Conducting a comparative analysis of the system state options under various external influences

V L Romanovsky¹, E I Alekseeva¹, L N Gorina²

¹Department of Industrial and Environmental Safety, Kazan National Research Technical University Named after A.N. Tupolev-KAI, 10 K. Marx St., Tatarstan 420111, Russia
²Department of Industrial and Environmental Safety Management, Togliatti State University, 14 Belorussskaya St., Tolyatti 445020, Russia

E-mail: kleongardt@bk.ru

Abstract. One of the principles of increasing the sustainability of cities as a part of the campaign “My city is getting ready!” states: “Identification and study of risks, use of scenarios of existing and future risks”. The city is a complex system, “packed” with all kinds of dangers. Dangers affect all elements of this system and it is necessary to identify and monitor processes that contribute to the development of hazards into threats, i.e. conduct research, in this case, “urban risks” and learn to manage them. In our opinion, the “Tree structures” method of risk analysis may be suitable for the study of “urban risks” [14], which allows, in particular, to analyze various but interrelated situations and events in relation to the entire system within a single “tree”.

1. Introduction

One of the principles of increasing the sustainability of cities as a part of the campaign “My city is getting ready!” states: “Identification and study of risks, use of scenarios of existing and future risks”. The city is a complex system, “packed” with all kinds of dangers. Dangers affect all elements of this system and it is necessary to identify and monitor processes that contribute to the development of hazards into threats, i.e. conduct research, in this case, “urban risks” and learn to manage them. The term “urban risks” was proposed in [13] for specific risks of possible implementation of threats of a highly concentrated network of hazards of a complex system called “city”.

2. Methods

In our opinion, the "Tree structures" method of risk analysis may be suitable for the study of “urban risks” [14], which allows, in particular, to analyze various but interrelated situations and events in relation to the entire system within a single “tree”.

The system “man-technology-environment” is characterized by the extreme complexity of internal and external relationships and their dependence on a very large number of factors, and the quantitative characteristics for new systems are not always predictable. On the other hand, replacing a person with a machine is not always possible and advisable. Man remains the most universal, plastic and active part of the control system. The processing of information by a person depends on his individual characteristics, the degree of his training, functional and emotional state, type of his nervous activity,
motivation of actions, duration and type of work, etc. All these human properties should be taken into account when analyzing the final characteristics of the predicted system.

The method of “Tree structures” allows us to:
- clearly formalize the material in question;
- analyze various situations;
- analyze various, but interrelated situations and events within the framework of one “tree”;
- conduct an effective quantitative assessment of the conditions for preventing negative events or the conditions for achieving the goal;
- equally, within one “tree”, take into account all the elements of the system “man-technology-environment”.

Tree structure is a graphical representation of the relationship between various events of a specific system “man-technology-environment”.

Event is a state, incident, and phenomenon, action that could happen, happened or can happen in a system or element.

An event that is the goal of analysis is called a head event or a result event. The head event occurs as a result of a combination of various events. There can be several head events in a tree structure. In addition to strictly determined cause-and-effect relationships, the tree structure can also have feedback when the head event (or intermediate event) affects the previous one.

Events that are the root causes of the analyzed system and ultimately leading to the occurrence of a head event are called primary or initial.

Events located on a tree structure between the head and primary events are called intermediate.

The construction of the tree structure begins with the processes of synthesis and analysis, including several procedures.

The synthesis process includes determining the purpose of the analysis, the choice of a specific system "man-technology-environment" for the possibility of analysis of goal achievement.

The analysis process is carried out by induction and deduction and includes the following steps:
1. Some interconnected events of the system under consideration are selected, a specific scheme of the relationship between them is determined, this fragment of the relationship of events is graphically drawn up.
2. The graphic fragment expands further when answering one of the questions:
   - what can follow next?
   - what to do?
   - why did this happen?
3. Steps 1 and 2 continue until the tree structure matches the purpose of the analysis.

A comparative analysis of options for the state of the system under various external influences is carried out in the following sequence:
1) the purpose of the analysis is selected;
2) the available information is analyzed, information is selected in relation to the purpose of the analysis;
3) the tree structure of the system is constructed in relation to the purpose of analysis;
4) the mathematical experiment is conducted on the influence of external influences on the state of the system.

3. Results
As an example of analysis, we use the tree-like structure of the conditions for the preservation of cultural heritage objects [20]:
The initial events of the tree structure (external influences) in the general case can have a probability of realization in the range from 0 to 1. In the case $P = 0$, the event is impossible; when $P = 1$ an event is reliable. For all other events are $1 > P > 0$.

For a particular event in a specific situation, the most real value of $P = m$ exists. In probability theory, this quantity is called the mathematical expectation, distribution center, or average value.

4. Conclusions

Suppose that the probability of an occurring particular event has a certain scattering region of a random value near its average value, described by the so-called normal distribution law obtained by Gauss:

$$ f(x) = \frac{1}{\sigma \sqrt{2\pi}} \exp \left[ -\frac{1}{2} \left( \frac{x - m}{\sigma} \right)^2 \right] $$

(1)

where $\sigma$ is the standard (or mean square) deviation.

Usually, when conducting a quantitative analysis of the possibility of the onset of a head event using a tree structure, specific values of the probabilities of the implementation of the initial events are used.

There is no guarantee that these probabilities will be accurately determined. It is more correct to use this approach: “most likely the probability of implementation will be such-and-such”, i.e. to imply the possibility of spreading the value of $P$ around the most likely.

For example, the probability of the i-th event is likely to be 0.2, although a spread from 0.1 to 0.3 is possible (“allowed range of probabilities”).

---

**Figure 1.** Tree structure of cultural heritage conservation conditions.
Such reasoning makes sense for the possible probabilities of the implementation of all the initial events (external influences).

The quantitative analysis itself should be performed for all possible combinations of probabilities of initial events from the allowed ranges (“samples”). The final density of the probability distribution of the head event will be the result.

Such analysis is possible only with the help of a specially created computer program, since the number of “samples” is very large. A generator of random variables of the normal distribution for the selected values of \( m \) and \( \sigma \) is used for a specific sample of probability values of initial events.

Figure 3 shows the result of a mathematical experiment on the influence of external influences on the state of the specified system.

A comparative analysis of the system state variants under various external influences should be carried out in interactive mode with a computer program, changing the allowed probability ranges for the implementation of all initial events.
References

[1] Arefyeva E V 2007 Regulation of ground water conditions in case of project and built-up area inundation Industrial and Civil Engineering 11 47–48

[2] Aref'eva E V 2016 Information Support of Modeling and Forecasting of the Hazards Associated with Underground Hydrosphere Built-up Area Civil Security Technology 1 28–34

[3] Arefeva E, Rybakov A, Ziganshin A 2012 Situational and Optimisation Model for Determination the Danger of the Built Up Areas Scientific & Educational Problems of the Civil Defence, scientific journal 1 31–37

[4] Arefeva Ye V 2004 System for Prevention and Handling of Flooding-Related Emergencies (Moscow: Academy of Civil Defense, EMERCOM of Russia) p 143

[5] Arefieva E V, Bolgov M V 2018 Specifics of Natural Flood Forecast for Disaster Risk Reduction. Case Study of Krasnodar Krai Civil Security Technology, vol 15, 4(58) 40–48

[6] Information Bulletin on the Subsoil Conditions in the Republic of Tatarstan for 2016 (Informatsionny byulleten o sostoyanii nedr na territorii Respubliki Tatarstan).

[7] Kuzmin A V 2014 The Use of Innovative Methods of Risk Analysis to Reduce Emergencies on the Roads of the Republic of Tatarstan Vestnik NtsBZhD 3(21)

[8] Guidelines on the Risk Analysis and Assessment of Damage from Natural and Man-Caused Emergencies Vol. 1. (Moscow) 2008

[9] Muravieva E V, Romanovsky V L, Kuzmin A V 2016 Applied technosphere riskology - management of technosphere complexes Quality and Life (Moscow) 2(10)

[10] Muraveva E V, Romanovsky V L 2014 Urban Risks: Ability to Analyze and Forecast Izvestia of Samara Scientific Center of the Russian Academy of Sciences 16 1(7)

[11] Muraveva Ye V, Romanovsky V L, Davkayeva L D 2016 Tree Structures as a Risk Analysis Method to Identify the Systematic Connections of Hazards Proceedings of the 24th International Conference Prevention. Rescue. Aid. (Khimki: FSBHEI HE ACD, EMERCOM of Russia)

[12] Reutmann A G 1987 Building Deformation and Damage (Moscow: Stroiizdat) p 159

[13] Romanovsky V L, Semenov V Yu 2014 Principles and Approaches to the Concept of Urban Risks Vestnik NTSBZhD 2

[14] Romanovsky V L 2007 Graph-Based Risk Analysis by Means of Tree Structures Izvestia of Samara Scientific Center of the Russian Academy of Sciences. Special issue: ELPIT-2007. Series Mechanical Engineering and Ecology 2

[15] Romanovsky V L, Muraveva Ye V 2007 Applied Technosphere Riskology: a monograph (Kazan: RIC School)

[16] Romanovsky V L 2012 Use Graphic Analytical Methods of Risk Analysis "Tree Structure" to Find the Most Probable Cause Failure of Technical System Vector of sciences. Togliatti State University 1(19)

[17] Lyapin M N Scientific Foundation and Improvement of the Standards and Guidelines

[18] Gumerov T Yu, Faizullina G G, Dobrynina A F, Yusupov R A Features of complexing in the Al(III) - H2 O - OH- - Cl-(SO4 2-) - Flocculant system in the presence of the fat-containing disperse phase Journal of Water Chemistry and Technology 28(2) 19–24

[19] Shakurov R F, Sitnikov O R, Galimova A I, Sabitova A F 2018 Investigation of the influence of acoustic oscillation parameters on the mechanism of waste rubber products combustion IOP Conference Series: Materials Science and Engineering 317 012061

[20] Alekseyeva E I, Romanovsky V L 2014 On the possibility of using the risk-analysis method “tree structures” when making managerial decisions in order to increase the sustainability of cultural heritage of the Republic of Tatarstan Proceedings of the XXIV International Scientific and Practical Conference “Warning. The rescue. Help” (Khimki)