Formalization of the Disasters Impacts on Enterprises and the Population and Recommendations for Decision-making

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Abstract. Information model proposed to describe situations of impacts disasters on industrial facilities and population, to make recommendations for decision-making. Methodical questions of knowledge formalization on the impacts of disasters and recommendations for preventive activity presented. The structure of the database of threshold values of disasters indicators developed. The database on impacts and recommendations has been created for more than 100 dangerous situations, for various objects and activities, in the period before disasters (based on climate and prognostic information), at the time of disasters (real time data) and after the disasters.

Key words: Disasters, Impacts, Recommendations, Formalization

1 Introduction

Disasters – strong wind, rain, extreme heat, floods, fog, waves and others – cause enormous material damage and even result in death [8]. Many losses could have been avoiding if business leaders and the public would not only receive timely information about disasters, but also to know what can happen because of their exposure to the disaster and what should be done to reduce or prevent adverse impacts. To this required automatically bring information about disasters to the decision makers of it at the initiative of the system, not the person; visualize information about dangerous situations in the form of a text description, interactive maps, the results of monitoring of hydrometeorological situations with an indication of the level of danger (yellow, orange, red), separately for each object of economy and type of activity. Impacts and recommendations for making decisions should input with assessing potential damage and calculating the cost of preventive measures. Such tools call decision support systems (DSS). The main approaches to the development of such hydrometeorological support are presenting in the articles [1, 5, 9–11].

Decision makers gain experience in dealing with natural disasters in the course of their activities. Moreover, they are confronting with certain disasters (for example, tsunami, and earthquakes) sometimes only once during the entire period of their activity, in result accumulated experience is lost. Existing experience is not always reflecting in instructions, is poorly formalized and often is presenting in a much-generalized form. This experience is stored in the memory of a person in the form of non-formalized information, skills, and abilities. Traditional forms of knowledge representation in the form of instructions, Internet pages have the following limitations: a long search time, knowledge is presenting in different sources, sometimes even a contradiction arises in them.

Despite the fact that the first studies on the creation the DSS in the field of preventing the disasters impacts began in 1990 [9], this field of research is still in the "embryonic" stage. In other branches of DSS, they are already working in permanent mode, for example, in the field of energy [12]. The most advanced solution support system currently available is Watson, developed by IBM. This system is using as a medical assistant. Using the approaches implemented in the system for our tasks may be possible, but this solution is too expensive, system operation algorithms are not clear.

If at the beginning 90-ies the main problem when creating DSS was the lack of methods and tools of creating them, then in the late 90s there was a shortage of materials with impacts and recommendations for decision-making. Currently, the Internet and other publication contains a lot of different manuals, instructions and regulations that need to be formalized and presented in the form of knowledge base.

For the development of hydrometeorological services at the modern level of IT technologies development, it is necessary to create a knowledge base in the form of formalized information on potential impacts and recommendations for decision-making, a database of threshold values for disasters indicators, software tools for identifying disasters, and searching of knowledge.

2 Information Model of Knowledge Description

The basic idea of creating a DSS is as follows. Knowing of the environment conditions is possible to determine in advance the list of impacts of natural disasters for the population and enterprises. Knowing these impacts, you can make a list of recommendations on the behavior of the population in these situations, as well as a list of recommendations to support decision-making. For the same hydrometeorological conditions at different enterprises and depending on the time of year, there may be different solutions.

Before applying the knowledge accumulated in traditional sources, a person must find and interpret them to solve a specific problem. This complicates and slows down the process of preparing a decision, at the same time in practice the use of knowledge and decision-making should be carrying out immediately after receiving the initial information in real time. In addition, in traditional forms of storing knowledge, the process of changing and supplementing new knowledge seriously hampered.

To create a DSS, formalized knowledge of scientists and specialists, registered in the literature, should be introducing in the knowledge base. An important point in the formalization of knowledge is the understanding that, depending on the time of use knowledge (before, at the time and after disaster) you must to use a particular type of information (observation, analysis, short-term or long-term forecasts, and climatic data).

To create a knowledge base for impacts and recommendations, it is necessary to define a situation description unit, select attributes, and define attribute properties. If the description unit in the selected situation determines solutions for one value of the observation, forecast or climatic indicator, is basing on three dangers levels, for 50 disasters, hundreds of typical objects, four type of activity, then the total number of cases may exceed ten thousand.

The basis of knowledge are list of rules (if, then, else). In a semi-formalized form, these rules look like this:

DISASTER: <name>; BACKGROUND: <text>; GEOGRAPHIC AREA: <list>; PERIOD (DATE): <from … <to …>>; OBJECTS OF IMPACTS: <list>; IMPACTS: <list>; RECOMMENDATIONS < list >.

Knowledge written in the form of rules has a disadvantage – with a large number of them, it becomes difficult to check their consistency. Therefore, the DSS is proposing to use the no classical knowledge bases in the form of rules, and the database of thresholds values of disasters indicators depending on the object type, type of activity on object, the location of the object, dangers level, season, climatic region. Danger levels create for the population, technical systems, building structures, ships, ports, and so on. The analysis of various situations connected with disasters and the formalization of information about these situations allows suggesting the following form for describing them:

1) Name of disaster;
2) The determination of the disaster from the meteorological dictionary;
3) The causes of the disaster (text description);
4) Photos with examples of the manifestation of disaster;
5) Impact objects (port, housing and communal economy, population);
 5.1) Name of the object, which may be impact by disasters;
 5.2) Information type (climate, forecast, in the moment disaster and after the disaster);
 5.3) Impact indicators and their meanings;
 5.4) Level of danger;
6) Impacts (name, type of activity affected by disaster, priority, author, possible potential damage);
7) Typical impacts (using for several disasters);
8) Recommendations (name, level of management to which the recommendation, priority, author is intended, cost of preventive measures of the activities, reference);
9) Typical recommendations (used for several disasters);
10) Reference to situations related to others disasters;
11) Sources of information (bibliography).

The identification of disasters is a procedure for determining the list of possible impact on object for various levels of danger. Here one can use such indicators of disasters, as threshold values, probability of disasters, risk, etc.

Disasters reasons are prerequisites for their occurrence. There, an important role is playing by environmental conditions (mountains, deserts) in which prerequisites lead to disasters (for example, heavy rains in the mountains lead to mudflows).

Each case of a dangerous situation is characterizing by the geographical area of manifestation, the duration of the risk, time of year, the climatic zone. If for a particular impact are several values of geographical and time conditions, then are several situations of dangerous impacts. The geographic area, as an element of the situation, is very important, since it often predetermines the fact of occurrence of a certain type of disasters (for example, flooding at the mouth of a river) and possible consequences of a phenomenon (for example, silt deposition on the banks of rivers from flooding). This property extends from the region "North hemisphere", "subtropics", "mountain area" to the level of names of settlements, transport objects (airport, seaport). There are the next types of geographic objects:

- global – "Southern Hemisphere", "World Ocean", "Arctic";
- geophysical – "tropic region", "tundra", "lowland";
- continent – "Europe", "Australia";
- ocean – "Pacific", "Atlantic";
- name of transport object.

The geographical region may have a specific value of is, at any level of the classification system ("pool Barents sea", "Caspian Sea Coast"). Water areas can be open sea, bays, estuaries, port water area. To display different types of geographic areas, it is necessary, in addition to the value of the geographic region itself, to store the attribute "Type of geographic object" (countries, sea regions, mountains, lowlands).

It may note the following features associated with the identification of disasters and their manifestation. The situation may include several disasters (for example, wind, heavy precipitation), some of them are complex (for example, "storm" is "strong wind" + "waves").

The description of the situations with disasters should contain information on the disasters indicators (air and water temperature, wind speed, height waves, speed for "strong wind"). Moreover, the consequences of the disasters impacts are determined not only by the threshold values of the indicators, but also by the conditions in which the "disasters" occurs. That is, depending on the conditions of exposure to disasters, disaster may be dangerous to one degree or another. For example, the same water level rise for settlements nearly river may be disasters, and for building on the elevation – no danger. That is, according to the sensitivity of objects to disasters, it is necessary to specify threshold values for individual objects and regions.

The situation with the disasters (for example, "flooding in the seaport") may be associated with various variants of disasters impacts:

- one type of impact on several facilities or activities, for example, wind speed affects port cranes and loading or unloading, vessels traffic in the port;
- one type of impact – one object of impact – several consequences of disasters exposure, for example, high sea level affects the seaport (complication of mooring of vessels to the pier, moistening of cargo stored on the pier, impossibility of stay at the roadstead);
- several types of impact – one or several objects of impact and a wide variety of combinations leading to various consequences of in this situation, for example, a storm leads to flood in the river (heavy rain); tearing off roofs, trees falling down (strong wind); fires, of death to people (lightning).

The procedure for assessing impacts and issuing recommendations includes the following work:

- description of the existing situation (nature, causes of the disaster, objects of impact, activities);
- defining a list of possible objects that may be affected by natural disasters;
- assessment of natural disasters that affect the object;

- description of the sources of data used for impact assessment;
- list of all expected impacts (indicator, dangerous level);
- impact criteria (at what values of the indicator comes a negative impact);
- determining the significance of the negative impact for each disaster and the object for which the assessment is being conducted;
- loss assessment;
- identification of preventive actions;
- assessment of the cost of preventive actions;
- choice of alternative solutions;
- development of methods and tools for informing and consulting of the public about possible impacts.

3 Methodical Problems

3.1 Selection of Indicators

To create a knowledge base, it is necessary to use observable, predicted and climatic values of indicators of disasters – the probability of their occurrence; threshold levels of disasters indicators; impact lists and recommendations. The regulatory document of Roshydromet [13] determines the composition of disasters, their indicators and general threshold values. For some regions of Russia local threshold values of disaster indicators have already been introduced. This refers to the water level, wind speed, air temperature.

Spatial-temporal properties of disasters are important for assessing their level of danger. They determine the disaster scale (local, regional or global), the place of manifestation of disaster (the name of the settlement, the river), the response time to disaster, the period of possible impact (instant or gradual increase of the impact).

Important properties of disasters are their intensity, power, amplitude, magnitude, etc. Intensity meteorological processes (wind speed and height of the wave) translates them into the category disaster. For example, wind speed becomes dangerous if it is more than 15 m/s in 1/3 of a federal subject with phenomenon duration of 6 hours. Threshold values of wind speed for oceans, Arctic and Far East seas are not less than 30 m/s, and for the mountain regions – not less than 35 m/s [13]. Threshold values are establishing by regulation and are depend on their impacts on economic activities in specific geographic areas, taking into account their repeatability.

For some indicators dangerous both low and high values, e.g., pressure, humidity, temperature of air, etc. (Table 1). It should be noted that the temperature of the air, water and soil has yet another threshold value "transition through zero degrees", which is considered as a separate disasters – frost (transition from a plus to a minus) and thaw (transition from minus to plus). Here it is important to use the forecasts and warnings of disasters [6], as well as climate risk assessments [7].

When specifying values of indicators of disasters, not only threshold values can be using, but also other types of indicators, for example:

- average (background) value – climatic value (rate) for the considered temporal and spatial resolution, for example, the medium amounts of precipitation;

- repeatability of climatic values – the number of cases (years) the manifestation of measured values of parameters in the specified intervals (wind speed is zero, 1–4, 5–9, 10–14, 15–25, >25 m/s; water level <150, 151–200, >200 cm) for a certain period, as a percentage;
- anomaly – the deviation of the parameter value from the climatic norm, which is triggering if the difference between the current and climatic indicator values is greater than the set value that is significant for air temperature, pressure, humidity.

Table 1. Thresholds of indicators

Indicators	Situations						
	Catast-rophic	Dangerous	Moderately indignant	Normal	Moderately indignant	Dangerous	Catast-rophic
Air temperature, ℃	<–35	–35 ÷ –25	–24 ÷ –20	–19 ÷ 20	21 ÷ 24	25 ÷ 35	>35
Air pressure, mb	<985	985–994	995–1004	1005–1015	1016–1020	1021–1030	>1030
Humidity, %	<15	15–30	31–40	41–80	81–90	91–95	>95

3.2 Determining of Thresholds Values

The most laborious and decisive step in the development of knowledge is the formation of threshold values for disaster indicators. Attributes of indicators description should include the activities type; time of year (the same indicator of disasters has different risks depending on the season of the year); geographical area (in different parts of the country, enterprises and people are differently prepared for the same disasters, for example, in areas of constant exposure to strong winds and frosts, the population has already adapted itself to surviving in such conditions). Therefore, the threshold values for every of activities type, season of the year, geographical area should be clarified.

For disasters, impacting on enterprises, refined threshold values of indicators are needed, within which it is possible to compensate for their negative impact with the help of preventive measures. The values of threshold values for specific objects and activities is basing on the existing experience of the manager. On this basis, the level of danger is the subject of an assessment of the safety of the vital activity of the population and industrial enterprises from disasters. For example, of the thresholds values are level of water, influencing the activities of the seaport or shops on the embankments in St. Petersburg; air temperature and precipitation during loading and unloading of perishable goods.

For shipping in the shallow strait requires a constant knowledge of specific values of the water level every hour and even more often. At a certain value of the water level can pass vessels with some draft. At the same time, for the construction of port facilities, on the contrary, it is necessary to know the extreme values of water level. Examples of indicators for disasters are presented in Table 2.

Table 2. Examples of disasters, which influences on different enterprises and populations

Disasters type	Name	Indicators of disasters	Objects (managing level)
Marine disasters	Waves	**Current or forecast information**: wave height>5 m. **Climate**: wave height recurrence with different wind directions.	Vessel (port authority, captain, passengers); tourism (business leaders, local government)
	Early ice cover	**Current or prognostic information**: date of occurrence of ice cover well before the average long-term date. **Climate**: max and min dates of ice cover.	Ship (port administration, ship captain)

3.3 Development of Impacts List

After determining of dangerous situations, it is necessary to evaluate possible impacts. The impacts assessment procedure includes the next steps: identification and analysis of disasters; determination of the impacts of disasters on enterprises and the population; identification of individual objects subjected to disasters with complex social or technical conditions; the identification of economic vulnerability to disasters; identification of secondary impacts from accidents and disasters at enterprises; identification of areas with a high probability manifestations impacts.

Determining the degree of impact of natural disasters on such objects as schools, hospitals, transportation plays a key role in determining the list of resources and preventive actions; identify the danger level and objects of impacts; vulnerability assessments of these objects; choice of decision criteria (loss minimization, safety of people). When assessing impacts, it is necessary to use accumulated experience in environmental impact assessment and disaster risk management [2–4, 16].

Identification of individual objects prone to natural disasters with complex social or technical conditions, also includes, for example, determining the percentage of people with low living wages, the number of elderly, children, uninsured dwellings, people without transport; potentially dangerous objects, that can lead to various accidents in the form of “a domino” effect. It is also necessary to describe the sources of data used for impact assessment; determine the significance of the negative impacts for each disaster and enterprise.

Detailed impact assessments can confuse managers and divert attention and resources from major impacts. Consequently, impacts must have priorities.

As objects of impact are used a enterprises, buildings, vessels, ports and whole industries such as maritime transport, fishing, agriculture, as well as activities for transportation of people, loading and unloading materials, transmission of energy. In the situations under consideration, objects are exposing to unintentional (spontaneous) impacts of disasters. Impacts can manifest themselves in different economy sectors and at different levels of government. Specific objects can be dividing by industry: mining and processing of gas and oil; transport; construction, etc. In each industry the division is already carried out on the basis of traditional classification, for example, in the “marine transport” emit “port facilities”, “passenger transport”.

The object of impact can be not only a material object or the branch of material activity in general, but also a functional process. Therefore, together with the system of material objects, it is necessary to take into account the system of functional impacts on production processes: generation of electric current, emission of pollutants; breeding of fish and mariculture; cleaning the air and water; ore dressing; unloading / loading materials, products; energy transfer; transportation of people, substances, materials; storage of goods.

A sufficient condition for detecting disasters is the excess of the danger level (power, speed, force or any other value of the threshold of the object's sensitivity) above the level of the object's resistance to impacts (seismic resistance of buildings, wind resistance, noise immunity of communication lines). Each specific object can be characterizing by the level of resistance in relation to the impacts of disasters. Just like the thresholds values, characteristics of the stability of objects in relation to external influences (moisture resistance, frost resistance, drought resistance, fire disasters, wind resistance, wave resistance, comfort or severity of climate) may be a properties of object. You can talk about the universal property of objects "resistance to external influences". The value of this property plays the same role as the threshold value of the disasters indicators (wind speed, number of precipitation, water level).

Impacts are considered in the context of changes in the state of objects (the condition of roads deteriorates, the availability of settlements decreases); of destruction of the objects themselves (bridges are destroyed, vessels are killed); of damage component element of objects (demolished roof, broken water pipes); occurrence a negative processes (soaking crops, which leads to the death of the crop); changing an object properties (reduced strength materials deteriorated operational characteristics of equipment), and the properties of the processes (reduces fishing, increases cruises duration).The prerequisites of impacts are called impacts conditions. They should be sought not only in the environment, but also in the places of impacts manifestation (for example, landslides often arise as a result of construction work on the hillsides). The reasons for the landslide here are the condition of the soil after heavy rainfall, and the prerequisite is the construction work. Prerequisites for the occurrence of impacts can be current and remote in time. Knowledge of the prerequisites of the occurrence of impacts may allow preventive actions to be taking in order to prevent impacts of disasters or for reduce of their impacts. Therefore, for example, knowing remote prerequisites of impacts that lead to aging or corrosion of materials of structures and reduction of their physic-mechanical characteristics allows improving these structures in period the design or increasing the number of preventive actions during operation. Design defects, materials of structures exposed to natural processes (rain, snow) that reduce the reliability of structures, may also be prerequisites of impacts.

When assessing impacts it is important to know, what information (climatic, prognostic or observed) are used an impact assessment. When forecasting the impact of disasters on the population and enterprises, the tendency of changes in the values of disasters indicators is determined. Need continuously to identify trends, since trend values indicate the possibility of increasing or decreasing disaster impacts.

Delayed consequences may be associated with several situations. For example, if one of the situations of the consequences of natural disasters "Loss of ship management" is a delayed consequence: "Shipwreck" and "Oil spill".

According to the time of exposure can be:

- long-term (with a long delay) negative impacts, which is taken into account when designing and decommissioning business facilities;

- possible impacts in the near future (related to disasters prediction), which are taken into account in the construction and operation of enterprises;
- direct impacts (with the passage of the disaster), which are taken into account in the construction and operation of facilities;
- after the passage of a natural disaster – impacts taken into account in search and rescue and rescue operations.

Depending from the time lag of impacts manifestation and the category of information used (climate, prognostic, observed), the record of impacts should reflect future, present and past impacts. Future possible distant impacts are recording in an indefinite form of the verb (violates, makes difficult, limits, excludes, creates, violates). The nearest predicted impacts are recorded with a touch of probability (may be destroyed) or in the future tense. Impacts occurring at the moment of disasters passing are recorded in the present tense. After past disasters the impacts are writing in the past tense (washed away, destroyed).

3.4 Preparation of Recommendations

For some disasters, existing forecasting methods provide insufficiently accurate results, and the user faces a dilemma: to apply or not to apply protective actions past receiving forecasting of disaster is. He has three possible strategies: never take protective actions; always take protective actions; apply protective actions selectively, focusing on intuition or additional information.

Recommendations that do not lead to substantial economic damage are giving lower priority for their implementation. It is determined what level of costs exceeds the benefits of a corresponding reduction in losses for the enterprise.

When creating a knowledge base, it should use all kinds of unstructured knowledge – textbooks, guidelines, practical guides, and even news. This information is processed and converted into formalized information. During the period of normal conditions, instructions are being developing that allow managers to prepare for disasters. The manager's actions and responsibilities for inaction should be defining in normative documents. After the acquisition legislative powers recommendations must be strictly adhered to.

In preparing recommendations, it is necessary to take into account, both existing and develop technical regulations, the provisions on interaction [14, 15]. They developed as rule based on international and national standards adopted to protect the life and health of citizens, the property of individuals and legal entities, state and municipal property, environmental protection, animals. They must contain exhaustive lists of regulatory objects for which recommendations are establishing taking into account all categories of the population and industrial facilities, and contain rules of conduct to ensure the safety of the public and industrial enterprises in the case of disasters. With the help of the regulations we can speed up the process of filling the knowledge base. Recommendations are creating separately for different levels of enterprise management. An example of impacts and recommendations for the "Amateur fishermen on ice" situation is presented below.

Indicators: ice thickness <30 cm, wind speed >15 m/s, ice drift >0.5 m/s.

Sources: 1) Guidelines for the development of a Safety plan for water objects of the Russian Federation in the winter period. – Approved the EMERCOM of Russia. 01.07.2013 N 2-4-87-15-14.

2) Regulations on the interaction of rescue services of ministries, departments and organizations at sea and water basins of Russia. – M.: The EMERCOM of Russia. – 1995. Approved 21.06.1995.

Type of information: forecast.

Impacts for *amateur fishermen*:

Possible separation of ice from the shore.

Recommendations for *amateur fishermen*:

Do not depart from the coast further 300 m.

Leave the car on the beach.

Type of information: at the time of disaster.

Impacts for *people are on the ice*:

A crack of ice is heard.

There are rustling sounds - snow and ice fall into the cracks.

Crack width increases.

Carries an ice floe with fishermen in the sea.

Recommendations for *amateur fishermen*:

Inform the local authorities of the Ministry of Emergencies about what happened (indicate the coordinates of the place, the number of people on the ice).

To use for transition of cracks auxiliary materials – long boards, poles, logs, etc.

Count the available products. Divide the products for 2–3 days.

Prohibit the try to look for opportunities to reach the shore in single.

Wait for the rescue service.

4 Results

The collected materials on the impacts of disasters formalized in the form of 3,000 situations for 108 disasters, 30 typical objects, 100 types of activity, 3 dangerous levels, four situations (future climate change, forecast disaster, real-time data, after the disaster) with a total volume of >10 thousand impacts and recommendations are presented in the PostgreSQL database management system. An application, created for access the database (http://test.shpirat.net/), get out formalized information about dangerous situations, as well as organize the replenishment and editing of information about impacts and recommendations.

As a result of the study, a demo version of the DSS created to transfer information about disasters to the public on mobile Internet devices with the ability to provide information on the impacts of disasters and recommendations to reduce these impacts.

For receiving recommendations, may use the following variants of implementation. The user independently obtained from any official sources (radio, TV, EMERCOM of Russia, Roshydromet) or even from an unofficial foreign source information about a possible disaster, and selects the appropriate disaster in application on base their classification and ordering in alphabetical order. In the future, the search will organizes for situations related to the type of object and activities for which recommendations are necessary; the level of dangerous, the type of data used (observed, predictive, climate), the level of making decision.

A more promising implementation is associated with the automatic detection of dangerous situations based on threshold values of disasters indicators using integrated data from the Unified State System of Information on the Situation in the World Ocean [17], http://portal.esimo.ru. The system integrates the observed operational data received via the global telecommunication system of the World Meteorological Organization; forecast data in the regular grid, coming from the Hydrometeorological Center of Russia and other forecasting organizations; climate data obtained on the basis of generalization of historical data RIHMI-WDC. At the same time, dangerous situations for each object are identifying separately based on threshold values of the indicators of disasters and are automatically delivering directly to the MeteoAgent program is running on Internet device of the decision makers. After receiving a message about disasters, the MeteoAgent program is initializing on a mobile Internet device and, if necessary, the decision-makers will receive information about the possible impacts of the disaster detected and recommendations for decisions making. At this stage, it is possible to connect economic models that allow one to assess the possible damage and calculate the cost of preventive measures before the onset of the disaster.

In more detail with the existing demonstration version of the implementation and the prospects for the development of DSS can be found in the articles [1, 5, 18].

5 Conclusions

As a result of the work done for the first time in field hydrometeorology: an information model has been developed for describing information about the impacts of disasters and recommendations for taking preventive measures; methods of formalizing information about the impacts and recommendations for decision-making are tested; an experimental database of threshold values of disaster indicators, characterizing type objects, type of activities depending on the year season, geographic area, climatic zone has been prepared; materials on the manifestation of various disasters are collected; demo variant DSS for disasters created.

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