and to automate identification of the possible dangers. Supplement of the classical methods with the means of intellectual analysis specifies and refines the forecasts within the temporal and spatial scales. It is really important for the territories of Siberia and Far East with a wide spacing of meteorological stations and hydrometric stations.

BigData, being the basis for the forecast seems to be Global Forecast System (GFS). Meteorological information written in 354 layers for all of the Earth surface with a spatial resolution of 0.25° is updated four times daily [11]. Operative and archive observations of the surface water regimes are also available in the Internet [12]. The source of Big Data is a technology of the Internet of Things (IoT) involving sensors of the operating conditions for the objects, cloud and dim calculations [13].

Since prognostic models are characterized by the different content of the input and output data and algorithms of processing it seems reasonable to apply container calculations [14,15]. Universal analytical platform is projected with the account of the possibility to solve various problems. It includes sizes of floods during the spring flood high water, ice jamming during ice break, accident rate at hydraulic facilities, etc. Complex validation of the risks includes ranking of the territories by a degree of their vulnerability under the impact of dangerous factors, a control for preparedness of the power and means to the emergency responses.

4. Adaptive organizations of the informational resources

Modern information technologies allow automatic formation the shared information resources with the adjustable access and independent services of the analytical and situational simulation used for the development of the management decisions [16]. This is supported by increase of the number of the data sources in monitoring systems including information on the operative situation and the ordered archives, and unification of the formats for data access. Projecting of organization of the informational resources is a basis of the informational-and-analytical systems and services. Conceptualization of the informational resources in the form of ontology unlike of the data-logic model makes it possible to represent the change in the data content in a dependence of the problems, technologies, and external informational environment.

Ontology of the informational resources (Figure 1) can be represented as:

\[ A = < O, P, T, D, IT, M > \]

Where \( O \) – are characteristics of the objects used for the description of the safety state for territories. Their list is determined by analysis of the occurred events;

\( P \) – are the processes of the dangers advance; the processes of loss of the functional capabilities for the protected objects under floods of different provision or as a result of the accident scenarios at hydraulic facilities; processes of elimination of the ES consequences, protection and supply for the population, etc.;

\( T \) – informational support of the management decision;

\( D \) – structure, content, regulations of the data updates, determined by characteristics of the monitoring systems;

\( IT \) – informational technologies of data processing determining requirements to the data storage;

\( M \) – analytical and situational models.
The size and format of the article does not allow to consider in details the classes of the ontology objects and relations between them. Novelty of the approach is in the inclusion of not only tables of data, handbooks and classifiers into the informational resources but also the knowledge of the dangerous processes, their consequences and the variants of easing for the negative consequences of ES. Specification of ontology integrates the structure model of data, formalized descriptions of the simulation results as well as the knowledge which prove to be a basis for the formulation of solutions in certain environment. Relations of \( M \rightarrow O \) form dynamic passports of territories [17], \( M \rightarrow P \) – predicting probabilities, sizes and consequences of the land floods [18], \( M \rightarrow T \) is a complete cycle for the formation of solutions under a threat of ES occurrence [19].

5. Simulation

Model of actions for the elimination of ES consequences takes into account the distribution of time for a design of the aggregate of facilities for the operative performance of the rescue operations. With the account of uncertainty and incompleteness of the information a lot of the alternative solutions is described \( X = \{x_1, \ldots, x_n\} \), where \( x_s \) – are alternatives, \( s = 1,\ldots,n \). In order to choose the optimal variant of action a pairwise comparison is made by the use of the system of coefficients. These coefficients characterize the external factors of the ES environment \( Y \). Note that the persons making decisions do not know a certain state \( y \) form a set of \( Y = \{y_1, \ldots, y_d\} \). For a lot of set of solutions \( X = \{x_1, \ldots, x_n\} \) and \( Y = \{y_1, \ldots, y_d\} \), the characteristic is determined, described by utility function \( F_i = \|f_i(x_s, y_j, p_j)\|, x_s \in X, y_j \in Y \), or by loss function \( s_t, x_s \in X, y_j \in Y \).

In the process of validation several situations are possible that is connected with the presence of information on the status of external factors in ES of hydraulic type:

- It is assumed that the leader making decisions knows the distribution of the probabilities

\[
p = (p_1, \ldots, p_d): 0 \leq p_j \leq 1, \sum_{j=1}^{d} p_j = 1 \text{ theonsetofanemergency } y_j \in Y.
\]

- ES of hydraulic character tends to the choice of the states \( y_j \in Y \), providing the least (the greatest) value of the utility function (loss function) from a lot of its maximum (minimum) possible values.
The leader making decisions has inaccurate information on the states of external factors of ES. Thus it is required to solve the problem of choice – to separate the best alternative \( x_s \in X \). The introduced utility function \( F_i \) is used for the estimation of the system characteristics, \( c_i \), describes utility, probability of the goal attainment. For the decision-making the entropy \( H_i \) can be applied, that is a measure of uncertainty estimation.

Solution is presented in the form:

\[
c_i(p, x) = \min_{x_s \in X_1} H_i(p, x_s) = \min_{x_s \in X_1} \left( -\sum_{j=1}^{d} \frac{p_j f_i(x_s, y_j)}{\sum_{j=1}^{d} p_j f_i(x_s, y_j)} \ln \frac{p_j f_i(x_s, y_j)}{\sum_{j=1}^{d} p_j f_i(x_s, y_j)} \right)
\] (1)

The considered criteria of the choice between the variants of solutions are taken as a basis of algorithm in support of decision making (Figure 2.).

**Figure 2.** Algorithm of choice between the actions for the elimination of ES consequences of hydraulic character under conditions of indeterminacy.

It is shown that solution of the problem of analysis and improvement of existing system for the elimination of ES consequences operating at the hydraulic object is possible with the use of Markov process.

6. System architecture

Flexibility of presentation of the information resources designed in order to use the modern information technologies is extended in the system architecture. The architecture determines the functional of the developed informational-analytical system for different modes of operation \( G \) and various management
levels for the flood-control protection of territories, substantiates the choice of the program components for the rational ways of complex solution of the management tasks. Figure 3 represents the components of system architecture:

- data warehouse with a unit for consolidation of the information resources;
- subsystems and services for data processing;
- subsystems and services for data processing;

![System Architecture Diagram](image)

- **Consolidation of information resources**
  - Web resources
  - Data consolidation tools
  - Corporate monitoring systems

- **Emergency services**
  - Data store
  - Directory maintenance subsystem

- **Implementation of management tasks through the functions of information systems**
  - **g_1**: Operational identification of flooding threats, analytical modeling; forecasting the situation, situational modeling; formation of possible emergency scenarios; information and notification; formation of recommendations.
  - **g_2**: Rescue and life support of people, analytical modeling; situational modeling; protection and rehabilitation of flooded areas; formation of recommendations.
  - **g_3**: Comprehensive assessment of flooding risks, analytical modeling; situational modeling; control of measures to reduce risks; formation of recommendations.

- **Management processes**
  - **g_1**: Day-to-day management
  - **g_2**: Prompt response
  - **g_3**: Strategic planning

- **Human-machine interface**
  - Specialized PC, analytical modeling, situational modeling
  - PC administration, data management, access control

- **Application / Purpose**
  - Web site: operational monitoring, access to archives, information exchange gateway, data collection, dynamic model atlas
  - Mobile applications: notification, data collection, visualization of the situation

**Figure 3.** Architecture of multi-service informational-analytical system.

Data are updated in the daily mode of functioning \( g_1 \). In the emergency case response \( g_2 \), it is possible to use data describing objects and processes from a set of spatial data \( d_4 \) directly from the external systems or straightly from external systems. For example, while integrating service of simulation with the Rosreestr (State Registration, Cadaster and Cartography service) spatial request forms a list of the flooded buildings. Basing on their characteristics and calculations of the damage rate it is possible to estimate the scale of consequences, amount, meaning and the order of execution of measures for protection and life-support of population, the works for recovery of the infrastructure operations.

Subsystems (services) for the data processing are combined in groups in the order of use of the systems by different subdivisions while employing the information support of the management system. Analytical processing of the operative monitoring of the data reveals the threats in the data flows and it is applied for the formation of ES forecasts. The preparation processes of ES scenarios and realization of the management procedures are complementary ones. Accumulation of the knowledge on the order of responses is performed by formalization of the occurred situations and modelling of the possible events by the experts during exercises and trainings. Development of the standards in the field of knowledge exchange makes it possible to form federal base of scenarios, to escape mistakes in management under occurrence of the large-scale events which are rarely appear for municipality \( l_2 \).
Solution of the problems of strategic management $g_1$ is based upon the complex risks validation. For example, ranging of hydraulic facilities by a degree of danger depends on the number of factors, among them the state of a dam, capacity of reservoir, conditions of formation of the excess water volume during spring flood, urbanization level at the tail water, the degree of “protection” of the settlements and objects in the areas of the higher risks by the rescue teams, by possibilities of the timely evacuation, implementation of the medical, anti-epidemic and other measures. For the acquirement, ranking, seeking of dependences between dozens of the rates and presentation the results of analysis in a convenient form the technologies of OLAP, Data Mining, GIS, dynamic web-infographics are applied as well as the other ones.

In all of these processes the task of transferring information up to recipients is solved. In case of emergency alert it is simply a brief message that is enough for an adequate response with the following refinement of the current situation. In the processes of $g_1$ and $g_2$ when there is a time float for making decisions the results of the analytical processing include a detailed description of events and objects with several types of their presentations.

Web-administrating facilities are necessary for the adjustment and modernization of the data acquiring subsystem, representing information on-site, management of access to the resources of the informational-analytical system. With the development of web-technologies it is possible to realize the functions of consolidation, management and processing of the informational resources through the use of internet-browsers, including the work with the sources of data, development of the analytical and situational models, designing of the results presentation.

The gateway allows interacting with the other systems using API technology. Basing on the browser request data sampling is generated in JSON and XML formats.

Mobile applications are developed on the cross-platform basis and they realize functions of data acquisition, mapping of monitoring environment information and characteristics of the territory. One of the main functions is the exchange with the emergency messages and operative alerts. In order to localize information geo-positioning facilities are applied and for the work with personal data – encryption facilities are used.

7. Conclusion

The problems of territorial management for their safety provision are formalized in the work. Model of organization of the informational resources was developed allowing to realize analytical and situational simulation for the management problems in the dangerously flood situations.

The model of choice between the actions was implemented allowing estimating and verification of realization of the plans concerning ES elimination. The model diminishes the time spent for the choice, justification, coordination and concordance of the actions while responding the occurrence, development, localization and elimination of ES consequences that are connected with the landfloods.

System architecture of the end-to-end support for the processes of management of the territory safety has been developed in the work that making it possible to design multi-service program complexes. Unlike of the known variants the elaborated architecture makes it possible to determine the functional of the designed system for the different operation modes and different management levels, to justify the choice of the program components and rational ways for the complex solution of the management problems.

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