Improving the sustainability of cultural heritage sites using the INFORM Method

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Abstract. The article presents proposals on the use of the risk index method to determine the sustainability of cultural heritage sites. This INFORM method is based on the assessment of the three risk components by measuring the relevant indicators in each of three directions: the degree of danger; level of vulnerability; counteraction (overcoming) potential. The method includes about 50 different indicators for measuring hazards and impact on them, vulnerability indicators and determining the necessary resources for stopping hazards. The integral risk index is formed as the geometric mean of the component indices: danger, vulnerability and lack of counteraction potential. The application of the INFORM method for the development and adoption of managerial decisions to increase the sustainability and security of cultural and historical heritage sites makes it possible to assess risk, and in the future, planning measures for the restoration and maintenance of cultural heritage sites.

1. Introduction

Against the background of the current state of culture, the problem of preserving and restoring objects of cultural heritage is of particular importance due to the great importance of preserving cultural heritage [1]. However, the complexity of this problem is also in the fact that many cultural heritage sites over the past century have been in a very neglected state, and in order to preserve them, it is necessary to look for new methods for assessing and predicting their condition [2-4].

Over the centuries-old history of cultural heritage monuments, especially the twentieth century subjected them to a test of stability, creating conditions different from normal for the work of supporting structures and soil bases [5]. Radical changes in the environment as a result of human construction and economic activities pose a serious threat to maintaining the sustainability of cultural heritage sites.

The methodological importance, in this case, will be the representation of “danger” as an objective reality (state, property, property of a material object), which is the natural habitat of man and "risk",...
which is used as “probabilistic losses” that can be established by multiplying the probability (frequency) of a negative event by the amount of damage from it [6].

The Handbook for local government leaders, “Making Cities Resilient to Disasters” developed as part of the Worldwide Campaign "Securing cities: my city is preparing", says that cities are considered sustainable where “measures are taken to prevent and mitigate the impact of disasters, monitoring technologies are introduced and early warning to protect infrastructure, the public domain and citizens, including their homes and property, cultural heritage, natural and economic resources, and where camping to minimize the material and social damage caused by extreme weather events, earthquakes or other threats of natural origin or caused by human activity". Thus, the objects of cultural heritage are given special attention.

In the Republic of Tatarstan, which participates in the implementation of the Sendai framework program for disaster risk reduction for the period 2015-2030, great attention is paid to the preservation and restoration of cultural heritage sites, which there are more than 7 thousand in Tatarstan. 1540 objects of cultural heritage are under state protection, 150 of them are of federal significance, 1076 are of republican significance, 314 are of local significance. At the same time, 364 objects are in federal ownership, 200 in the republican, 770 in the municipal, and 206 in private ownership. Of the total number of cultural heritage sites, 513 are situated in Kazan. Observations of their condition in the regions of Tatarstan show that almost all of them are highly susceptible to destruction due to the impact of adverse natural and man-made impacts. In order not to lose the historical past, it is necessary not only to preserve and restore, but also to create conditions for the continued existence of ancient monuments.

Karsts and landslides characteristic of Tatarstan, including its capital Kazan, pose a serious threat to the historical heritage of our Republic. On the night of April 28, 1977, the most beautiful building of the Alexander Passage collapsed. This was not unexpected, in 1890 the Black Lake block of the Passage building sank by 6 cm. The situation became even more dangerous in 1934 when, due to the Kuibyshev reservoir, the Volga level rose and karst became more active. Attempts to “cure” the building on their own were unsuccessful. Only the Polish company “Budimeks” from Warsaw managed the hole in the Black Lake block. First, builders cleared the rubbish accumulated over many years. Karst voids through pipes lowered to different depths were filled with a special grout. The foundation, without violating the cultural and historical originality of the building, was replaced with a similar but ceramic brick. A 6-meter-thick reinforced concrete slab was placed under the Foundation. The internal floors were planted on a separate frame, and the frame itself was cunningly hidden inside the wall, since its thickness (90–120 cm) made it possible to do this without much difficulty [6-9].

2. Methods
In order to ensure the safety and operational reliability of the cultural and historical heritage of the Republic of Tatarstan, it is necessary to take timely measures to protect such objects from natural and man-made threats.

Cultural and historical objects of the Republic of Tatarstan are located in various zones of natural and man-made risk, have a different degree of preservation. In this regard, in order to develop adequate preventive and protective measures, it is necessary to conduct timely monitoring, evaluation and development of management decisions aimed at increasing the stability and preservation of cultural and historical heritage objects. Therefore, it is advisable to use various international tools to assess the condition of objects and evaluate protection and prevention measures [10-14].

From the authors’ point of view, the most effective method is INFORM (index for risk management), based on an assessment of three risk components by measuring the relevant indicators in each of three directions: the degree of danger; level of vulnerability; counteraction (overcoming) potential [1].

The INFORM method, based on the index method, is the first global, objective toolkit developed in 2012 by the European Commission to understand the risks of humanitarian disasters.
The INFORM integrated risk index includes about 50 different indicators for measuring hazards and their impact, vulnerability indicators and identifying the necessary resources for stopping hazards.

In this case, it is necessary to consider as indicators: the whole range of possible dangers and threats of a natural and man-made nature (danger); the state of the protected object (its vulnerability); the presence and condition of the engineering protection system, emergency response system (overcoming potential).

The main hazards can be considered: floods and surge phenomena; seismic activity; landslides, mudflows, avalanches; natural fires; hurricanes, tornadoes, strong winds; flooding; man-made emergencies at potentially dangerous facilities (radiation, chemical, fire and explosion hazard, hydraulic structures); man-made emergencies in transport communications [13-17].

The vulnerability can be considered: the vulnerability of the population, including vulnerable groups (people with disabilities, children, etc.); the vulnerability of potentially dangerous facilities (including depreciation); vulnerability of housing and communal services (including depreciation); vulnerability of the territory [18-22]. As a counteraction potential, it is recommended to consider: the availability and coverage of warning and information systems; emergency response system; reserves of material and financial resources, medical supplies, etc.

In accordance with the structure of the integrated risk index, indicators are distributed in three dimensions (danger, vulnerability and lack of potential to counter dangers and threats), in each of the three dimensions, the corresponding index is evaluated on a 10-point interval scale [23]. To obtain an integral risk index, instead of the index “counteraction potential”, the index “absence of counteraction potential” is used. This technique allows us to use both averaged formulas (geometric mean, arithmetic mean, etc.) and linear combinations in the calculations of the integral risk index. All indicators are normalized and take values from 0 to 10. The closer the value of the indicator to zero, the more favorable the situation in that area, which is measured by the corresponding indicator [24,25].

Based on particular indicators for the three components of the integral risk index - danger, vulnerability and lack of countermeasures, calculated dependencies are formed for calculating the corresponding indices and the general risk index of the emergency. The integral risk index is formed as the geometric mean of the component indices: danger, vulnerability and lack of counteraction potential [26-28].

\[ I = \sqrt[3]{G \times V \times L} \]  

where \( G = 0.5(I_{nat} + I_{techno}) \); \( I_{nat}, I_{techno} \) - indices of natural and technogenic hazards; \( V \) - index of vulnerability \( (I_{vuln}) \); \( D = 1 - I_{poten} ; I_{poten} \) - is an index of counteraction potential.

For example, the index of natural and technological hazards for objects of cultural and historical heritage can be determined by the formula:

\[ I_{pr} = \sum_{i=1}^{m} \lambda_i I_i \]  

where \( \sum_{i=1}^{m} \lambda_i = 1; \lambda_i > 0 \), \( \lambda_i \) - weights that reflect the significance of the hazard; \( I_i \) - hazardous process index; \( m \) - the number of hazardous processes most significant for the municipality (M), N - total number of population living in the territory of the municipality, people.

3. Results

The use of the INFORM method for developing and making management decisions to improve the sustainability and security of cultural and historical heritage objects makes it possible to assess the risk, which is that most of the information for filling the database can be performed automatically or filled in by the operator from open databases.

The INFORM risk assessment technology algorithm for historical built-up areas includes:
the formation of an annual database of indicators of dangers, vulnerability and countermeasures for the objects of historical and cultural heritage of the Republic of Tatarstan;

interconnected methods and calculation formulas for calculating hazard indices, vulnerabilities and countermeasures for a specific historical built-up territory;

analysis and assessment of the current situation, assessment of vulnerability, forces and means in the subject, and in individual municipalities and determination of the integral risk index based on the components of the risk index;

ranking of historical territories by indicators of the integral risk index, individual components of the integral risk index;

identification of lagging municipalities by component risk indices and the definition of advanced municipalities;

recommendations for improving risk indicators by selecting effective preventive and protective measures based on hazard index indicators (natural and man-made fires, earthquakes; geological hazards, meteorological conditions; hydrological and hydrogeological conditions, as well as man-made hazards.), indicators for the formation of the vulnerability index (socio-economic development of the locality; depreciation of fixed assets, dependence on external assistance, etc.), the main indicators for the formation of the counteraction potential index (fire protection measures; seismic protection of buildings and structures; landslide and anti-settlement measures; anti-karst and anti-shrinkage measures; measures against meteorological hazards; anti-hydrological measures, etc.).

4. Conclusions

Thus, using the INFORM method, it is possible to make a reasonable forecast on the current state of the cultural heritage object, to give forecasts on its state in time, for carrying out preventive work and the possibility of restoration.

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