ISBN 978-989-9121-27-0
50th ATHENS International Conference on "Advances in Science & Technology"
(AICAST-23)
Athens (Greece) July 4-6, 2023

Expert System for Assessing the Environmental Safety of the Territory

Zh.K. Smagulov[1], B.V. Potapov[2]

[1]Karaganda University of the Name of Academician E.A. Buketov, Kazakhstan

[2]Moscow Institute of Physics and Technology

***Abstract*:** *To determine the relative level of assessment of the territory, taking into account environmental safety, an expert system is proposed based on the use of the method of pairwise comparisons on a qualitative basis with a quantitative assessment of preference in combination with a fuzzy model. This method allows you to reduce the subjectivity of the assessments and does not require consistency from experts in their judgments. To obtain relative information, a fuzzy variable is selected that describes the level of assessment of the territory taking into account environmental safety, and a function of belonging of territories to a fuzzy set is constructed, the meaning of which is formalized by the selected fuzzy variable. To determine the relative weights of territories, the fuzzy variable "acceptable level of territory" was used.The extent of the level of assessment of the territory, taking into account environmental safety, is determined by interviewing experts as to how much, in their opinion, one territory corresponds more to the meaning of the fuzzy variable "acceptable level of territory" than another territory. To make assessments, the expert uses the T. Saati scale to compare the levels of assessment of the territory assumed by him, taking into account environmental safety.*

Keywords: *environmental safety, expert system, pairwise comparison method, fuzzy model, T. Saati pairwise comparison scale, acceptable level of territory.*

1. Introduction

The issue of ensuring the environmental safety of the city is currently relevant.The development of territorial towns is complicated by natural and man-made factors. This requires a scientific approach to the issues of its engineering-geological, hydrogeological and ecological research. The issues of environmental safety of the territory are given attention in the scientific works of Russian scientists V.I.Osipov, V.E.Merkin, E.Y. Kulikova, etc. [1-7].The ecological safety of the territory is determined taking into account information on the identification and analysis of environmental risks, the possibility of managing these risks, taking measures to reduce them and evaluating the effectiveness of decision-making to prevent or reduce their consequences. This article discusses the issues of determining the level of assessment of the territory taking into account environmental safety and suggests an expert system for its implementation in practice.

2. Methods for Determining the Level of Assessment of the Territory Taking into Account Environmental Safety

Determining the level of assessment of the territory of the underground space, taking into account environmental safety, is associated with significant difficulties associated with the uncertainty of the initial data, the adequacy of computational models, etc. In this regard, methods for determining relative characteristics, in particular, expert methods, have a significant advantage.An analytical review of some of them (intuitive estimates, the von Neumann-Morgenstern method, the method of pairwise comparisons, the method of pairwise

comparisons with a quantitative assessment of preference) is considered in detail in the works of the authors [1-7,10].

The methods discussed above do not have a clear physical interpretation and do not have the ability to interpret the estimates obtained as subjective probabilities, which makes it difficult to use the conceptual and mathematical apparatus developed in probability theory to process the results obtained. Therefore, a model is proposed to obtain quantitative information about the relative level of assessment of the territory of the underground space, taking into account environmental safety, based on the theory of fuzzy sets.

To obtain relative information, we will select a fuzzy variable that would describe the level of assessment of the territory of the underground space, taking into account environmental safety, and construct a function of the territories belonging to a fuzzy set, the meaning of which is formalized by the selected fuzzy variable.

To determine quantitative estimates of the level of the territory of the underground space, taking into account environmental safety, we introduce a fuzzy variable "acceptable level of assessment of the territory", defined on a discrete set of $\Theta = \{\theta\}$ of territories. The fuzzy set $\tilde{A}$ on the set Θ is a collection of pairs $\tilde{A} =$ ¿¿, where $\mu_A(\theta)$ - is the degree of belonging of the territory $\theta \in \Theta$ to the set $\tilde{A}$, which can be interpreted as a subjective probability. Large values of $\mu_A(\theta)$ correspond to territories that more closely correspond to the meaning of the selected fuzzy variable.

To calculate the degrees of belonging of territories to the fuzzy set $\tilde{A}$, we will use the method of pairwise comparisons on a qualitative basis with a quantitative assessment of preference. To obtain matrices of pairwise comparisons, experts are interviewed as to how much, in their opinion, the territory θ_i corresponds more to the meaning of the fuzzy variable "territory" than the territory θ_j. To estimate W_{ij}, the expert uses the *T.* Saati scale [8] (Table. 1) compares the estimated levels of assessment of the territory for the placement of IC for a pair of territories.

TABLE I: The scale of pairwise comparisons by T.Saati

Value W_{ij}	**Definition**	**Explanation**
1	The territories are the same	Territories have approximately the same level of assessment of the territory, taking into account environmental safety
2	Intermediate value	
3	Weak superiority	The expert believes that the level of assessment of the territory, taking into account the environmental safety of the first territory of the pair, is slightly higher than the second
4	Intermediate value	
5	Strong superiority	The expert believes that the level of assessment of the territory, taking into account the environmental safety of the first territory of the pair, is definitely higher than the second
6	Intermediate value	
7	Clear superiority	The expert believes that the level of assessment of the territory, taking into account the environmental safety of the first territory of the pair, is clearly higher than the second, and statistics confirm this
8	Intermediate value	
9	Absolute superiority	The expert has no doubt that the level of assessment of the territory of the underground space, taking into account the environmental safety of the first territory of the pair, is significantly higher than the second

To increase the reliability of the calculated relative weights of the territory, taking into account environmental safety, the following methods can be used:

1) to reduce the subjectivity of the assessments received by one expert, involving a group of z experts in the assessment. At the same time, the relative weights of territories obtained by each of the group members, averaged or calculated taking into account the competence of experts, are taken as relative weights of territories, taking into account environmental safety on the basis of the considered attribute;

2) assessment of the consistency of expert opinions in order to determine the possibility of using the results obtained. To do this, the coefficients of variation are calculated

$$\vartheta_{ij} = \frac{\sqrt{\frac{1}{z-1}\sum_{l=1}^{z}\left(w_{ij}(l) - w_{ij}\right)^2}}{w_{ij}}, \quad (1)$$

where $w_{ij}(l)$ - elements of the matrix *W(l)* obtained from the l th of z expert; w_{ij} - their average values. Consistency is considered satisfactory at 0.3 $\vartheta_{ij} \le 0{,}3$ $\forall ij$ and good at $\vartheta_{ij} \le 0{,}2$ $\forall ij$. In case of unsatisfactory consistency, experts are invited to critically evaluate the results of comparisons of territories and, if necessary, make adjustments. After that, the processing of the newly filled matrices of pairwise comparisons is repeated and consistency is evaluated.

As a result of expert evaluation, we obtain matrices of pairwise comparisons, which in general are not transitive.

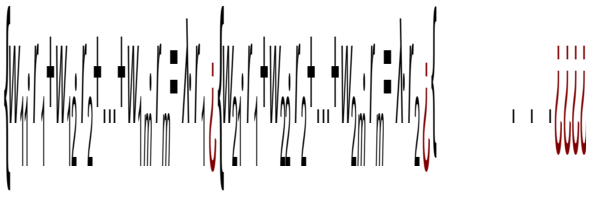
When processing matrices of pairwise comparisons, the components of the maximum eigenvector of the matrix of pairwise comparisons W are taken as weights obtained as a result of expert evaluation, for the calculation of which the exact and approximate methods are used.

The exact method. Let *r* be the maximal eigenvector of the matrix W. In order to calculate its components , we solve the equation [9]

$$W \cdot r = \lambda \cdot r \quad , \quad (2)$$

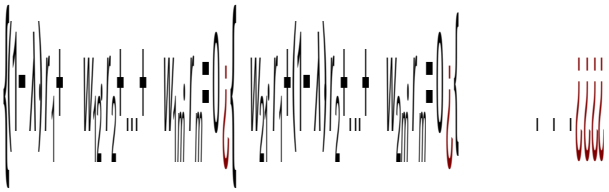
where λ - is the eigenvalue of the matrix W.

Let's rewrite (1) in coordinate form:



, (3)

Taking into account the fact that for $i = j \quad w_{ij} = 1$, we represent (2) as a system of homogeneous equations:



, (4)

or, in matrix form, $(W-\lambda E)r=0$, where E - unit matrix of the mth order. It is known that a system of homogeneous linear equations has a non-zero solution only if the determinant of the corresponding matrix is zero:

$$\det(W-\lambda E)r=0. \tag{5}$$

Decomposing this determinant, we obtain a characteristic equation of the mth degree with respect to λ. The solution of this equation will give m values of λ. Then it is necessary to find the components of the eigenvector of the matrix W corresponding to λ_{max}, which requires the solution of a system of homogeneous equations $(W-\lambda_{max} E)r=0$.

Approximate method. Let's introduce a vector

$$q^{(k)}=W q^{(k-1)}, \tag{6}$$

the components of which characterize the weight of territories, where k - the step number of the algorithm. Then the normalized vector $\bar{q}^{(k)}$ is determined by the formula

$$\bar{q}^{(k)}=\frac{q^{(k-1)}}{\lambda^{(k)}}, \tag{7}$$

where $\lambda^{(k)}$ - sum of vector components $W\bar{q}^{(k-1)}$.

If W is an indecomposable matrix, then procedure (9) converges, since for $k\to\infty$ $\lambda^{(k)}\to\lambda_{max}$, a $\bar{q}^{(k)}\to\bar{q}^{(k)}_{max}$. The calculation of the components of the maximum eigenvector is carried out until the specified accuracy ε is reached.

Examples of solving problems in exact and approximate ways are presented in [9].

It should be noted that with pairwise comparisons of four or more territories, the above method of calculating the maximum eigenvector of the matrix W becomes difficult for practical implementation.

The above algorithm of approximate calculations is relatively easy to implement on a computer and allows, by increasing the number of iterations, to achieve any given accuracy in calculating the relative weights of territories, taking into account their environmental safety.

With satisfactory consistency of expert opinions, the degrees of belonging of territories to a fuzzy set $\tilde{A}$ are determined, the values of which are equal to the averaged (or calculated taking into account the competence of experts) values of the components of the maximum eigenvector of the matrices of pairwise comparisons normalized by one: $\mu_A(\theta_j)=q_j/q_1$.

3. Methodology for Obtaining Information About the Relative Level of Assessment of the Territory, Taking into Account Environmental Safety

The methodology for obtaining information on the relative level of the assessment of the territory taking into account environmental safety, based on the considered fuzzy model, is as follows:

- selection of the compared territories taking into account environmental safety;

- selection of experts;
- selection of a fuzzy variable that best describes the level of assessment of the territory, taking into account environmental safety;
- calculation of the degrees of belonging of territories to a fuzzy set, the meaning of which is formalized by the selected fuzzy variable

The sequence of operations in this case is as follows:

- calculation of the relative weights of the territory, taking into account environmental safety, based on the method of pairwise comparisons with a quantitative assessment of preference;
- calculation of degrees of belonging of territories to a fuzzy set.

The calculation of the relative weights of territories is carried out in the following sequence:

- assessment of pairs of territories by members of the expert group (filling in matrices of pairwise comparisons);
- processing of matrices of pairwise comparisons;
- combining the relative weights of territories obtained by experts;
- assessment of the consistency of the opinions of the group's experts.

4. Conclusions

To determine the relative level of assessment of the territory, taking into account environmental safety, an expert system is proposed based on the use of the method of pairwise comparisons on a qualitative basis with a quantitative assessment of respect in combination with a fuzzy model. This method allows you to reduce the subjectivity of the assessments and does not require consistency from experts in their judgments.

To obtain relative information, a fuzzy variable is selected that describes the level of assessment of the territory taking into account environmental safety, and the function of belonging of territories to a fuzzy set is constructed, the meaning of which is formalized by the selected fuzzy variable. To determine the relative weights of territories, the fuzzy variable “acceptable level of territory" was used.

The degrees of the level assessment of the territory of the underground space, taking into account the ecological safety of *Y*, are determined by interviewing experts as to how much, in their opinion, the territory of the θ_i corresponds more to the meaning of the fuzzy variable “acceptable level of the territory” than the territory of the θ_i. To assess the w_{ij}, the expert uses the *T*. Saati scale to compare his estimated levels of assessment of the territory of the underground space, taking into account environmental safety.

5. References

[1] Антипов О.А., Потапов Б.В., Циммерманн Ю. Риски в антропосфере и социальная организация общества // СПб Реноме. – 2010. – 303 с.

[2] Антипов А.В., Кошкарев А.В., Потапов Б.В., Филиппов Н.В. Единое геоинформационное пространство города Москвы как составная часть инфраструктуры пространственных данных РФ // ООО Проспект. – 2013. – 224 с

[3] Куликова Е. Ю. «Экологическая безопасность при освоении подземного пространства в крупных городах» // Издательство: Издательство Московского государственного горного университета, – 2001. – 376с.

[4] Куликова Е.Ю. Идентификация и анализ экологических рисковпри подземном строительстве // ГИАБ / МГГУ. – 2002. – №5. – С. 115-118.

[5] Куликова Е.Ю. Организационно-экономический механизм управления риском в городском подземном строительстве // Горный информационно-аналитический бюллетень. – 2020. – № 6-1.– С. 128-136.

[6] Меркин В.Е., Зерцалов М.Г., Конюхов Д С. Управление геотехническими рисками в подземном строительстве // Транспортное строительство. – 2013. – № 3. – С. 10-12.

[7] Осипов В.И. Природные опасности и стратегические риски в мире и в России // Экология и жизнь – 11-12(96-97). – 2009. – С. 5-16.

[8] Саати Т. Принятие решений: метод анализа иерархий. Перевод с англ. Р.Г. Вачнадзе // Радио и связь. – 1993. – 314 с.

[9] Потапов Б.В., Радаев Н.Н. Экономика природного и техногенного рисков // Деловой экспресс / ФИД . – 2001. – 513 с.

[10] Kulikova E.Yu. Operational Safety and Environmental Sustainability in the Development of Urban Underground Space / Proceedings WTC 2018 // ITA — AITESWORLD TUNNEL CONGRESS Dubai. –21-26 April. – 2018. – PP. 992 - 106.