

Method of increasing data maturity for territorial safety management ¹

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Abstract—The creation of intelligent systems for supporting territorial security management includes a new method for designing information resources. The main problem in making coordinated decisions on emergency prevention and rapid response to hazardous events is the low quality and incompleteness of data. Increased trust in data among decision makers is possible due to the compactness of data presentation, determined by the organizational model and the connectivity of information using the knowledge model. Unlike existing solutions, the proposed method allows to increase the efficiency of the emergency protection system by systematically changing the processes of solving management problems. The purpose of the method is to minimize the costs of obtaining and pre-processing data. Reducing routine procedures by approximately 80% allows you to focus on developing optimal solutions and comprehensively considering alternatives. Improving the quality of territorial protection management leads to a reduction in losses from emergency situations.

Keywords: intelligent system, information resources, data maturity, base of knowledge.

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1. INTRODUCTION

Ensuring natural and man-made safety of territories is a national strategic priority for Russia. Digitalization of emergency risk management processes includes solving the problems of extracting constructive, useful information from big data, discovering and disseminating knowledge. A systematic approach to organizing data helps reduce the uncertainties decision makers. These uncertainties are caused by a multitude of difficult-to-measure factors that determine the emergence and development of dangerous situations, and the entropy of the data collected and processed.

Now there are numerous signs of a phase information transition. Rapid and radical changes in technology cause difficulties for people to adapt to the new reality [1]. Managing complex systems requires a high level of competence that the education system cannot provide. The exponential growth of data volumes is roughly equal to the limit of its comprehension. The information content and quality of data are decreasing. The resource intensity of decision-making processes is growing. The creation of intelligent systems for corporations and public administration is relevant. The processes of creating and transforming data must be accompanied by an increase in their value [2].

Receiving and processing complex monitoring data is the main process of ensuring natural and man-made safety of territories [13]. Now implementing data consolidation from many information systems, sensors and other sources [4]. The accuracy of models of situations that take into account a large number of factors, their scale and probability of occurrence is increased [5]. However,

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decision-making is usually based on weakly formalized reports, only a small part of which is collected using specialized services. The quality of management remains low due to the imperfection of regulatory and methodological documents governing interdepartmental information exchange and the lack of a systematic description of information resources.

J. Davis (SAS Institute, 2009) identified eight levels of analytical data maturity, from simple reporting to predictive modeling and optimization [6]. The concept of data maturity is defined through the ability to effectively manage, analyze and use data. This depends on the degree of integration of data into management structures, business processes and decision making [7] Increasing data maturity and transitioning to intelligent workflows are an integral part of the implementation of digital platforms in state and municipal administration, including for ensuring territorial safety [8].

As part of the strategy for digitalization of the Russian economy, the Government Coordination Center, together with the Ministry of Digital Development, is developing a federal incident monitoring system [9]. The main focus is on monitoring the execution of orders from higher authorities. The system does not cover the entire cycle of situational management. Important information needed to build knowledge about rational ways to ensure the safety of territories is ignored.

The central element of the digitalization of the management of natural and man-made safety of the territory is the Automated Information and Management System (AIUS) [10]. Its components (Risk Atlas, Thermal Points, etc.) display a small part of the information necessary for prompt response and planning of measures to prevent emergencies. The volume of informal documents duplicating electronic resources is growing.

The widely used information Systems "112" and "Safe City" are designed for operational monitoring of events [4]. Decision support for dispatchers is implemented at the level of action algorithms in typical situations. When large-scale events occur, management is carried out by groups of experts, the information for which is processed manually.

We propose a method for increasing data maturity using a management model and a knowledge base. Systematic implementation of data, metadata and knowledge management processes is necessary for the creation of multi-tasking intelligent systems, expansion of the scope of application of analytical and situational modeling, formation and justification of management decisions.

The paper is organized as follows. Section 2 describes the problem statement. Section 3 presents the components of a data maturity improvement method. The process of increasing data maturity is discussed in Sect. 4. Finally, we conclude the paper in Section 5.

2. PROBLEM STATEMENT

The idea of this work is the hypothesis of the possibility of creating an intelligent system that allows a decision maker to effectively manage the security of territories, even with a lack of experience. Rule-based systems are used in energy [11–13], aviation [14], and medicine [15, 16]. The expert system for emergency response ESPLA developed at the ICM SB RAS provides support for operational duty shifts in natural and man-made emergencies [17]. Users of such systems have special training and have confirmed their qualifications through numerous exams and tests. In essence, industry intelligent systems are virtual assistants that generate optimal management strategies based on precedents with a calculated degree of similarity.

The situation is different in territorial administration. Decision makers hold elected positions and do not have the opportunity to gain practical experience in emergency management. Preventive measures programs are unique for each territory and period, which makes it difficult to apply standard schemes and algorithms. Formal approach to emergency action plans underway. The form of presentation of plans does not allow for the prompt use of constructive data.

Analysis of past emergencies revealed typical management errors:

- incorrect assessment of the significance of factors determining the management result;
- incorrect assessment of the number and composition of decision executors;
- incorrect assessment of the required material resources;
- erroneous planning of the timing of decision implementation;
- erroneous planning of the volume of work performed, leading to overspending of resources, an increase in the volume of related processes;
- incorrect sequence of process execution;
- unjustified replacement of a process with a less effective one.

Mistakes in decision making can be minimized by using scenario modeling. It is based on: analysis of similar situations; recommendations for actions taking into account the current and predicted factors of the situation [18]. The effectiveness of decisions directly depends on the quality of data with a reasonable level of detail, the reliability of which is beyond doubt among decision makers. Solution options should be presented in a form that is convenient for decision makers: infographics, dynamic maps, short texts. For example, processes are ranked according to criteria such as location, volume, and optimal sequence of their implementation. It is necessary to correctly compare deterministic indicators (financial resources) and probabilistic ones (damage, losses, etc.).

The transition from data to management is possible through knowledge – a special form of representing processes. Unlike a neural network, the compactness of the concepts used and the rules for forming situation scenarios minimizes the number of incorrect decisions. The applicability of decisions generated by an intelligent system depends on two factors. This is the completeness of the descriptions of processes in the knowledge base, which defines typical management techniques for different situations and the maturity of the data that forms solutions for a concrete task. To form and verify knowledge and record the opinions of different experts, high-quality data is also necessary.

According to [2], data governance is the development, implementation, and control of policies, programs, and practices for providing, verifying, protecting, and enhancing the value of data and information assets throughout their life cycle. The objectives of management are to identify and serve the information needs of the organization and to ensure the effective use of data. Information needs, in turn, are determined by the business processes being implemented.

Our method defines the rules and requirements for constructing information resources in the form of a set of typical patterns that simplify understanding of the structure and purpose of data and information processes. For this purpose, an organizational model and a knowledge model are used.

3. DESCRIPTION OF PATTERNS FOR INCREASING DATA MATURITY

The diversity of emergency and crisis situations and the variability of their scales require the involvement of a large number of actors performing the tasks of warning, response, preventing escalation, and eliminating the consequences. The difference in authority and available resources determines the variability of management decisions, formed in different ways from different sets of data. This complicates the development and implementation of cross-agency decision support systems.

The systematization of the functions of actors is implemented in the organizational model [19]. This is a matrix where the terms are the levels of territorial management: federal, regional, municipal; facility. The columns of the matrix list the actors – territorial administration bodies, divisions of the Russian Emergencies Ministry and other departments that are solving a concrete task. For

example, for power system accidents these are network organizations, for natural fires – divisions of the Federal Forestry Agency, the Ministry of Agriculture, etc. Consideration of the characteristics of the matrix elements made it possible to determine the indicators used for decision-making, taking into account the authority and resource availability of actors. The connections between elements show the processes of data exchange and determine the policy for using third-party information resources to solve management problems.

The information support of an actor (the element of an organizational model) can be represented in an IDEF0 context diagram (Fig. 1).

The application of an organizational model pattern to a specific type of situation and management task is the *first step* in data systematization. "Inventorying" actors, their powers, decisions taken, the data required for this and algorithms for their processing allows us to reduce the complexity of understanding the entire diversity of data; justify the necessity and sufficiency of information; requirements for its structure and volume. The novelty of the method lies in the exclusion of "open-loop control", when the data consumer does not form decisions, or controls the execution of orders without clear criteria for the effectiveness of the results.

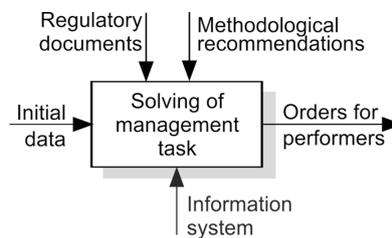


Figure 1. A pattern that defines the use of data by the actor

The *second pattern* used to improve data maturity is defined by the data model (Fig. 2). The model logically links event catalogues, territory passports, formation registers and resources used with crisis action plans and preventive measures programmes. This data set is sufficient to implement situational management. The advantage over other approaches is the compactness of data representation. The typical data structure is suitable for management in different types of situations. The tables contain two sets of indicators: those common to all emergencies and those specifying the decisions being made depending on the task (fields marked in italics). Model instances are used to provide information support for related management tasks, such as situation monitoring, management in high alert mode during an emergency, etc.

Analysis of homogeneous information (for example, only catalogs of events) does not allow for the formation of specific management decisions based on risk assessments. It is not advisable to complicate the proposed structure. Related management tasks, such as monitoring the situation, management in a high-alert mode in the event of an emergency, can be represented as an instance of a structure without loss of information content. The entities in the diagram have the following composition: field – primary key (PK); field – secondary key (FK); atomic field (+); reference on classifiers (-). Their content such as "Event type", "Object category", "Event type" is defined by normative [20]. The fields shown in italics vary depending on the type of situation and management task.

Below are the procedures used to process the data set. ETL() and API() provide intersystem exchange. Analytical models are used for pre-processing and dynamic visualization of data. The most difficult to implement are the Constructor of situation() and the Planner of measures().

Event attributes E allow risk assessment and mapping using traditional methods [21]. Unfavorable factors include uncontrollable factors (difficult weather conditions), as well as factors that

require preventive measures to eliminate M . For example, conditions that complicate fire extinguishing include the remoteness of fire stations and water sources; blockage of passageways; the presence of explosive and flammable materials/substances; the level of people’s awareness of fire safety measures and emergency response skills. The implementation of protective barriers as a result of preventive measures M allows for a more effective elimination of a dangerous situation and its consequences and a reduction in losses. At the same time, it is not always correct to compare material damage and prevention costs due to the subjectivity of assessments and long-term changes in external factors that determine the safety of facilities and territories. The register of protected

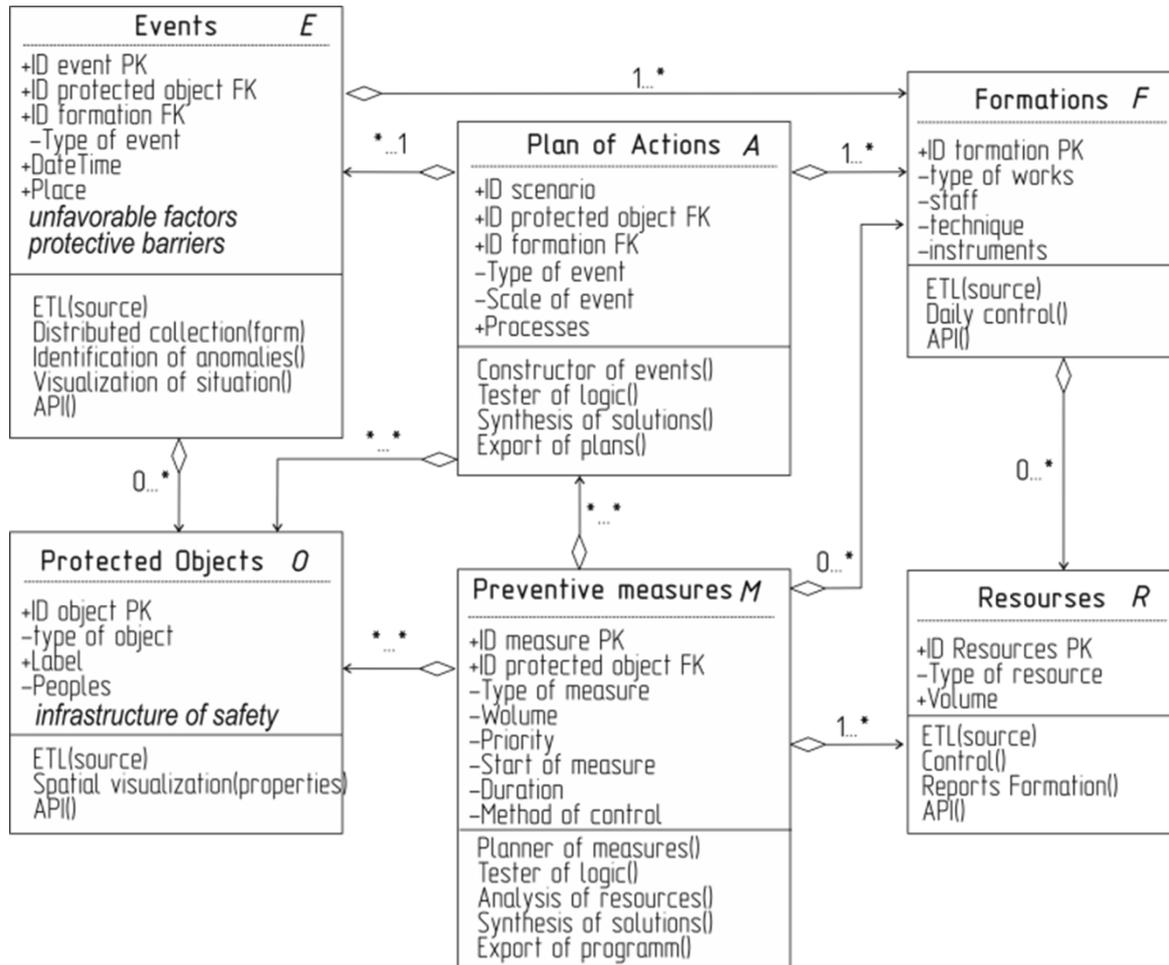


Figure 2. Data structure in the form of a class diagram

objects O contains data on populated areas, infrastructure, as well as information on objects of supervision located in them, potentially dangerous industries, institutions with a large number of people, etc. Depending on the position of decision makers in the territorial management hierarchy, the model allows data to be presented with varying degrees of detail. At the same time, the volume of data is practically constant, since such a presentation is convenient for the decision maker.

The register of formations F contains information on all formations participating in the response to E , including rescuers, professional and volunteers, volunteers, as well as divisions of ministries, departments, and organizations. There is a limitation on maintaining the event catalog - forces and means can be selected from the list, and not registered simultaneously with E .

Resource data R includes consumables, fuel, food, medicines, and life support supplies for victims. They are used both in emergency situations and during preventive measures. To control the established standards in R and F , reference books of criteria developed on the basis of regulatory documents are used.

Plan of Actions A contains a description of the use cases. Joint analysis of process descriptions in A and E is used to eliminate “inconsistencies” and gaps in planning operational activities. The precedent knowledge base describes the processes of eliminating hazardous factors and consequences of emergencies, organizing the protection and life support of the population in the form of a sequence of atomic processes, logically linked by metrics. This allows constructing scenarios based on standard templates using graphical and text interfaces [22].

The results of solving the prevention tasks are reflected in the table “Preventive measures” M . The formation of a database of completed and planned work will allow it to be used as a training sample for recommendation services, for searching for analogs, and also as a teaching aid for decision makers.

The data from the registers has a cartographic link, which allows us to construct maps of risk distribution and situation dynamics. Spatial analysis tools can be used to verify the distribution of hazardous factors, determine the areas of responsibility of formations, and assess the consequences of emergencies for O . Some analytical services are deployed on the geportal of the Institute of Computational Modelling and Matrosov Institute for System Dynamics and Control Theory of Siberian Branch of Russian Academy of Sciences.

The *third pattern* contains characteristics of the data entry and transformation processes. The DMBOK Guide [2] lists the types of data flows that are an integral part of data models. For ease of description in relation to the area of ensuring territorial security, we will divide them into groups.

Getting data

The main tool for data formation is the *consolidation* process. Currently, there is an imbalance between well-developed technologies for intersystem interaction and the episodic practice of interdepartmental information exchange on a permanent basis.

A promising direction is data *federalization* – providing access to remote resources for performing calculations without copying the original information.

Distributed data collection technologies ideally involve filling out forms via a browser into cloud storage with automatic updating of analytical models. Most of the existing solutions used by territorial government bodies only implement export to Excel. The maturity level of such data exceeds that of .pdf and .ppt formats, but cannot be considered satisfactory for use in analytics and decision making.

Working with data arrays

The variety of tasks and conditions for making management decisions determine differences in data storage methods. System-forming data (directories, classifiers) uniform for the entire country should be available through cloud services. Data warehouses are the most convenient for processing monitoring information [23]. Autonomous management in the Arctic requires the use of local databases and data *movement* services – operational synchronization.

To implement *data dissemination* methods needs the standards for the design and operation of government information systems. They must establish requirements for information gateways and metadata content. The implementation of the law on data disclosure is still spontaneous and complicates the construction of a common information field.

Data *protection* technologies in the field of natural and man-made safety have been implemented in relation to passports of potentially hazardous objects, civil defense, and action plans for special period.

Monitoring data used to verify predictive models are subject to *archiving*. The life cycle of all data ends with the *deletion* process.

Transformation of data content

The multitude of sources of complex monitoring data and the diversity of the data obtained determine the relevance of improving pre-processing methods. For verification we developed the criteria for filtering false signals. The *improvement* includes filling in time series gaps, changing field formats (dates, geographic coordinates, units of change, etc.).

The organizational model shows a limited list of tasks that require the use of personalized data. When exchanging information, it is recommended to *anonymize* data. According to I.S. Ashmanov, the rules for using personal information should be identical to the rules for handling radioactive materials [26].

Linking data greatly increases its value for management [24]. This process is mandatory, for example, when using spatial analysis, comprehensive risk assessment, etc. [27].

When developing government information systems, due attention is not paid to the *data certification* process. It is necessary to consolidate the status of state information resources for the results obtained through analytical and situational modeling using approved methods. For example, data on ranking a territory by risk (flooding, seismic hazard, etc.) as part of the land registry should be taken into account not only in emergency response plans, but also in master plans for the development of territories, when calculating insurance rates, and solving other territorial management tasks.

The listed processes determine the maturity of the data. Its level correlates with the effectiveness of decisions. Most decision makers consider the dynamics of achieving the target indicators defined by the decree of the President of Russia to be effective management [27]. However, in addition to reducing the number of people affected by emergencies, damage from natural disasters and man-made disasters, it is advisable to assess the costs of obtaining information, the duration and structure of its life cycle.

The implementation of the listed processes allows a systematic approach to the formation of the information space as an ordered set of data suitable for machine support of management. The applicability analysis performed for pattern 3 for each type of situation and manage task. For example, territorial security characteristics are formed mainly through distributed data collection. It is advisable to consolidate data on population and development using certified sources. Processing of the results of operational complex monitoring, with a sufficient level of maturity, is based on the data federalization [28].

The *fourth pattern* is defined by the knowledge model and is used to formalize the stages of solving a specific management problem. Verbal formulations of control actions are contained in decisions of emergency and fire safety commissions, orders and instructions of various departments and levels of territorial administration. “Classical” processing of a text array by large language models in order to find solutions for a specific set of situation parameters is not advisable for several reasons. This is the lack of a Russian-language corpus of texts on territorial security management of sufficient volume; additional costs for verifying high-quality solutions in the training sample; strict requirements for the reliability of the solutions obtained.

A pattern is an ontology that describes the relationships between concepts in the form of rules. Situations are presented in a graphical form, reflecting the sequence, conditions of execution and characteristics of processes. This simplifies the most problematic stage – the extraction and formalization of expert knowledges. The degree of maturity is determined by the possibility of replication for multiple use. Ontologies have been built for the basic risks of Siberia, systematizing possible options for responding to emergency situations and dangerous precedents, as well as linking a set of preventive measures into a single logical scheme [29]. We exploring the possibility of identifying

concepts that are key to decision-making from regulatory and methodological documents through the construction of cognitive maps.

4. DATA MATURITY PROCESS

The process of using the listed patterns together (Fig. 3) consists of twelve steps and is repeated for each type of situation and management task (1).

Based on differences in the composition and volume of data, the tasks of ensuring natural and man-made safety are divided into four types:

- collecting or consolidation information, identifying and responding to situations requiring management action (daily management);
- response to emergencies and dangerous situations (operational management);
- planning and implementation of long-term risk reduction measures (strategic management);
- management in cyclic (seasonal) emergencies.

Further (2) describes the sets of possible management decisions formed by actors within the framework of the organizational model, information processes and initial data. If it is possible to reduce data processing links (3), proposals are made to optimize management processes (4). This is a necessary stage in the digitalization of management. The authors' experience has shown that using the actor interaction scheme (5) "as is" does not allow building intelligent systems with a long life cycle. In step 6, an instance of the data structure is developed for a specific task. In this case, all possible processes of their processing are analyzed (7-10). Starting with (11), scenarios of situations are formed and debugged. They are then integrated into emergency action plans and programs for improving territorial security for government bodies at various levels [18].

5. CONCLUSION

Territorial security has shown the need for high-quality data for current operations and long-term planning. In the process of building an intelligent system, a lot of work is required to formalize information resources in accordance with the given patterns. Taking into account the factors presented in the typical data structure will allow achieving greater information content than using "classical" assessments of territorial risks [30].

The proposed approach is currently being tested in several municipalities of Krasnoyarsk Krai. The results demonstrated the effectiveness of "data-driven management", using information as a strategically important asset. Proposals have been prepared for the use of research data in the creation of a Coordination Center for Regional Management.

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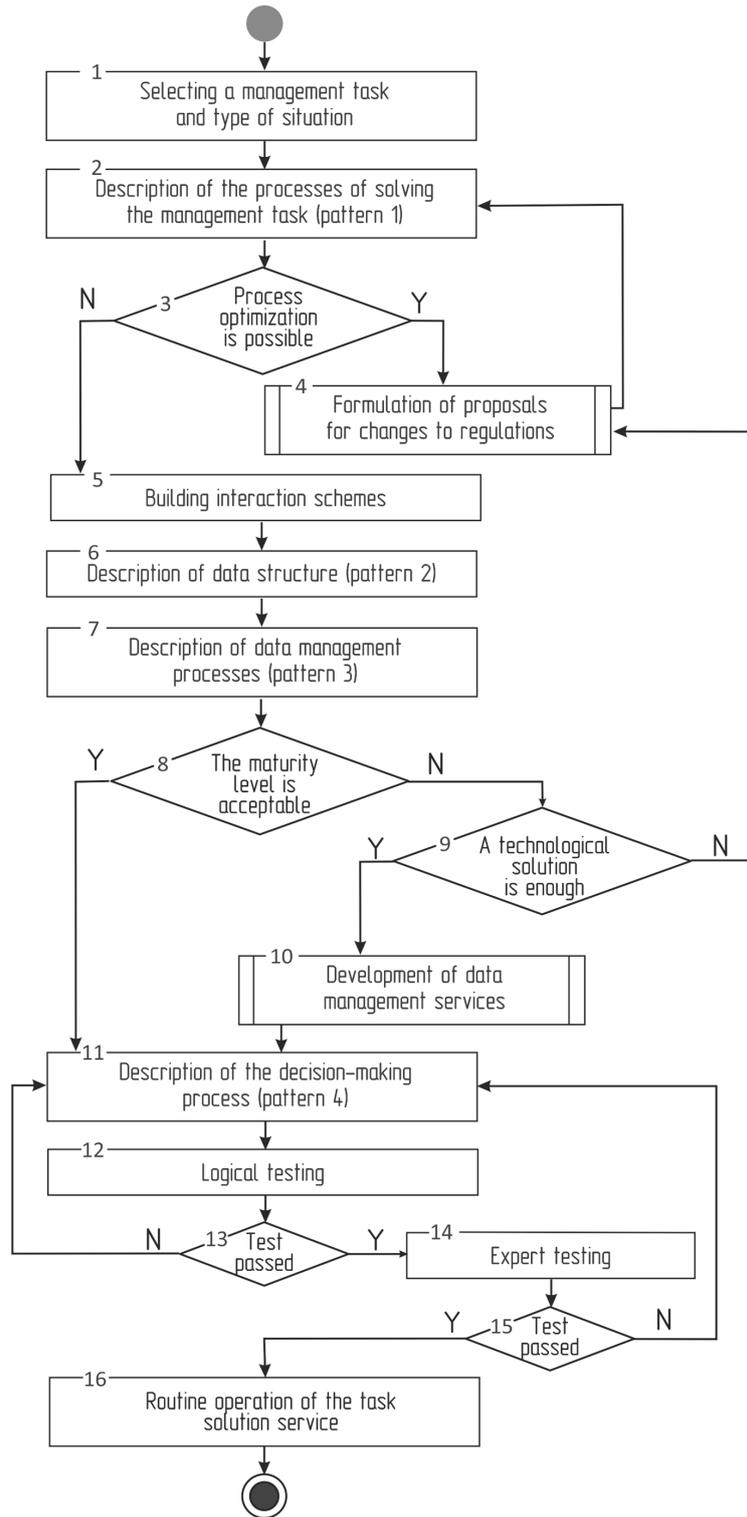


Figure 3. An algorithm for applying patterns to increase data maturity and use them in territorial safety management

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