Assessment of Compliance with Regulatory Requirements of Life Support Facilities of Modern Neighborhoods

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Abstract. It is proposed to evaluate the level of comfort of the urban environment on the basis of a methodology for quantifying the feasibility of city functions: livelihoods, providing entertainment and recreation, creating conditions for power, charity, gaining knowledge, realizing creative needs, strengthening connections with nature. It is proposed to introduce a system of quality indicators of planning and design solutions for the territories of urban housing estates as indicators that quantitatively reflect the level of implementation of city functions and their components. The study developed an algorithm for calculating indicators characterizing the correspondence of city functions to the standard values of parameters adopted for assessing the quality of the state of its elements. The numerical implementation of the indicator calculation algorithm is performed for the city's Life Support function, which plays a key role in dramatically improving the comfort of the urban environment. For a more complete analysis of the effectiveness of urban decisions aimed at increasing human potential and satisfying the rational needs of a person, as well as for the comprehensive consideration of comfort characteristics, it seems possible to carry out a scientific substantiation of an extended list of indicators for the implementation of city functions and the accessibility of socially significant everyday objects.

1. Introduction

The starting point for ensuring a comfortable living environment of the city from the perspective of system analysis is the thesis that it is a complex dynamic structure [1], due to the interaction of three entities: the natural environment, social organization of the population and the technogenic component of the city’s economy [2]. The structure of the city’s living environment is characterized by dynamic processes [3], which take into account the diversity of relationships and cause-effect relationships [4] and functional interactions between independent subsystems of various types in its composition - natural, social and technical.

The work [5] describes a conceptual model of the urban life support system in the form of a multicomponent natural and technogenic structure. The fundamental difference in constructing a conceptual (systemic) model of a comfortable living environment of a city from other known models (A. Tensley’s “ecosystem”, V. Volter, A. Lotka, mathematical models of population growth and their
interactions, S. S. Schwartz’s evolutionary system model, the model of the biocenosis state of K. Möbius and the model of biogeocogenesis NF Reimers and other scientists) in this case is that its condition is determined by specific laws based on the mutual influence of its components. Moreover, the inclusion of a number of components of the natural and social environments in the structure under consideration is determined in each case by the importance of their influence and contribution to the life processes of the city. In [6], a mathematical model of an open dynamic system compatible with the urban life support system with a choice of control parameters was developed.

To calculate the justification of the parameters and indicators of the comfort of the city’s living environment, we define ourselves: by a comfortable urban environment we mean such urban environment conditions under which a harmonious human development (physical, spiritual and material) is achieved in symbiosis with the surrounding natural environment [7, 8].

2. Materials and methods

To analyze and systematize the whole variety of factors that determine the comfortable state of the city’s living environment, a hierarchical approach and decomposition method were used in the work. Figure 1 presents a diagram reflecting the hierarchy of the components of the concept of comfort of the city’s living environment.

![Diagram of the hierarchy of the components of a comfortable living environment of the city](image)

Figure 1. Diagram of the hierarchy of the components of a comfortable living environment of the city.

Obviously, the life environment of the city is a hierarchical structure with several levels. The system consists of three components, each of which is represented by components. For example, the technogenic component of the living environment is represented by components - functions of the city [9, 10] (see Figure 1).

Numerical studies of the feasibility of city functions were performed in [11, 12, 13]. The work [14] presents a methodology for providing an accessible urban environment for people with disabilities based on the creation of a system of quantitative indicators for assessing the city’s life support facilities. Based on the analysis of statistical data, a correlation and regression analysis of the dependence of the number of people with disabilities of various categories on a number of factors of socio-ecological nature was carried out and a short-term forecast for the growth of the number of people with disabilities and the disabled population was given [14].

The main problems associated with the organization of green spaces in the urban environment when implementing the paired functions of the city “Life Support” and “Communication with Nature” were considered in [15-19]. In [20], the results of earlier studies were developed and a multi-level scale of indicators for assessing the current state of the urban subsystem was constructed.
3. Results. Algorithm for assessing the level of comfort of life support objects when implementing the functions of the city (for example “Life support”)

The city function $\Phi_i$ is a component of the technogenic component. Each city function is implemented through some infrastructure of a residential quarter or microdistrict - a component of the city’s i-th function necessary for its implementation (Figure 2).

$$\Phi_1 - \text{component "Life support"}$$

$$C_{1}^{\Phi_1} \quad \text{"Housing"}$$

$$C_{2}^{\Phi_1} \quad \text{"Institutions, organizations and service enterprises"}$$

$$C_{3}^{\Phi_1} \quad \text{"Mini-production"}$$

Figure 2. The hierarchy of the function of the city $\Phi_i$: Life support.

The component $\Phi_1$ contains 8 groups of elements $C_{1}^{\Phi_1} (j = 1, 2, 3, ..., 8)$.

The component $\Phi_2$ contains 4 groups of elements $C_{2}^{\Phi_2} (j = 1, 2, 3, 4)$.

The component $\Phi_3$ contains 2 groups of elements $C_{3}^{\Phi_3} (j = 1, 2)$.

The component $\Phi_4$ contains 2 groups of elements $C_{4}^{\Phi_4} (j = 1, 2)$.

The component $\Phi_5$ contains 2 groups of elements $C_{5}^{\Phi_5} (j = 1, 2)$.

The component $\Phi_6$ contains 3 groups of elements $C_{6}^{\Phi_6} (j = 1, 2, 3)$.

The component $\Phi_7$ contains 3 groups of elements $C_{7}^{\Phi_7} (j = 1, 2, 3)$.

Each component is evaluated by the state of the j-th group of life support objects $C_{i}^{\Phi_j}$.

For each group $C_{j}^{\Phi_i}$, $k$-integral indicators of the state of the infrastructure objects $I_{ik}$, belonging to the j-th group are set up, which are necessary for the implementation of the i-th function, used further to assess the state of the corresponding component $\Phi_i$ ($k$ is the number of the indicator). For example, for the component $\Phi_1$ element $C_{1}^{\Phi_1}$:

- $I_{111}$ - the level of comfort of the premises;
- $I_{112}$ - the level of housing affordability;
- $I_{113}$ - the level of comfort areas.

For a component $\Phi_2$ and all its elements: $C_{j}^{\Phi_2} (j = 1, 2)$:

- $I_{211}$ - the level of feasibility;
- $I_{212}$ - level of availability.

For the calculation of the integral indicator $I_{ik}$ accepted normalized indicators (regulatory requirements), adopted for the assessment. Below is proposed an algorithm for calculating the
indicators characterizing the compliance of the infrastructure necessary for the implementation of the city’s “Life support” function \( (i = 1) \) to the standard values of the parameters adopted to assess its quality.

First we turn to the group \( C_{1}^{φ1} \), which is the first element \((j = 1 - “Housing”\) - part of the infrastructure of the city’s living environment, which is necessary for the implementation of the city’s function “Life Support”. This group consists of a set of \( m \) residential buildings, for each of which the requirements of regulatory documents are conveniently presented in the form of a multicomponent vector

\[
\tilde{z}_i = \{n_{i1}, n_{i2}, \ldots, n_{ij}, \ldots\},
\]

where \( \tilde{z}_i \) – is the vector of the aggregate requirements for the \( i \)-th residential building from the group

\( C_{1}^{φ1} \) \((i = 1, 2, \ldots, m)\);

\( n_{ij} \) – \( j \)-th requirement for the \( i \)-th residential building from the group \( C_{1}^{φ1} \) \((j = 1, 2, \ldots, p_i)\);

\( p_i \) – the number of requirements for the \( i \)-th building \((k = 1)\).

(Note. Thus far, only the requirements characterizing the level of comfort of the premises are taken into account, that is, \( k = 1 \). Thus, the total number of requirements for a residential house is divided into two groups \( p_1 \) and \( p_2 \), where \( p_1 \) – are the requirements that characterize the level of comfort of the premises; \( p_2 \) – requirements characterizing housing affordability \((k = 2)\).)

Experts assign \( n_{ij} \) a dimensionless quantity to each requirement \( l_{ij} \) - a weighting factor characterizing the degree of significance of this requirement \( (0 \leq l_{ij} \leq 1) \). The sum of the weights is subject to the condition:

\[
\sum_{j=1}^{p_i} l_{ij} = 1.
\]

Weighting factors \( l_{ij} \) are also represented by vector components.

\[
\tilde{l}_i = \{l_{i1}, l_{i2}, \ldots, l_{ip_i}\}, \quad (i = 1, 2, \ldots, m).
\]

As a result of monitoring the status of a group of residential buildings and the local area, the actual values of parameters (requirements) \( \phi n_{ij} \), which are components of vectors \( \tilde{z}_i \), are determined. To compare the actual values of the parameters \( \phi n_{ij} \) with the normative \( \eta n_{ij} \), their relationships are calculated

\[
\lambda_{ij} = \frac{\eta n_{ij}}{\phi n_{ij}} \text{ or } \phi n_{ij} = \frac{\eta n_{ij}}{\lambda_{ij}}.
\]

which show the degree of deviation of the actual values from the standard.

Similarly to vectors \( \tilde{z}_i \), is introduced for consideration the vector \( \tilde{\lambda}_{ij} \) of estimated characteristics

\[
\tilde{\lambda}_{ij} = \{\lambda_{i1}, \lambda_{i2}, \ldots, \lambda_{ip_i}\}.
\]

Then, it’s defined the correspondence indicator of the \( i \)-th residential building from the group \( C_{1}^{φ1} \) as the scalar product of vectors \( \tilde{\lambda}_{ij} \) and \( \tilde{l}_i \)

\[
\eta_i = \tilde{l}_i \cdot \tilde{\lambda}_{ij} = l_{i1} \cdot \lambda_{i1} + l_{i2} \cdot \lambda_{i2} + \ldots + l_{ip_i} \cdot \lambda_{ip_i}, \quad (i = 1, 2, \ldots, m).
\]

A set of indicators \( \eta_i \) can be represented as components of the vector \( \overline{\eta}_{(i=m)} \)

\[
\overline{\eta}_{(i=m)} = \{\eta_1, \eta_2, \ldots, \eta_m\}.
\]
The overall significance of residential buildings in the group $C_1^{\Phi_1}$ is different. It’s introduced a vector of building weights $\vec{\mu}_{(1+m)}$

$$\vec{\mu}_{(1+m)} = \{\mu_1, \mu_2, \ldots, \mu_m\}, \sum_{k=1}^m \mu_k = 1$$

(7)

where $\mu_k$ is the weight coefficient of the $k$-th building ($k = 1, 2, \ldots, m$) from the group $C_1^{\Phi_1}$.

Then the measure of compliance of the set of $m$ buildings in the group $C_1^{\Phi_1}$ (residential area) to regulatory requirements takes the form of the scalar product of vectors $\overline{\phi}_{(1+m)}$ and $\vec{\mu}_{(1+m)}$

$$\eta^{\Phi_1} = \overline{\phi}_{(1+m)} \cdot \vec{\mu}_{(1+m)} = \mu_1 \cdot \eta_1 + \mu_2 \cdot \eta_2 + \ldots + \mu_m \cdot \eta_m.$$

(8)

In the case of the equal value of houses, the conformity indicator will be equal to the average value of the conformity indicators for houses

$$\eta^{\Phi_1}_c = \frac{\sum_{i=1}^m \eta_i}{m}.$$  

(9)

(Note. This indicator was obtained taking into account only the requirements for comfort of the premises - a group of requirements $p_1$).

Quite similarly, taking into account other requirements characterizing housing affordability, an indicator for $k = 2$ - $\eta_2^{\Phi_1}$ is built. Then both indicators $\eta_1^{\Phi_1}$ and $\eta_2^{\Phi_1}$ can be considered components of the vector

$$\vec{\eta}^{\Phi_1} = \{\eta_1^{\Phi_1}, \eta_2^{\Phi_1}\}.$$  

(10)

If we assume different significance of the characteristics: the level of comfort and the level of accessibility, then introducing a vector of weighting coefficients of their significance

$$\vec{\nu} = \{v_1, v_2\},$$

(11)

we get a comprehensive indicator of compliance of the group $C_1^{\Phi_1}$ (residential area) with regulatory requirements, as the scalar product of vectors $\vec{\nu}$ and $\vec{\eta}^{C_1^{\Phi_1}}$

$$\eta^{C_1^{\Phi_1}}_{\text{coman}} = \vec{\nu} \cdot \vec{\eta}^{C_1^{\Phi_1}} = v_1 \cdot \eta_1^{C_1^{\Phi_1}} + v_2 \cdot \eta_2^{C_1^{\Phi_1}}.$$  

(12)

Component compliance rate $\Phi_i$ - Life support is defined as

$$\eta^{\Phi_i} = \xi_1 \cdot \eta_1^{\Phi_i} + \xi_2 \cdot \eta_2^{\Phi_i} + \ldots + \xi_8 \cdot \eta_8^{\Phi_i},$$

(13)

where $\xi_j$ is the weight coefficient of significance of the group $C_j^{\Phi_1}$ ($j = 1, 2, \ldots, 8$).

Indicator of conformity of the technogenic component from the realizability of all functions of the city to regulatory requirements

$$\eta^Z = r_1 \cdot \eta^{\Phi_1} + r_2 \cdot \eta^{\Phi_2} + \ldots + r_7 \cdot \eta^{\Phi_7},$$

(14)

Where $r_i$ - is the component weight coefficient $\Phi_i$ ($i = 1, 2, \ldots, 7$);

$\eta^{\Phi_i}$ - indicator of compliance of the $i$-th component to regulatory requirements.

4. Conclusions

A methodology has been developed for a quantitative assessment of the comfort level of the city’s living environment. The assessment methodology is the identification of compliance of environmental components and its individual elements with regulatory requirements. Using the example of the city’s “Life Support” function, which plays a key role in achieving comfort indicators, an algorithm is developed for a multilevel assessment of the city’s living environment.
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