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METHOD OF TERRITORY RANGING IN TERMS OF THE LEVEL OF DANGER

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Abstract

In this paper, the problem of estimation of index danger for different territory with geoinformation technology is considered. The authors propose methods estimation based of spatial database, environment monitoring and structured precedent database. The method purpose is minimizing subjective components available in the expert assessment methods. Paper presents the common algorithms for danger estimation on macro level and local territory. The questions of information decision support activities providing of search and rescue teams in areas of extreme tourism is described.

Key words: *complex safety index, geoinformation systems, bank of spatial data, territory classification, macro level estimation, local danger estimation*

1. INTRODUCTION

The social and economic development of regions and countries is indissolubly associated with «safety». According to a number of works (Shaparev, 2010; Levkevich, 2010), Russia is to make transition to the sustainable development in view of different natural and human hazards tend to increase for the last ten years. The data of the Ministry of the Russian Federation for Civil Defense, Emergency Management and Natural Disasters Response shows that there are of about 1500 emergency situations annually occurred in Russia with 70% out of this number are appeared to be man-caused. There are more than 18.9 mln. people located in the hazard impact areas on the territory of 27 developed districts of the RF (Information and communication technologies, 2006). The average population density in the possible impact areas is ranging from 200 to 6000 people/km^2 for the Central, North-West and Privolzhsky regions. Such numbers are differentiated for the Siberian Federal District ranging from 1 to 160 people per square kilometer caused by the population distribution discontinuity.

The territory safety is connected with the balanced correlation of factors devoted to environment, techno sphere and society (Markov, 2012). If the natural and anthropogenic systems are constantly monitored and interrelated on the basis of the material and information support, the safety territory model is possible to elaborate. The safe and sustainable development of the territories is to comprise the characteristics of the social and economic, natural and human factors which are appeared to be subsystems.

There is a number of the integral indicators revealing the population living standards, economic welfare and human development index used by the United Nations to evaluate different countries. However, there is no unique dimension for the territory danger estimation to be used for the territory comparison as the information base to reduce the emergency situations hazard. Territory estimation is impossible without the GIS application. The GIS enables to calculate complex and atomic index, analyze its spatial distribution, show the dynamic statistical information and monitoring data of environment and techno sphere objects, elaborate different territory maps of the hazard statement. (Bychkov, 2011).

The work overviews the analysis of the estimation methods for the territory hazard of different levels. When the GIS application has been extended and the great volumes of monitoring and statistics data have been revealed, it has become possible to receive the objective standards of the territory risks by the spatial modeling means and online analytical processing. The role of the GIS danger estimation is increasing in case of the territory ranging due to the small scale with the great variability of the risk factors characteristics. Such areas in the Krasnoyarsk territory function to realize large investment projects in the sphere of power engineering, oil and gas exploration. The areas for the extreme tourism are also included.

2. THE ISSUES OF ESTIMATION AND TERRITORY SAFETY MAINTENANCE

The macro-level estimation shows that the most vulnerable objects on the territory of Siberia endangered by natural, terroristic and man-caused hazards are central and local government, population life-support systems, social sphere, transport, telecommunications and other infrastructure objects. The issues on the safety control in the regions are defined by the following factors:

– Great amount of potentially dangerous and important objects comprising the economic potential of the district;

– Industrial and infrastructure objects expansion with technological resources completely exhausted;

– Out-of-date systems, complexes and safety control means of the objects;

– Human factor impact including constant violation of entitlements and operation regulations at the dangerous installations;

– Management efficiency and population and territory safety control are required to be improved in terms of the natural, terroristic and man-caused hazards increased;

– Cooperation and coordination between the RF government executive bodies, local authorities, holders of the dangerous installations and dangerous objects operating companies are to be reinforced;

– Regulatory framework on territory and population safety precautions due to the natural and man-caused hazards is to be overhauled;

– The innovation technologies and fundamental and applied research results are to be involved into the safety sphere.

While estimating the territories locally (for example, extreme tourism), the multiple outdoor environment factors are considered to be taken into account. The extreme tourism danger comprises two factors: increased traumatizing risk due to local and climate conditions, long period of rescue teams' feedback. The newest life support technologies used in difficult conditions have established the distorted confidence in absolute tourist safety. Un-skilled and amateur tourists willing to do extreme sports cause the great number of accidents and emergency situations. The emergency situations and accidents are dangerous by direct damage and economic consequences as they can affect the tourist demand. Nevertheless, the tourist flow including the extreme tourism is increasing on the Russian Federation territory. According to the World Travel and Tourism Council (WTTC), Russia will be on the 9th place in the popular tourist area rating by 2020 and China will be on the first place in the rating (Journal «Tourism..», 2005).

The issue on the macro level territory ranging in terms of the likelihood of the emergency situations occurrence is committed to develop the action plan of the emergency prevention and control, elaborate strategies of the territory sustainable development, evolve the risk hedging system and do the territory planning. Local safety estimations are needed to provide permanent and temporary residents of the research area with the appropriate safety level.

The works on risk evaluation received the government status in Russia in the mid-1990s when the State scientific program «Population and commercial objects safety in terms of natural and man-caused disaster risks of emergence» had been developed. The first fundamental risk research was elaborated in a number of the institutions of the Russian Academy of Sciences. Then the research was extended with R&D institutes, industrial corporations involved in the process. (Safety of Russia, 2006).

For the long period of time, safety requirements remained qualitative in most cases and referred to work safety. However, it has become obvious that the safety should be considered as a well-defined, controlled and regulated parameter after a number of the largest natural hazards, technological accidents at the nuclear power plants, oil gas and aerospace factories occurred. To achieve the goals, it is suggested to use the danger quantitative characteristics and make measurements not only at the objects level but also for distinct territories, regions and countries as a whole.

3. METHODS OF DANGER TERRITORIES EVALUATION

The absolute safety measures are difficult to define because of uncertainties in the initial data and statistics of the emergency situations and model adequacy in dynamic analysis of the consequences of the emerged natural hazards and disasters, etc. Such difficulties can be multiplied in case the integral (complex) safety measures are required to be obtained. (Akimov, 2000). To make the comparative territory estimation in terms of the danger levels, the following methods are applied:

– Statistic based on the emergency situation data analysis in accordance with the regions and specific period of time and the hazard index identification;

– Probabilistic based on the mathematic models connecting a prerequisite to the emergency situations to the possibility of their occurrence;

– Heuristic based on the expert evaluation methods with the fuzzy-set theory applicable.

The statistic method stands out from the others by its objectivity but it is non-applicable for rare (non-annual) emergency situations coming with the drastic consequences. The probabilistic method enables to take into consideration the potential hazard outflow which is rarely occurred but full of disastrous consequences (for example, the accident at the hydrodynamic hazardous installation). However, the method requires great labor intensity and lots of initial data. In Russia this ideology is realized in terms of the complex (natural and human) human risk identification within the framework of the regulatory document «Methods of the complex natural and man-caused emergency hazard evaluation for the population» (Shakhramanyan, 2002).

To organize the complex territory estimation in terms of the safety levels, the authors suggest to use three complex factors:

– Location characteristic (physiographic, natural and climatic);

– Peculiarities of the human activities (techno sphere characteristics);

– Forces and facilities availability to organize the search and rescue urgent works within the inspected area.

All the factors mentioned above are considered to be the complex index of the territory risk and hazard *R(S)*. In general, the safety index can be displayed as

$$R(S) = \langle \text{Danger, Vulnerability, Security} \rangle$$

or

$$R(S) = \langle \text{Probability} \times \text{Losses, Vulnerability, Security} \rangle.$$

Taking into account the multiple risk-factors, the rating formula for the risk assessment will be as follows

$$R(S) = \sum_j P_j v_j z_j U_j(S)\,;\; j = 1, N;\; z \le 1;\; v \ge 1$$

with *N* – a number of risk-factors occurred on the territory *S*; *P* – risk-factor probability, *v*, *z* – vulnerability and security index; *U* – possible (direct or indirect) losses and damages.

The term *hazard* is reserved for the actual occurrence of events that have the potential (it can be a material, energy or information) to produce casualties and damage at a level exceeding a community's ability to cope (Makhutov, 2006). The data on risk signs based on the monitoring analysis data and the on-site inspections are obtained.

Territory vulnerability v characterizes the location and object response to the impact of the certain risk-factor or a group of risk-factors. The vulnerability is defined through the urbanization level (population density, transport network, industrial infrastructure and other indicators).

Territory security z characterizes the resource system capability to fight against the inside and outside risk-factors and the disaster recovery. It is identified through the forces and facilities available to mitigate the emergency situations and the number of actions and reserves used in the period of the disaster. According to the Russian National Standard *22.0.02-94*, the emergency security overviews the idea of preventing, eliminating and reducing the impact of the potential emergency hazards on the population, economic infrastructure and environment.

3.1 MACRO LEVEL ESTIMATION OF THE TERRITORY HAZARD

To estimate the territory safety level, the risk-factors are needed to be defined. They are represented by the objective index based on the characteristics of the objects and infrastructure located at the research area, population and hazard location distribution data and also the monitoring data identifying the indicators dynamics. As the index contribution is differentiating, it is essential to define its relative share in estimation of the complex territory safety indicator and the cross effect. When a list of the risk-factors (analyzed indicators) is identified, it is necessary to formalize them due to the numerical value as the terms used in safety estimation may not have the obvious quantification.

The estimation of hazard, vulnerability and security is considered to be the sophisticated issue demanding the complex approach and in-depth study of the territories inspected. At the present moment, the indexes mentioned above are obtained in accordance with the summarized expert reviews. The reason is a lack of the widespread implementation methods based on the data direct conversion and cognitive modeling. There is a problem of the researched factors decomposition into the level of the individual assessment criteria and the relative share quantification of the factors while evaluating the problem situation.

The methods of the territory ranging are widely used to develop ecological, seismic maps and the indicators visualization in different fields of economics and social sphere. The territory ranging is showcased in terms of the ecological intensity level (Encyclopedia 2007). The seismic risk zoning maps are generated in accordance with the renewed seismic event catalogue (Simonov, 2004).

Apart from the graphics of the territory characteristics and the analyzed events, the maps are appeared to be the framework for a diverse range of the management decisions, regulations development, finance distribution, optimization of the condition monitoring network, the task forces and means build-up depending on the hazard level and classification. For example, the maps of seismic risk zoning and permafrost distribution are considered to be the framework for decision-making in urban construction. The maps of forest fire and phytopathological monitoring are used to identify the calculated felling rate. The evaluation of complex and individual safety index distribution is required to develop the efficient system of the natural and man-made emergencies protection initially devoted to the extreme situations prevention.

Mapping of the territory hazard indicators can be achieved by two ways:

- Composition of the territory digital print-out demonstrating the averaged values for the specific locations;
- Visualization of the safety indicators distribution based on the computational grid.

The most complicated stage in the first way is to calculate indicators based on different initial data and variable evaluation methods (see Figure 1). The GIS is committed to visualize results, define a number of classes and borders of the classification intervals. This way is basically applied in macro level estimation of the large regions. In the second way (Figure 1 on the right), the majority of risk-factors are evaluated via the cartographic analysis methods widely displayed in the professional GIS, i.e. ArcGIS. The complex safety index coverage construction is used to estimate the local territories via the large-scale maps and the remote sensing data. Figure 1 shows the general calculation scheme and visualization of the territory hazard complex index.

a) Preparation stage

1) Definition of the map scale display

2) Primary data structuring. Hazard geocoding.

Territory classification. Selection of the map display. Hazard coverage composition.

b) spatial analysis and data visualization

3. Territory division on area objects (local authorities, forest farms, geological province, etc.). Computational grid development.

4. Complex index calculation and its correlation to the cartographic features. Cartographic analysis of risk-factors.

5. Selection of object classification. Hazard isolines calculations and territory coverage build-up.

c) Map design

6. Map model preparation (symbols, signs, legend)

7. Addition of clarifying elements into the map (insets, diagrams, figures, comments).

Mapping procedure includes the following steps:

1. Map presentation scaling. Macro-level territory hazard estimations (for example, territory seismic activity, natural hazard occurrence and other risk-factors required no detalization) are displayed at the small scale maps. The calculation data of the impact area of technological accidents, natural disasters and other local territory hazard estimations (flood water zones, oil spills, extreme tourism, etc.) is more convenient to visualize at the large scale maps sized M1:50 000 or wider.

2. Development of the subject schedule of the risk-factor values mapping based on the characteristics with further geocoding of hazards, vulnerable objects and territory resistance infrastructure.

3. Selection and design of «base layer» with the descriptive data showcasing the complex safety index value the specific territory. The geographical units (municipal; districts, forest farms, geological province) or regular network may be used as the base layer. In this case, the lowest value of the territory safety index will be close to the risk sources ranging per value with the controlled parameters applicable. Such maps are susceptible to hazard recession/uprise and its value fluctuation.

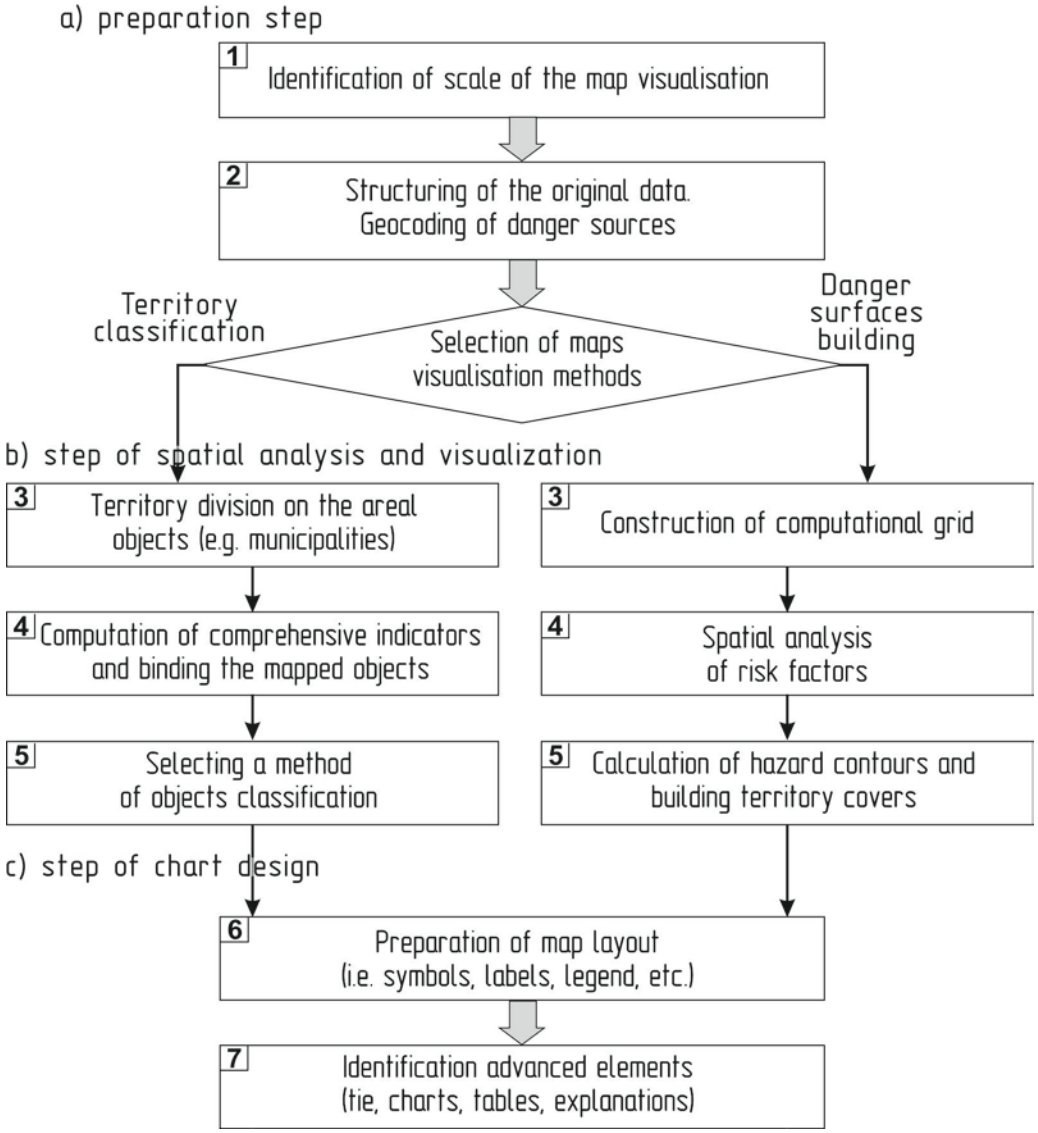


Figure 1. General mapping pattern of the territory complex hazard index

4. Additional territory classification with different styles of subscriptions, icons and charts applicable. Such opportunities are available in all the professional GIS and some web-systems.

5. Extraction of the specific fragments required the detailed review. If the risk-factors are accumulated at the small area as opposed to the territory assessed, the enlarged scale fragments are added to the main map. The general table or the geographically-distributed index schedule also enables to improve acquisition of the data represented on the main map.

Web maps come with the concept note describing the primary data for calculations, comparison of the complex safety index value with Russian and international ones, security actions characteristics, etc.

It is necessary to specify the second step «Primary data structuring» in details. The data volume and quality for different territories may be incommensurable due to many reasons. For example, the infrastructure of the environment monitoring network in Siberia is much narrower than the one in the European part of Russia, the long-term data on the natural hazards is represented by the small-scale maps or the general overviews. Table 1 shows the data application procedure to end up with the complex danger index. The complex index accuracy and relevancy also depend on the primary data and the data processing methods.

Table 1 Evaluation procedure of the data application for macro level territory danger estimation

№ step	**Data source**	**Data pre-processing**	**Cartographic processing results**
1	Danger: number of emergency situations and other negative events, damages	Normalization by year	Territory clustering, danger chart
2.1.1	Technogenic hazard	Hazard geocoding. Application of weighting factor for the object characteristics	Visualization of the industrial risk source
2.1.2		Consequences modeling of different emergency scenarios	Visualization of the hazard impact area
2.1.3	Industrial risk source. Monitoring data	Probability estimate. Monitoring network geocoding	Event maps, territory clustering, cartograms
2.2.1	Natural risk source. Risk exposure	Digitalization of static maps for long-term observations	Risk atlas. Territory clustering, cartograms
2.2.2	Natural risk source. Monitoring data	Natural hazards probability estimate. Events geocoding	Event maps, territory clustering, cartograms
2.2.3	Natural risk source.	Emergency consequences modeling of different reliability	Visualization of impact area
3	Vulnerability: number of communities, population, territory area; number of buildings, community accessibility	Weight coefficient of index	Territory clustering, cartograms
4	Security: forces and resources for emergency prevention and control	Characteristics weight coefficient	Object visualization. Territory clustering, cartograms
5	Complex territory safety index	Weight coefficient of risk-factors	Territory clustering, cartograms

Thus the territory clustering is possible to be accomplished even with little amount of data available. The step 1 presents the data on emergency situations registered. However, such approach is reported to be inappropriate due to several reasons:

– Inaccurate to compare numbers and consequences of the man-caused emergency situations in the industrially developed territories and districts with agricultural sector prevailed. Due to the same reason, the number of forest fires would be greater in the districts with developed forest industry;

– When the data base on emergency situations and accidents in Russia has been forming, the criteria of event assignment to the emergency situation has been changing (EMERCOM Order…, 2004) thus caused sudden trend alteration in terms of specific types of emergency situations (industrial and household fires, traffic accidents). It is important to take into account the exchange inflation to compare the damage indicators occurred because of the emergency situations;

– While ranging the vast territories of Siberia, it is inaccurate to generalize the safety index with the whole subject due to irregularity in distribution of population, industry and physiographic conditions diversity. For example, the Krasnoyarsk territory is located in seven climatic zones with economic entities stretching along the Trans-Siberian line. The population density is changing more than 50 times from south to north.

Step 2 of the procedure suggests applying the data on industrial and natural dangerous installations to estimate risks. Unfortunately, it is impossible to measure the hazard level impact on the complex territory index without expert analysis. Hydro-dynamical, radioactive, chemical, explosive and flammable probability objects and consequences of emergency management are difficult to be compared in magnitude thus it would be reasonable to conduct expert survey in the field of industrial safety at this estimation step with further data processing via the Saaty analytic hierarchy process (Saaty, 2008).

According to the formulas mentioned above, it is necessary to estimate weight coefficient of the territory vulnerability and safety index to obtain the complex territory safety index (final step of the procedure). Risk-factors can be defined via the statistics data of the GIS as well as weight coefficient is based on the expert evaluation.

Due to the procedure described, the emergency risk atlas of the Krasnoyarsk territory similar to the federal atlas of hazards and risks was elaborated (Anisimova, 2004). It includes the following maps:

1) Territory overview: administrative division, population, infrastructure,

2) Security characteristics: rescue teams ground locations with zones of responsibilities defined, condition monitoring network, health facilities, warehouses with inventory, transport companies, etc.

3) Hazard of man-caused emergency situations: origin of radioactive and chemical hazards, explosive and flammable objects, hazardous cargo transportation route, pipelines.

4) Natural hazards: seismic zoning maps, natural fires sources, flood hazard area, avalanching areas, sill flows, mud slides, karsts and other disasters typical for the territory.

5) Hazardous natural phenomenon (irregular temperature, precipitation, hurricanes, etc.).

6) Biological and social emergency hazards: areas of people, animal and plant epidemy; land use maps endangered by different threats, etc.

7) Ecological monitoring maps: sources of emissions to the atmosphere, water and soil pollution, overall environment condition.

8) Complex risks maps (individual and social risks) overviewing the particular risk indicators of each emergency situation.

At the present moment, the maps of the region are specified to the municipal districts level thus differentiating in composition due to hazard diversity. There are of about 20 maps elaborated in total as well as there are more than hundred layers, raster graphics and subject schedules in the bank of spatial data.

3.2. RISK ESTIMATION METHOD FOR LOCAL TERRITORIES BY USING THE GIS

The local estimation procedures of territory safety slightly differ from the macro estimations in terms of the data composition or the methods applied. The area of taiga and mountains of the Ergaki natural park located in Western Sayan Mountains (Ermakovsky district of the Krasnoyarsk territory) was used as a sample territory to elaborate the estimation methods of the complex safety index. Nowadays the park is developing dynamically with tourist flows increasing for more than 20% annually.

1. Picture 2 shows the risk-factors hierarchical arrangement utilized to define the complex safety index. The territory classifications comprise the danger indicators, tourist flow is represented as hazardous location. The degree of security is designated by characteristics and activities of the Siberian regional rescue team of the Ministry of Emergency Situations of Russia positioned on the territory of the natural park and also by the infrastructure available to provide safety on the territory of the park (Trofimova, 2013).

Most of the partial criteria are equal to the cartographic cover areas applied to solve the issues of territory zoning in terms of the danger level. In general, the decomposition scheme is depicted by the following functional relation:

$$\{f\ (x, y)\} \rightarrow\ A^{(n)},$$

with $f\ (x, y)$ – variety of space-distributed assessment tools of territory hazard level with x and y coordinates, – n-level decomposition establishing a rule for criterion selection preference required for appropriate territory hazard level estimation.

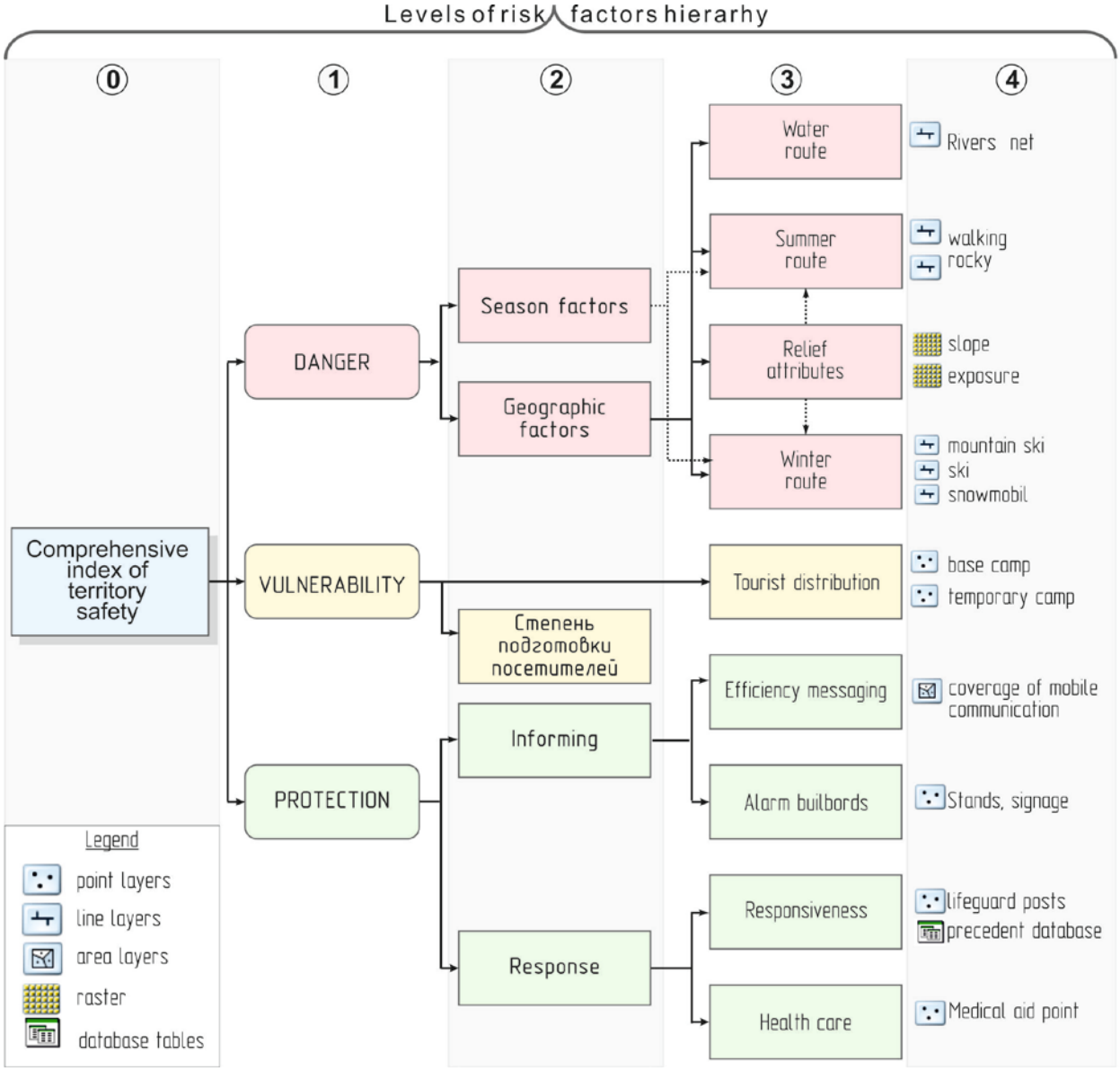


Figure 2. Concept scheme of the comprehensive territory safety index estimation for tourist activities

The 5-level incomplete dominant factors hierarchy with their estimation criteria and weight coefficients included is used to evaluate collectively the complex hazard level index for the taiga and mountains area suitable for tourist activities.

The (0) level presents the research goal – estimation of the complex hazard level index for the taiga and mountains area suitable for tourist activities. The first decomposition level shows risk factors, territory vulnerability and security.

Risk-factors hierarchical arrangement

0 – Complex territory safety index, map keys, point layers, linear layers, area layers, raster coverage, data table

1 – Danger, Vulnerability, Security

2 – Seasonal factors, Geographical factors, Level of visitors' training, Informing, Reaction

3 – Water routes, Summer routes, Landscape classification, Winter routes, Visitors' distribution, Messaging efficiency, Threat warning, Response efficiency, Access to health care

4 – River net, hiking, rocking, surface slopes, direction of slopes, mountain skiing, skiing, oversnowing, stations, encampment, signal coverage area, stands, navigation, rescue team stations, case base, medical treatment units.

The factors decomposition was elaborated at the second level of the hierarchy arrangement:

– Territory safety control is specified by the parameters of threat warning and response efficiency available when the accident happens;

– Territory hazard is characterized by a diverse range of natural and climatic, physiographic and anthropogenic danger parameters affecting the tourists.

The natural and climatic territory parameters estimation via the spatial analysis requires the observation network and statistically valid database of weather monitoring available. As there is a lack of such materials on the territory of Western Sayan mountains, the method described consists of seasonal characteristics of territory hazard with winter and summer tourist activities applicable.

The third decomposition level defines the criteria enabling to numerically assess the parameters of informing and response. They characterize the territory safety factors and evaluation criteria fully showcasing the physiographic and anthropogenic parameters in terms of injuries typical for each specific area of tourist activities.

The statistic analysis of tourist injuries was accomplished to define the physiographic and anthropogenic danger parameters of taiga and mountain areas. The literature data (Umryukhin, 2010) and the search and rescue reports made by the Siberian regional centre for athletic performance and rescuer rehabilitation were used (Research report…, 2011).

The specific issues considered (falling off the rocks, stone falling and avalanche accidents, ski slope injuries) do not provide opportunities to clearly define the criteria of quantitative hazard assessment of taiga and mountain areas as the results are likely to become fractional and non-indicative. There are many works describing different accidents with the events hardly comparable in terms of reasons and consequences. Consequently, the origin of injuries was characterized in accordance with the types of tourist activities typical for taiga and mountain area (mountain skiing, water touring, hiking and rock climbing). The groups of hazard sources affecting (thus causing injuries) the majority of tourist activities were formed.

The fourth level of the hierarchy arrangement shows the cartographic equivalents of assessment criteria. These are «atomic» indicators describing the quantitative specifications with the spatial distribution applicable. The semantical information of topographic and thematic layers was used to calculate the indicators. The contribution of each atomic indicator was standardized due to the expert analysis.

The map model of the natural park was developed to measure the assessment criteria distribution on the surface (of the territory), define their value in each location and the spatial relations of the locations observable. The map model is a block scheme showing the range of well-disposed actions with cartographic data available for the decision process modeling concerning the spatial objects. The spatial analysis process automatization was realized in Pyton software envelope via ArcMap 10.0 functional relations of the spatial analysis. The process of the hazard level estimation of the local territory by means of the spatial analysis consists of three stages.

Pre-processing stage – systematization of the primary data to the cartographic equivalents of the assessment criteria. In order to get that done, the feature layers of traffic, route network and wild areas are generated via the layers connecting function (Merge). The surface slope layer is generated at the pre-processing stage when the Triangular Irregular Network (TIN) applied to develop the landscape surface is constructed from the feature layer of the topographic contour. TIN is basically established due to the Delaunay triangulation method.

Surface measurement stage represents the functions execution sequence of transformation of the cartographic equivalents of assessment criteria into the continuous raster surface displaying the criteria distribution density at the researched territory. Based on the landscape digital model, the layer of the polygonal objects classified by the surface slopes was established via (Slope) function. The surface slope criteria are measured for each TIN triangle and calculate the maximum steepness of the specific territory. The layer of mobile communication coverage area is generated via (View Shed) visibility function. The input measurement parameters were the point layer of the mobile communication towers with the attributive information about their height according to the digital elevation model. The raster pattern is the result of measurement with each cell visualizing the territory accessibility value from the observation points relevant to the mobile phone towers' location. After that, the

output raster pattern is transformed into the polygon (Raster To Polygon) with the buffer zones (Buffer) of the mobile communication coverage area availability at the pitches of 1, 3, 5, 10 и 15 km are calculated.

(Kernel density) function is used to measure point and linear density. This function is applied at the area of 2 km pitch enabling to figure out the point and linear object density around each output cell. The density value in each output raster cell is computed via all the nucleus value composition in the points of resolution cell centre overlapping. Then, the smooth spun surface is built for each point or line. The surface value is maximized in the point location and is gradually minimized if the distance from the point is increased thus reaching zero at the distance equal to the search radius set from the point. The raster continuous surfaces are analogically elaborated showcasing the distribution density of other territory hazard assessment criteria applicable for summer and winter tourist seasons.

When the density of the polygonal objects specifying the distribution criteria of the wild areas is estimated, the relative proportion of the space suitable for the polygon is defined. For this aim in view the polygonal layer of the wild area is converted into the point layer via (Polygon To Raster) function with further calculation of the point objects' weights relevant to the initial polygon area values in the attribute table.

The result of the second processing stage is the continuous density surface for each assessment criterion. The value measurement units of the assessment criteria distribution density are regulated within the range of 0…1.

The **zoning stage** comprises the summarization of the raster patterns obtained via the raster calculator function. The value of the complex hazard level index is clustering by means of Unsupervised Classification of total raster pattern with 5 classes specified. When the vector map of the taiga and mountain area with danger level zoning for the tourist activities is developed, the classified raster pattern is transformed into the vector polygonal layer with aggregation of small (up to 0,5 km^2)polygons.

Zoning map of the natural park «Ergaki» for summer tourist season is presented on the Picture 3.

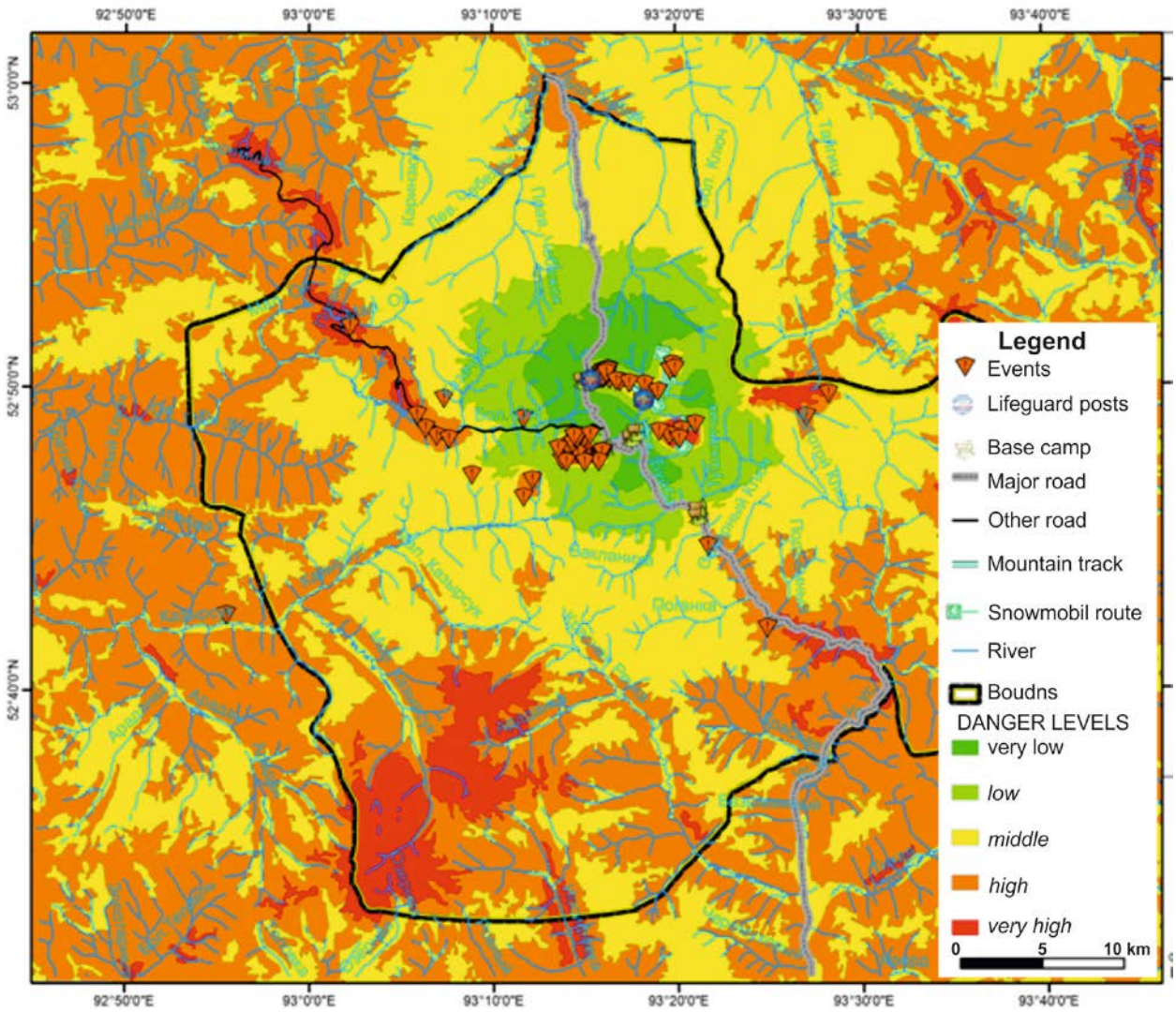


Figure 3. Zoning map of the natural park «Ergaki» in terms of hazard level for tourist activities in summer season

The data of the registered accidents for 2010-2013 was used to check the accuracy of the complex hazard index estimations obtained. The linear dependence of the tourist accidents distribution density is traced in accordance with the zones of the territory hazard levels. Determination coefficients $R^2 = 0.83$ of winter tourist period and $R^2 = 0.89$ of summer tourist period shows the appropriate data consistency. Dependence function of the tourist accident density with territory zoning describes the primary data with more than 80% of probability. It enables to conclude about adequacy and relevance of the assessment and zoning method elaborated for taiga and mountain area suitable for tourist activities.

The geoinformation system of the territory estimation developed is implemented in activities of the Siberian search and rescue team. The GIS integration into the environment monitoring systems, accident data collection and analysis and rescue works may provide background for further information support reinforcement to make decisions at different levels of emergency management.

CONCLUSION

Two methods of the territory safety estimation were overviewed. To increase the accuracy and solvability of the results obtained, it is required to:

– Collection and structuring of the primary data describing factors of safety, vulnerability and security of territories represented as statistics, monitoring and spatial data;

– Elaboration and confirmation of expert analysis in reference books applied in models as risk-factors weight coefficient, interconnection considered, etc.;

– Development (improvement) of the spatial analysis methods for local estimation of the complex territory safety index with other physiographic characteristics and hazardous locations.

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