Methodology to assess the comfort level of the residential development of a microdistrict in the city

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Abstract. According to the RAACS urban planning principles, it is proposed to evaluate the level of comfortable and safe urban environment, based on a new methodological approach - technologies compatible with the biosphere - and a quantitative evaluation of the implementation of the city functions for each inhabitant. Among the functions of the city in the present work are considered: life support, providing entertainment and recreation, creating conditions for power, mercy, learning, realizing creative needs, strengthening ties with nature. As indicators that quantitatively reflect the level of implementation of the functions of the city and its components, it is proposed to introduce a system of quality indicators for the planning and design decisions of the territories of the urban districts. Using the vectorial representation of the current state of the system in this paper, we developed a methodology to assess the level of comfort and viability of the life support processes in a residential and neighborhood districts. The numerical implementation of the methodology for assessing the level of comfort is made for the component "Housing", which plays a fundamental role in a cardinal increase in the comfort of the urban environment.

Introduction

Overcoming negative tendencies and degradation processes is vital in the activity of cities, ensuring human development and increasing human potential, according to researchers, should be a strategic goal of a city-planning device. The achievement of this goal will be facilitated by the adoption of scientifically grounded standards for urban planning, based on symbiosis of urban planning systems and biospheric processes of evolutionary development. The application of the principles of urban planning in the practice of developing and adjusting planning solutions for residential quarters and neighborhoods will allow, along with the creation of full-fledged conditions for human development, to balance the results of human activity and increase the life potential of the Biosphere.
Currently, in the methodological and regulatory documents there is no strictly defined the meaning of “comfortable urban environment”, as well as well-defined parameters for assessing comfort as a state. Some researchers understand the natural purity of air, water, soil and vegetation layer, the presence of a favorable level of noise, vibrations and electromagnetic effects as the comfort of the urban environment; improvement of climate comfort, etc. The most complete definition of urban comfort is given by the Russian Academy of Architecture and Construction Sciences (RAACS): a comfortable urban environment refers to such conditions in which harmonious human development is achieved in symbiosis with the natural environment, taking into account the public interests of all categories of the urban population without political and religious preferences.

1. Research problem statement
The prerequisite for ensuring the comfort and safety of the urban environment from the standpoint of harmonization of nature, society and man is the thesis that the urban environment is a complex dynamic structure, due to the interaction of three components: the natural environment, social organization and the component of the city's economy. The comfort and safety of the environment of the city’s vital activity should be considered as states due to the internal interaction of the components within the single nature-socio-technical structure, taking into account external influences, that is, eco-socio-technological safety.

The following components are highlighted in the structure of the model of eco-socio-technological safety of the environment of the city’s livelihoods:
- the natural component as part of the external environment, which contains resources that use the objects of the environment of the vital activity of the city, and it is subjected to their negative technogenic impact;
- the social component as part of the external environment, interacting with the objects of the city’s living environment and expecting satisfaction of its needs. A person as a representative of society, indirectly through the natural component, is experiencing a negative anthropogenic impact;
- technogenic component affects the natural and social environment, and determines the place of satisfaction of human needs and the level of anthropogenic impact.

The system in accordance with its structure is characterized by the following states:

- **X** - is a set of states of the natural component (NC), characterized as a potential (resource) of the biosphere, ecological capacity of the territory, reproductive capacity and others depending on the impact of urban infrastructure and human activity, as well as external disturbing influences. Impacts on the natural component: \( Z_{NC} \) - production and technical component and \( Y_{NC} \) - social component;
- **Y** - is a set of states of the social component (CC), characterized as “human potential” in the composition of the system under consideration, and dependent on the impact of the other two components. Impacts on the social environment: \( X_{CC} \) - natural component and \( Z_{CC} \) - production and technical component;
- **Z** - is a set of states of the technogenic component (TC), characterized as the potential (resource) of the technosphere. Impacts on the anthropogenic (technical) component: \( Y_{TC} \) - social component and \( X_{TC} \) - natural component (consumption of natural resources).

The states of each of the three components of the system are described by nonlinear functions:
\[ F_1(X, Y_{NC}, Z_{NC}), F_2(X_{CC}, Y, Z_{CC}), F_3(X_{TC}, Y_{TC}, Z). \]

Providing the planned requirements in the field of comfortable and safe life of the city is possible according to the system of signs and factors - indicators for its individual components of the urban environment \( X, Y, Z \). The indicator is a quantitative, measurable indicator that characterizes various objects, the structure and theory of the urban environment.

2. Research methodology level of comfort of residential development
Analysis of the state of the urban environment with these components \((X, Y, Z)\) is in assessing the compliance of the real indicators of the functioning of the structural elements of the \(X, Y, Z\) components with the requirements of the current standards and regulations.

The satisfaction of human needs in the urban environment occurs through the functions of the city according to the structure proposed by Academician RAACS V.A. Ilyichev: providing priority living needs for housing and recreation, creating conditions for power, mercy, obtaining knowledge, realizing creative needs, strengthening ties with nature.

An indicator that takes into account the availability of design solutions for modern residential neighborhoods and microdistricts with vital and socially significant objects, first of all, comfortable and affordable housing, and reflecting satisfaction of rational human needs from different social groups, may be an indicator of the city’s functions.

Let us consider an algorithm for calculating indicators characterizing the compliance of the city’s life support function with the normative values of parameters adopted for assessing its quality.

The function of the city of \(\Phi_1: \text{"Life support"}\) is a component (subsystem) of the technogenic component of the eco-socio-technological safety of the urban environment. In accordance with the current standards of urban planning includes eight components:

\[
C^{\phi_1}_1, C^{\phi_1}_2, \ldots, C^{\phi_1}_8,
\]

where \(C^{\phi_1}_1\) - Housing; \(C^{\phi_1}_2\) - Institutions, organizations and service enterprises; \(C^{\phi_1}_3\) - Engineering preparation and protection of the territory Environmental Safety; \(C^{\phi_1}_4\) - Transport and the road network. Parking lots, service stations and gas stations; \(C^{\phi_1}_5\) - Engineering networks; \(C^{\phi_1}_6\) - Improvement; \(C^{\phi_1}_7\) - Waste management; \(C^{\phi_1}_8\) - Miniproduction.

The hierarchy of the components of the function of the city of \(\Phi_1: \text{"Life support"}\) is shown in Figure.

![Figure 1. The hierarchy of the constituent functions of the city of \(\Phi_1: \text{"Life support"}\)](image)

The requirements of the current standards for each component (element) of the considered function of the city of \(\Phi_1: \text{"Life support"}\) can be represented as vectors. In particular, the requirements of regulatory documents for each element of \(C^{\phi_1}_i (i = 1, 2, \ldots, 8)\) will be presented in the form of a multi-component vector:

\[
\overrightarrow{C}^{\phi_1}_i = \left\{n^{C_1}_i, n^{C_2}_i, \ldots, n^{C_{k_{c_i}}}_i\right\},
\]

where \(n^{C_j}_i\) is the \(j\)-th requirement for the \(i\)-th element \(C^{\phi_1}_i (j = 1, 2, \ldots, k_{c_i})\),

\(k_{c_i}\) is the number of requirements for the \(i\)-th element (the number of components of the vector \(\overrightarrow{C}^{\phi_1}_i\)).
Each requirement \( n_{i}^{c} \) experts put in correspondence the dimensionless quantity \( l_{i}^{c} \) - the weight coefficient characterizing the degree of significance of this requirement \((0 \leq l_{i}^{c} \leq 1)\). The sum of the weights is subject to the condition: \( \sum_{i=1}^{k_{c}} l_{i}^{c} = 1 \).

Weighting coefficients \( l_{i}^{c} \), corresponding to each component of the first level vector \( \mathbf{C}_{i}^{\phi_{1}} \), are also represented by the components of the vectors \( \mathbf{l}^{c} = [l_{1}^{c}, l_{2}^{c}, ..., l_{k_{c}}^{c}] \). The requirements of the regulatory documents for the element \( C_{i}^{\phi_{1}} \) - "Housing" will be presented in the form of a multicomponent vector of the first level \( \mathbf{C}_{i}^{\phi_{1}} \).

As a result, of monitoring (auditing, quality control) of the state of the dwelling and the adjacent territory, the actual values of the parameters that are components of the vectors \( \mathbf{C}_{i}^{\phi_{1}} \) are determined.

By comparing the actual values of the parameters \( n_{j}^{c} \) with the normative "\( n_{j}^{c} \)\), their relations are calculated:

\[
\lambda_{j}^{c} = \frac{n_{j}^{c}}{n_{j}^{c}} \quad \text{or} \quad \left( \frac{n_{j}^{c}}{n_{j}^{c}} \right), \quad (j = 1, 2, ..., k_{c}),
\]

which show the degree of deviation of the actual value of the parameter from the standard.

The characteristic \( \lambda_{j}^{c} \) varies from 0 (complete non-compliance of the actual value of the parameter with the regulatory requirement) to 1 (full compliance).

When calculating the coefficients \( \lambda_{j}^{c} \), the following rules should be followed:

1. When specifying the norm by the inequality, the characteristic \( \lambda_{j}^{c} \) is taken equal to 1 if the actual value of the parameter satisfies this inequality;
2. The characteristic \( \lambda_{j}^{c} \) is taken equal to 0 or 1, when the actual value of the parameter is not equal to or equal to the standard value of the parameter;
3. In the qualitative task of the regulatory requirement (yes / no), the characteristic \( \lambda_{j}^{c} \) is equal to 1/0, when the normative and actual requirements are the same (opposite) in meaning.

Similarly to vectors of the first level, the vector \( \mathbf{\lambda}^{c} \) is introduced for consideration, the components of which are the characteristics \( \lambda_{j}^{c} \).

Next, we define the index of conformity of the element \( C_{i}^{\phi_{1}} \) to the norms of urban planning design as the scalar product of the vectors \( \mathbf{\lambda}^{c} \) and \( \mathbf{t}^{c} \):

\[
\eta^{c} = \mathbf{\lambda}^{c} \cdot \mathbf{t}^{c} = \sum_{p=1}^{k_{c}} \lambda_{p}^{c} \cdot t_{p}^{c} = \lambda_{1}^{c} \cdot t_{1}^{c} + ... + \lambda_{k_{c}}^{c} \cdot t_{k_{c}}^{c},
\]

Note that the above calculation of the compliance index \( \eta^{c} \) refers to each residential house included in the set of \( C_{i}^{\phi_{1}} \) - “Housing”.

Denoting this indicator \( \eta_{j}^{c} \), where \( j = 1, 2, ..., m \), where \( m \) is the number of residential houses surveyed, and assuming the weight of each house is the same, the indicator of conformity of the total number of houses in the residential zone will be equal to the average value of the corresponding home indicators:

\[
\eta_{m}^{c} = \frac{\sum_{j=1}^{m} \eta_{j}^{c}}{m}.
\]

Similarly, to assess the implementation of other elements and components \( C_{i}^{\phi_{1}} \) of the city function "Life support", established by the rules of urban planning are introduced vectors of the second and subsequent levels.
The calculation of the indicator of the feasibility of the component “Health care” of the function “Life-support” (by the example of polyclinic services for low-mobility groups of the population).

Let the average capacity of clinics (including all offices and premises) in a given territory:

\[ W_{icp} \]

The number of work shifts per year is calculated as the number of workdays (minus weekends and holidays), taking into account the fact that on workdays the clinic operates in two shifts, the number of shifts per year is 604.

Considering that about a quarter of the doctor’s workload falls on home calls, the number of work shifts is reduced by \( \frac{604}{4} = 151 \).

Consequently, the actual number of work shifts is 604-151≈450. Thus, the number of visits that the clinic can make in a year is \( 450W_{icp} \).

If we designate through \( x \) - the number of visits to the polyclinic of average capacity by representatives of people with limited mobility, whose number in a given territory is \( -N_u \), and through \( y \) - the number of visits to the polyclinic by the other inhabitants of the territory, the number of which is \(-N_H\), then clearly

\[ x + y = 450W_{icp} \tag{5} \]

Medical practice shows that the duration of reception of people with disabilities is twice the duration of the reception of people of the mobile group. This implies:

\[ \frac{y}{N_H} = \frac{1}{2} \frac{x}{N_u} \tag{6} \]

Solving the system of equations (5) - (6) for unknowns \( x \) and \( y \), we get

\[ x = \frac{450W_{icp}}{1 + \frac{N_H}{N_u}}, \quad y = \frac{450W_{icp}}{1 + \frac{2N_u}{N_H}} \tag{7} \]

For example, if group of limited mobility and people with disabilities make up a quarter of the population of a territory, that is \( \frac{N_H}{N_u} = 3 \), \( x = 180W_{icp} \), \( y = 270W_{icp} \).

The number of visits per year per representative of the group of limited mobility and one other visitor, respectively, is as follows:

\[ \frac{x}{N_u} = \frac{180W_{icp}}{N_u} \quad \text{and} \quad \frac{y}{N_u} = \frac{270W_{icp}}{N_H} \]

Based on the requirement that every resident of the region can visit the clinic at least once every six months (medical examination, prevention, counseling, treatment, etc.), is possible to get the required average capacity of the clinic from the system of inequalities:

\[
\begin{aligned}
& \frac{180W_{icp}}{N_u} \geq 2, \\
& \frac{270W_{icp}}{N_H} \geq 2.
\end{aligned} \tag{8}
\]
The population of the city of Orel in 2012 is 319,100 people, of whom 32,995 people are disabled, i.e. \( N_u = 32995, N_H = 286105 \). From system (8) follows:

\[
\begin{align*}
W_{1cp} & \geq \frac{N_u \cdot 2}{180} \geq 366, \\
W_{1cp} & \geq \frac{N_H \cdot 2}{270} \geq 2120,
\end{align*}
\]

i.e. the required average capacity of polyclinics in the region should correspond to the inequality:

\[ W_{1cp} \geq 2120. \]

The actual capacity of eight polyclinics of the city of Orel, among which both children’s and dental ones are taken into account, is 880.

Based on the above, the indicator of feasibility of polyclinic service is:

\[ \beta_f = \frac{W_{1cp}^\beta}{W_{1cp}} = \frac{880}{2120} = 0.41, \]

where \( W_{1cp}^\beta \) - the actual average capacity of polyclinics in the region. It should be noted that the obtained estimated value of the feasibility index corresponds to 100% availability of such objects. If we recalculate this indicator to the actual level of accessibility of healthcare facilities, we obtain lower values.

**Summary**

Has been built a multi-level scale of indicators for assessing the current state of the city’s sub-life support system “Housing”. Using such structure of indicators, it is also possible to evaluate other components of life in neighborhoods and micro-districts, including social, transport and engineering infrastructure, as well as assess the change in the state of these components in view of management decisions. The developed methodology for assessing the provision of residential buildings and the viability of the life-support processes of modern neighborhoods can contribute to the development of quality of comfort levels and safety of various activities in urban areas and optimize the security management of all city life-support systems.

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