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Integrated security assessment engineering construction object

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Abstract. Following the direction from traditional urban development to urban development, the problem of ensuring the safety of buildings and structures on the principles of biosphere compatibility has been formulated. The existing concepts and modern methods of ensuring the safety of engineering and construction objects of the city's living environment are analyzed. It is concluded that it is necessary to apply an integrated approach to ensuring the safety of buildings and structures, the definition of integrated security from the point of view of the concept is presented. Criteria have been developed to ensure the integrated safety of engineering and construction objects of the city's life environment from the perspective of transforming the city into a biosphere-compatible and developing person. It's proposed an algorithm of calculation analysis to determine the parameters of the integrated security of engineering and construction projects of the city. Numerical studies were carried out to assess the level of integrated safety of engineering and construction projects using residential facilities for the city of Kursk as an example.

1 Introduction

A person's life takes place in his environment, which is potentially dangerous for his life, therefore, in modern concepts of ensuring safety, the urban environment is a territory of increased danger. However, human activity is also potentially dangerous for the environment, in connection with which the concept of absolute safety is rejected in world practice and the concept of risk is used. Analysis of human activity shows that it is impossible to achieve zero risk, therefore, the concept of acceptable risk is used as a compromise between the level of security and the possibilities of achieving it [1]. The safety of the living environment is associated with the technological safety of engineering and construction projects, which serve as an important element of the urban economy and the city's economy [2-4].

Currently, in the world, the concept of sustainable development has been adopted as the main one, within the framework of which it is planned to make cities and settlements "open, safe, resilient and sustainable". The fundamental category that defines the basic principles,

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goals, objectives, priorities and strategic directions of the state policy of sustainable development, including the architecture, urban planning, and construction sciences, human potential is emerging [5].

However, a retrospective analysis of security concepts showed that, taking into account the developed programs, no country in the world has made a transition to sustainable development until the date. Cities as a whole still remain unsustainable in the sense that is embedded the term of "sustainability" [6,7], and the larger the city, the less effective it is in organizing interaction with its natural environment.

In recent decades, basic science has been conducting research to develop new concepts for ensuring the safety of the city's living environment based on the mechanism of self-sustaining development of urbanized territories and the principles of symbiotic human interaction with the environment [8-10]. The symbiosis of the city with the Earth's Biosphere (hereinafter referred to as the Biosphere) is necessary and possible only with the development of the person living in it, changing its philosophical and moral-ethical views in favor of cooperation with the Biosphere. The main problem of modern humanity is not the lack of housing and food, but the antagonistic contradiction between the revolutionary, degrading and pathological development of humanity and the evolutionary, progressive and gradual development of the Biosphere.

Given the interdisciplinary nature of the problem of guaranteeing the security of the city's living environment, its structure should be discussed in terms of symbiotic systems and the safety of the living environment should be considered as an eco-socio-technogenic security, that is, a security integral, which includes social characteristics and indicators of a balanced interaction of the city with the natural environment.

Every modern city constantly needs support for its development at the expense of external resources. From the point of view of the principles of biosphere compatibility, a safe city is an open natural-socio-technical system in which a person is organically included in the technosphere he creates, which does not replace or displace the Biosphere.

2 Methods

The principles of biosphere compatibility in the formation of safety requirements for the objects of the city's living environment are based, first of all, on the observance of a balanced biotechnosphere in the region and human development. These principles are implemented in the process of urban development and provide ecological balance and balance of the biotechnosphere, positive dynamics of human potential, and favorable living conditions for people to meet their rational needs and limit the negative impact of economic and other activities on the environment. When comfortable living conditions are provided to city residents, opportunities for public life, social communication appear and as a result the security of vital environments and functions is obtained [11, 12].

3 Results and discussions

Using the fundamental principles of biosphere compatibility, the safety criteria for engineering and construction objects of the city's life environment were developed in the works [12–16].

1. The criterion of ecological equilibrium — an indicator of the biosphere compatibility of a territory η_{BC} — describes the state of safety of engineering and construction objects in a dynamically stable state in which the potential of the biosphere B_{ik} is greater than the potential of the technosphere T_{ik}. It is used as one of the comprehensive criteria for the classification

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of environmental situations in an urbanized area and for determining the environmental conditions of environmental objects in a city.

2. The criterion for the balance of the biotechnosphere establishes harmonious proportions between different parts of the Biosphere, including the population, as well as the list and amount of consumed natural resources per unit time with reference to the city.

3. The criterion for assessing the effectiveness of building technologies involves assessing the applicability of new biosphere-compatible technologies that use pathologies as a resource, as well as allowing them to be used in some new quality with minimal consumption of natural resources. Evaluation of the effectiveness of construction technologies can be performed on the basis of a generalized indicator of the environmental efficiency of the building E_b.

4. The criterion for assessing development progress includes socio-economic indicators and the quality of life of the population, combined by the level of human potential.

5. The criterion for assessing the level of auspiciousness of the urban environment determines the characteristics of the urban environment: the spatio-temporal accessibility of the urban population and the provision of vital and socially important objects in the implementation of the functions of the city.

6. The criterion for assessing the comfort of the urban environment governs social standards and various socio-demographic characteristics of the living environment.

7. The criterion for assessing the level of eco-socio-technogenic safety - security is achieved when all the principles of the concept of biosphere compatibility are fully implemented.

Based on the proposed criteria, based on the principles of biosphere compatibility, this document builds an algorithm for the analysis of eco-socio-technogenic safety calculation of the city's engineering facilities, based on the calculation of individual indicators for each of its three components.

The calculation analysis algorithm for determining the parameters of eco-socio-technogenic safety of engineering and construction objects of the city's life environment on the principles of biosphere compatibility consists of several stages:

1. Definition of parameters on which integrated security depends.
2. Collection and analysis of baseline information on the identified parameters of the three components of safety: technical, natural, social.
3. Calculation of parameters characterizing the technical component of the integrated security of the facility.
4. Calculation of parameters characterizing the natural component of the integrated security of the facility.
5. Calculation of parameters characterizing the social component of the integrated security of the facility.
6. Definition of a comprehensive indicator of the security of an engineering and construction object of the city's life environment and conclusions about the condition of the object based on the safety rating scale.

We will test the algorithm for calculating the eco-socio-technogenic safety of the engineering and construction facilities of the city using residential buildings located in different areas of Kursk as an example: st. Radishchev, 84; st. Friendship, 1; st. L. Tolstoy, 7B and their adjoining territory.

At the first stage, we analyze the sources of danger from the external environment. According to federal law No. 384 "Technical regulation on the safety of buildings and structures", which regulates identification features, we will perform identification of residential buildings (Table 1).

Table 1. Identification of the surveyed residential buildings in the city of Kursk.

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№	Identification features	Address of the investigated object		
		Radishchev, 84	Druzhby, 1	L. Tolstoy, 7B
I_1	Function	residential	residential	residential
I_2	Belonging to objects whose functional and technological features affect their safety	no	no	no
I_3	Possibility of dangerous natural processes, phenomena and technological impacts in the territory in which the building is operated	no	no	no
I_4	Belonging to hazardous production facilities	no	no	no
I_5	Fire and explosion hazard	F1.3	F1.3	F1.3
I_6	Availability of premises with permanent residence of people	yes	yes	yes
I_7	Level of responsibility (high, normal, low)	normal	normal	normal

Based on the analysis of the sources of danger, the safety components of engineering and construction objects are determined, taking into account the weight coefficients determined on the basis of the expert assessment method:

B_1 - mechanical safety ($k_{(1)} = 0.6$);

B_4 - safety for human health of living conditions and stay in buildings and constructions ($k_{(4)} = 0.2$);

B_6 - accessibility of buildings and structures for the disabled and other groups of the population with limited mobility ($k_{(6)} = 0.1$);

B_7 - energy efficiency of buildings and structures ($k_{(7)} = 0.1$).

In order to obtain reliable information about the technical condition of the buildings in question in 2016-2018. Surveys were carried out on residential buildings, which included:

1) the implementation of the necessary engineering and measurement work to study the structures and elements of the building;

2) conducting a survey of the technical condition of building structures and engineering networks of the building;

3) identification of defects and damages of the examined structures (Fig. 1);

4) an assessment of the degree of influence of the identified defects and damage on the bearing capacity of building structures;

5) assessment of the technical condition of the surveyed building structures and the building as a whole.

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Fig. 1. Materials of photofixation of survey objects and their defects.

Based on the defects identified during the inspection, the physical deterioration of the main building structures was determined and the current technical condition of the building was revealed (Table 2). So, the technical condition of residential buildings at the address: st. Radishchev, 84 and st. L. Tolstoy, 7B as a whole at the time of the examination should be characterized as limited-functional, and the technical condition of the residential building at the address: st. Druzhby, 1 - as workable. Based on the analysis of the identified defects, recommendations were made and measures for capital and repair work were developed.

Table 2. The results of the survey of residential buildings in the city of Kursk and assess their technical condition.

Constructions, elements, engineering systems	Radishchev, 84		Druzhby, 1		L. Tolstoy, 7B	
	Wear, %	Technical condition	Wear, %	Technical condition	Wear, %	Technical condition
Foundation	45	OR	40	Foundation	45	OR
Walls	20	R	0	Walls	20	R
Overlappings (coverings)	10	R	10	Overlappings (coverings)	10	R
Roof	60/65	OR	0	Roof	60/65	OR
Windows / doors	65/45	A	45	Windows / doors	65/45	A
A blind area / porch / peaks / basement entrances	70/75/ 55/75	A/A/ OR/A	-/75/ -/75	A blind area / porch / peaks / basement entrances	70/75/ 55/75	A/A/ OR/A
Heat supply	75	OR	60	Heat supply	75	OR
Cold and hot water supply. Water disposal	65	A	-	Cold and hot water supply. Water disposal	65	A
Power supply	60	A	60	Power supply	60	A
Total	56	OR	26	Total	56	OR

Note: I – good condition; R – working condition; OR – limited-functional state; N - unacceptable condition; A - emergency condition

Based on the amount of physical deterioration and the identified technical condition of the building, we determine the values of the indicator characterizing mechanical safety using the following scale (Table 3).

Table 3. The scale of the indicator of mechanical safety, depending on the technical condition of the object.

Physical deterioration of the building, %	Technical condition	Scale marks
100 - 76	Emergency condition	0.00 – 0.20
75 - 61	Invalid state	0.20 – 0.37
60 - 31	Limited functional state	0.37 – 0.63
30 - 11	Working condition	0.63 – 0.80
10 - 0	Working condition	0.80 – 1.00

The values of the mechanical safety index can be obtained on the basis of the physical wear of the surveyed building by interpolating the boundary values of physical wear and scale marks, respectively, for a given technical condition:

1. for the building on the street Radishcheva, 84:

$$S_m = Y_{sc}^{\max} + \frac{X - X_{Phd}^{\min}}{X_{Phd}^{\max} - X_{Phd}^{\min}} \times \left(Y_{sc}^{\min} - Y_{sc}^{\max}\right) = 0.63 + \frac{56-31}{60-31} \times (0.37 - 0.63) = 0.41;$$

2. for the building on the street Druzhby, 1:

$$S_m = 0.80 + \frac{26-11}{30-11} \times (0.63 - 0.80) = 0.67;$$

3. for the building on the street L. Tolstoy, 7B:

$$S_m = 0.63 + \frac{53-31}{60-31} \times (0.37 - 0.63) = 0.43.$$

According to the concept of biosphere compatibility, the basis for assessing the state of the natural component according to the criterion of ecological equilibrium is the principle of comparing external environmental impacts and internal processes of the urban ecosystem functioning, as a result of which ecological situations in an urbanized territory can be ranked according to their degree of favorableness [12, 13].

For the objects under consideration - residential buildings - due to the lack of large production facilities that have a significant anthropogenic impact on the local area, automobile transport is considered the main source of pollution.

The biosphere compatibility index of the territory includes two components: η_P - characterizing the ingredient pollution of the urbanized area from motor vehicles and η_N - characterizing the acoustic pollution of the urban environment from motor vehicles. The calculation of this indicator is performed according to the technique developed by the authors of the study [17]. Previously, this indicator was used to assess the state of production zones [12], transport infrastructure of the city [18, 19] and urban transport construction objects [13].

The obtained value of the indicator serves as a criterion for the ecological balance of the components of the urban environment - natural and technogenic, using the proposed state assessment scale (Fig. 2).

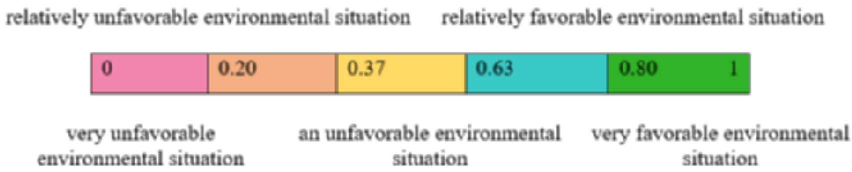

Fig. 2. Scale of assessments of environmental situations based on the indicator of biosphere compatibility of the territory.

At the next stage of the algorithm for calculating the eco-socio-technological safety of engineering and construction projects, an assessment of the effectiveness of construction technologies can be performed. This assessment is based on the definition of a generalized indicator of the building's environmental safety E_b:

$$E_b = \left(O_1 \times B_n \times C_n \times P_n \times F_n \times E_n\right)^{1/6} < 1, \quad (1)$$

where O_1 is an indicator of waste-free construction technologies;
B_n is the indicator of pollutant emissions into the atmosphere;
C_n is the indicator of wastewater discharges into water basins;
P_n is the indicator of soil pollution;
F_n is the indicator of land resources removed from the natural resources of the settlement (for example, land occupied by landfills);
E_n is an indicator of the energy intensity of construction products.

Due to the fact that the buildings under study were built in 1960-61, no biosphere-compatible technologies were used in the process of construction and operation, respectively, each component of this indicator, like the generalized indicator of the environmental safety of the building E_b, tends to 0. Therefore, in further calculations, this indicator is not taken into account.

The rating scale for assessing the favorable environment of life is developed in the work [20]. Define the level of favorable environment formed by the residential quarter for a residential building on the street. Radishcheva, 84:

$$K_f = \frac{\sum(\lambda_i \times K_i)}{N} = \frac{10\times0.1+10\times0.12+7\times0.15+5\times0.08+5\times0.12+3\times0.05+3\times0.1+5\times0.15+3\times0.05+5\times0.08}{10} = 0.60$$

where λ_i is the weight coefficient;
K_i is the value of the considered indicator according to the results of expert evaluation;
N is the total number of indicators considered.

Similarly, we find the coefficient of favorable environment for two other residential buildings.

An analysis of the local territories for residential buildings in the city of Kursk allows us to conclude that in general, they do not differ in the variety of landscaping and facades have a rather meager set of sites and small architectural forms, and they need reconstruction.

Based on the studies of the auspiciousness factors, the final value of the sponsorship indicator for residential premises and adjoining spaces can be determined:

For the object at 84 Radishcheva Street: $S_{as} = \dfrac{K_f + K_{fys}}{2} = \dfrac{0.60 + 0.54}{2} = 0.57;$

For the object at Druzhby street, 1: $S_{as} = \dfrac{0.52 + 0.53}{2} = 0.53;$

For an object at street by L. Tolstoy, 7B: $S_{as} = \dfrac{0.60 + 0.52}{2} = 0.56.$

The final step in the calculation of eco-socio-technological safety is the calculation of a comprehensive safety indicator of engineering and construction objects using the Harrington desirability function [21], which has the form.

$$S = \sqrt[3]{S_m \times S_e \times S_{as}}. \tag{2}$$

The calculation results are shown in table 4.

Table 4. Indicators of integrated (eco-socio-technogenic) security of residential buildings in the city of Kursk.

Address of the object	Mechanical safety indicator S_m	Environmental safety indicator S_e	The favorable indicator of residential premises and adjoining spaces S_{as}	Comprehensive facility safety indicator S	The final state of the integrated safety
Radishcheva , 84	0.41	0.42	0.57	0.46	balanced
Druzhby, 1	0.67	0.77	0.53	0.65	comfortable
L. Tolstoy, 7B	0.43	0.71	0.56	0.56	balanced

Using the value of the integrated safety indicator, obtained on the basis of this function, it is possible to categorize the state of engineering and construction projects and city systems as stable, balanced, comfortable and safe. For such a detailed assessment, a sufficient number of assessment indicators obtained as a result of the survey, the processing of relevant statistical data are necessary. For this purpose, the rating scale developed in [13] can be used (Fig. 3), which categorizes various states in accordance with the principles of biosphere compatibility.

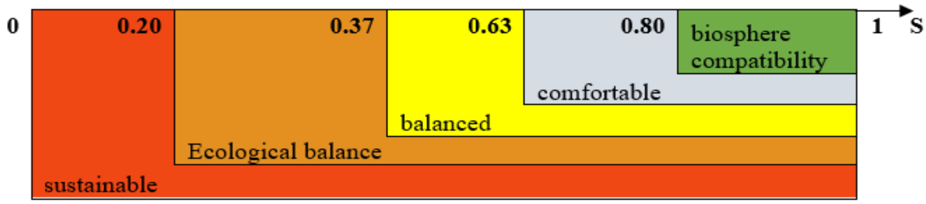

Fig. 3. The state of the integrated safety of engineering and construction projects.

4 Conclusions

After analyzing the results of the integrated security assessment of the investigated residential buildings in Kursk, it can be concluded that these objects do not fully meet the required conditions and criteria for integrated security, assessed on the basis of the principles of biosphere compatibility. Due to the fact that these objects were built in 1960-1961, their further operation is possible only after a set of measures has been taken to restore the proper technical condition and reconstruction of the adjacent territory. The values of mechanical safety index S_m of these objects are quite low and take values from 0.41 to 0.63.

The level of favorable living environment for residential buildings and the adjacent courtyard area is also not high enough (S_e = 0.53 ÷ 0.57) due to the fact that the objects studied do not differ in the variety of facades and layouts of apartments, they have a rather low provision with objects urban infrastructure. However, in the adjacent territories there is a potential for improving the favorable state of the living environment through the implementation of a range of improvement measures, the formation of an effective and convenient functional-spatial structure and subject equipment of the territories.

Higher values for the indicator characterizing the natural component of integrated safety (S_e = 0.42 ÷ 0.77). They correspond to a balanced and comfortable state of the urban environment. These values are achieved due to the presence of a greened area near the investigated object, as well as the remoteness of objects from large objects of transport construction and production facilities.

In general, the state of the integrated security of the investigated objects can be defined as balanced and comfortable.

Thus, the calculation showed that to ensure a comprehensive safety of engineering and construction objects of the city's vital activity environment, a new ideology is needed that would determine the possibility of urban life-building arrangements, ensuring balanced environmental relations with the natural environment and human development under these conditions. An appropriate set of urban planning measures should be provided for at all stages of the life cycle of engineering and construction projects.

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