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URBAN ENVIRONMENT DESIGN: NEW METHODOLOGICAL APPROACHES BASED ON THE BIOSPHERE COMPATIBILITY PARADIGM (PART 1)

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Statement of the problem. The question is raised about the need to develop methodological approaches to urban planning at the microterritorial level, aimed at creating a comfortable and safe environment for life in cities and settlements.

Results. The authors propose a methodology development project development plan for the area — planning documentation the town-planning elements of planning structure (blocks, neighborhoods, residential areas) based on the developed in RAACS paradigm of biosphere compatibility of cities and settlements that develop the man. The method of evaluating variants of planning projects based on a comparison of four blocks of indicators: environmental safety of residential areas, spatial and territorial resources, structural planning and architectural organization of the territory and provision of urban functions. For each of these blocks, the necessary and sufficient composition of indicators is determined, which are calculated based on the design solutions. The prospects for the development of quantitative evaluation of design solutions using the principles of the biosphere compatibility paradigm at the microterritorial level are shown.

Conclusion. The numerical evaluation of the design solutions shows the social content of the territory planning projects and reflects the decisions on the urban environment of the city.

Keywords: urban planning design; evaluation of design solutions; design methodology; territory planning project; paradigm of biosphere compatibility of cities and settlements that develop people, comfortable and safe environment of the city.

Introduction. Currently the task of forming a comfortable and safe urban environment requires development of new guidelines for its design, changes in the design methodology of territorial planning projects. [1, 2, 4].

It is the planning project of the area of functional planning residential formations or residential planning units (district, microdistrict, quarter, etc.) that is the type of urban planning documentation where the characteristics of the quality of an urban environment are identified.

The aim of the article is to reveal the possibilities of urban planning with a qualitatively new approach in relation to a detailed (micro-territorial) level of documentation, which refers to the planning elements of the structure of a city (quarter, microdistrict, residential area) considering the continuity of the existing urban planning methodology.

The issue of interaction of urban planning structures with the natural environment was the focus of studies by domestic and foreign scientists. In our country, these are the works of V. V. Vladimirov [3], N. F. Reimers [10], S. B. Chistyakov [11—12]. These issues were investigated by such scholars overseas such as H. Barton, M. Grant [18], P. Hall, W. Pfeifer [20], J. Birch [19].

Most of the studies by V. V. Vladimirov were dedicated to the study of the interaction of the city and natural structures at the macro- and mesoterritorial levels. At the same time, he outlined the ways of developing methods of urban environment for the microterritorial level. V. V. Vladimirov argued that “the micro-territorial level is distinguished by the great concreteness of the measures being developed to improve the urban environment <...>. Urban environmental research at this level is mostly based on urban planning, hygienic and technological methods” [3].

This kind of research is currently ongoing in this country aiming to develop mechanisms for assessing design solutions from the standpoint of designing a safe and comfortable living environment. As part of fundamental interdisciplinary research at the RAASN run by Academician V. A. Ilychev, a new paradigm of life was developed for man-made biosphere-compatible cities and settlements [5]. The sequence of the paradigm principles establishes priorities and a hierarchy of concepts, identifies issues in the organization of city life, allows one to calculate the level of symbiotic relations between the city and nature as well as to quantify the opportunities provided by the city for the development of its residents. The principles of the paradigm involve obtaining measurable results, which are a measure of achieving a goal, i.e., the biosphere compatibility of the city, reflecting the level of implementation of specific urban planning measures. Biosphere compatibility of a city is a state of symbiosis between the city and the surrounding biosphere where the city and its residents are experiencing a positive development with the biosphere retaining its ability to naturally evolve in a certain region. In fact, it is not only about “natural development in harmony with a natural envi-

ronment, but also about the restoration of the biosphere undermined in the process of urbanization of the territory".

In the studies by the Academician of the RAASN M. V. Shubenkov the features of the formation of sustainable urban systems are defined and modern approaches and methods for predicting their spatial development are outlined [15–17].

Hence the domestic urban planning science has a huge potential in regards to addressing environmental problems in urban planning activities, particularly the upper levels of design — territorial planning schemes, general plans. At the same time, currently the task of forming a comfortable and safe urban environment requires ongoing research that develops scientific and methodological approaches to designing an urban environment at the micro level, which will allow an objective assessment of design solutions at the stage of choosing a particular option of a planning project.

1. Territory planning project as a document defining the quality of the urban environment. A territory planning project (TPP) in compliance with Section 42 "Urban Planning Code of the Russian Federation" from December 29, 2004 N 190-FZ (modified on 08/02/2019) (amended and supplemented, came into force on August 13, 2019) is performed in order to highlight the elements of the planning structure, establish the boundaries of common areas as well as the zones of the planned location of major construction objects, identify the characteristics and priority of the planned development of the area. It is at this level that the fundamentals of the living environment of such planning formations of contemporary Russian cities as a residential area or microdistrict are laid. Thus, a project for the planning of the territory of functional planning residential structures or residential planning units is the type of urban planning documentation that identifies the characteristics of the quality of the urban environment of a future district.

Detailed regulatory information on the design of the residential environment of the city in the implementation of territorial planning projects is provided in the Code of Regulations SP 42.13330.2016 "Urban Planning, Planning and Development of Urban and Rural Settlements" in various sections, e.g., 5. Residential Areas, 6. Public and Business Areas, etc. Normative indicators are linked to individual urban subsystems (housing, services, transport, etc.), which is a characteristic feature of the functional approach to city design with rigid monozoning of its area.

2. Proposals for improving the design methodology for developing planning projects for residential areas using the paradigm of biosphere compatibility. The design method

adopted in Russian urban planning practice regulates implementation of “variants of planning and (or) volumetric-spatial solutions for developing territories in accordance with a project of business zones)” (Section 4.9, Article 42 of the Civil Code of the Russian Federation). In order to justify the decisions in the TPP, several options for draft architectural and planning proposals for developing the territory are being designed. Options of design solutions can be reduced to both alternative design concepts of a residential area, or a microdistrict, and to relatively identical design solutions differing in the number and location of individual objects, development of a system of pedestrian paths, construction of sports and playgrounds, parking lots, landscaping, up to small architectural structures. For each version of a draft architectural and planning proposal, a graphic and a textual parts are prepared (an explanatory note containing the basic concept of the spatial development of the territory, justification of the correspondence of the designed sketch to the guidelines of a particular task, etc.).

In order to compare the options in the planning projects for the territory of functional planning residential formations at the stage of selecting a viable design solution and assessing the degree of comfort and safety of the living environment, a methodological approach using the consistent implementation of the provisions of the biosphere compatibility paradigm is suggested.

1. Environmental safety of each and every resident;
2. Strategic planning, i.e., analysis of problems and development of solutions for improving the city’s livability;
3. Designing a favorable and comfortable living environment for each and every resident;
4. Environmental, social, technical safety of the city.

If all of the provisions of the paradigm are performed in stages, we have a safe man-made living environment. A distinctive feature of the above approach is the premises that the urban environment is considered a single territorial space characterized by a specific state of bio-, socio- and technospheric components critical to creating conditions for the development of an “individual” but not a “territory”. Thus, the choice of indicators related to an individual, residents, people will be made.

Let us consider an algorithm for the variant assessment of design solutions in relation to residential areas where almost 65 % of residents live daily. In accordance with the above provisions of the paradigm of biosphere compatibility four blocks of indicators for assessing options for design solutions are to be identified while developing planning projects for residential areas:

- Block 1. Environmental safety of residential areas (Regulation 1);
- Block 2. Spatial and territorial resources (Regulation 3);

Block 3. Structural and planning organization of the territory (Regulation 3);

Block 4. Urban functions (Regulation 3).

For each of these blocks, the authors propose indicators that are calculated according to design decisions. Based on the comparison of indicators, an appropriate version of the planning project is selected.

This article discusses in detail the content and methodology for quantifying the indicators of the first three blocks. The block of indicators for assessing provision of urban functions will be considered in the second part of the publication.

3. Assessment of the environmental safety of residential areas. The indicators of this block are developed based on the dualistic principle 2 "On the Comparison of Two Directions in the City's Activities" of the paradigm of biospheric compatibility of man-made cities and settlements [5]. In the urbanized environment dualism is external, i.e., the impact of the city on nature, and internal, i.e. the level of physical and social health of the population. The level of health of the urban population is one of the implications of the direct and indirect human impact on the natural environment.

In order to assess the environmental safety of residential areas for the corresponding block by the same name, the following indicators are suggested:

- “the environmental rank of the surrounding area corresponding to the administrative “level” of a particular city”;
- “correlational links between medical and demographic and environmental characteristics of the territory”.

The environmental rank is a complex indicator reflecting the level of environmental well-being of the territory of the entire city. It is estimated by the sum of points considering the weighting factors established by the expert assessment. It includes a large group of sanitary and hygienic and environmental parameters for comparing the values used to transform them into points, i.e., dimensionless indicators. While developing projects for planning the territory at the stage of engineering and environmental surveys, the environmental rank of the territory is accepted in accordance with the one previously established for the region. The environmental rank must also be considered while developing the section “Assessment of the Impact of an Urban-Planning Object on the Environment” of the urban planning documentation and (or) in the architectural and construction design of urban environment objects where the impact of a designed urban planning object on all the components of the natural environment is assessed: atmospheric air, water bodies, soil, etc.

For the first time, within the framework of the design urban planning methodology, the cause and effect: the ecological state of the territory and the health of the population living in this territory has been proposed in order to establish and consider the variant assessment of planning decisions. For this purpose, the identification and analysis of functional dependencies between medical and demographic and environmental characteristics can be performed by means of the mathematical methods of correlation-regression analysis and simulation. A similar indicator for assessing a demographic situation in the region depending on the pollution of atmospheric air and water resources was considered earlier in the studies by V. A. Ilyichev, V. I. Kolchunov, V. A. Gordon [6]. The calculation basis is statistics at the level of pollution of the components of the natural environment and (or) data from monitoring the state of the territory. The established functional connections and patterns show how dualism is implemented in the influence of a city (individual) on nature and how the level of health of a city resident has changed on a broader scale.

Two options for planning the territory of the Botanika microdistrict in the Zavodskoy district of Orel were chosen as an example of assessing the environmental safety of residential areas using the above indicators². The environmental rank of the urbanized territory was preliminarily identified in accordance with the degree of environmental hazard. The foundation for both of the design options for the Botanika residential area was the 4th rank corresponding to the permissible state when deviations from the environmental norm do not lead to considerable deviations in human health and the natural environment and deviations from the requirements of the principles of composition do not cause artistic and aesthetic and psychological discomfort.

In compliance with the suggested concept of the first design option (Fig. 1), the development of the Botanika microdistrict was proposed on the section between the Orel-Bryansk railway and the Oka River floodplain.

Fig. 1. General view of the Botanika microdistrict, Orel. The first design option

² The map of environmental zoning of Orel for environmental research.

In the northeastern part of the PPT adjacent to the existing railway, in accordance with the project there is a residential area represented by the construction of 9-16-storeyed residential buildings. The territory is divided by intra-block driveways closed to the city highway, Komsomolskaya Street. The recreational zone is organized in the water protection zone of the Oka River in the southern part of the master plan and is also represented by squares and boulevards of residential quarters. The natural park “Botanika” located in the immediate vicinity is not functionally considered in the project.

The main task in the design in the second option (Fig. 2) was to maximize the use of the existing natural park and coastal zone. The residential area represented by the development of 9—25-storeyed residential buildings is located in the northeastern and northwestern parts of the TPP, adjacent to the railway. Public residential and public business zones are represented by 3—17-storeyed buildings located along the central alley. The unloading highway (alternative to Komsomolskaya Street) is designed in order to address the transportation problem in the area.

Fig. 2. Planning design for the Botanika microdistrict, Orel. The second design option

The following characteristics which aggravate the environmental situation were taken as the original data: lowering of the relief and thus deterioration of the self-dispersing ability of the atmosphere; the border from the north with an industrial zone represented by food industry enterprises (Ltd. “Orlovsky Bacon”, vegetable oils plant); the border on the southern side with the industrial enterprise “Avtoselmash”, factories of concrete goods and “Foam

Concrete”. The microdistrict is influenced by the congestion of vehicles in the area of the bus station and a major highway, i.e., Komsomolskaya Street; on the western side it is bordered by a railway branch.

In order to assess the options for the design solutions for the residential area, we made use of an integral indicator of the biosphere compatibility of an urbanized area. For the first time this indicator has been considered in the article “Some Issues of the Design of Settlements from the Standpoint of the Concept of Biosphere Compatibility”, 2009 [7]. Using the biosphere compatibility indicator, it is possible to quantitatively “compare” the actual values of the volume of incoming pollutants with those that do not violate the environmentally safe state of the territory located in the zone of influence of technogenic objects considering the gas absorption capacity of green spaces located in this area.

While calculating and justifying the indicator of biosphere compatibility of the Botanika microdistrict, not the entire spectrum of environmental pollution factors was considered but rather the most significant ones: vehicle emissions (mainly CO) and municipal solid waste (MSW).

Table 1 shows the indicators for assessing the environmental safety of the two options for design solutions for the residential district “Botanika”.

Table 1

Block 1. Indicators of environmental safety of an area/microdistrict

№	Indicators	Variant 1	Variant 2
1	Environmental ranking	4 (permissible state)	4 (permissible state)
2	Indicator of biospheric compatibility: — vehicle emissions; — municipal solid waste. * Note. The value of the indicator is normalized in the range of 0 to 1.	$\eta_{CO} = 0.22^*$, $\eta_{TKO} = 0.24^*$.	$\eta_{CO} = 0.18^*$, $\eta_{TKO} = 0.24^*$.

As shown by the calculations, the values of the biosphere compatibility indicator of the territory for the two variants of design solutions for the Botanika microdistrict from different sources of pollution (vehicles and MSW) indicate a disturbed state of environmental balance between the technosphere and biosphere components (unfavorable state). This state of the residential microdistrict is due to the prevalence of the amount of automobile emissions in relation to the

natural component, i.e., atmospheric air, as well as low efficiency of the existing MSW management mechanism as evidenced by the low values of the indicator from the range of 0 ... 1.

4. Assessment of the spatial and territorial provision of the population of residential areas.

The category of urban space plays a critical role in the system of urban planning indicators while designing a favorable urban environment. The key concept in this category is “population”! [9]. Other urban planning categories “territory” and “development” determining spatial differences in the intensity of settlement at the design site can be considered secondary to the life environment of a biospherically compatible city [10]. The territory is the material basis as well as the major most valuable resource for designing an environment for human life, not only because it is a spatial resource for building but also is a resource for designing open urban spaces that are essential to the characteristics of the urban environment [14]. Excessive use of the territory “not only considerably reduces the living (spatial and psychological) comfort but also leads to overcrowding and an increase in epidemiologically dangerous contacts and the spread of diseases” [12].

The concept of “density” is related to the categories of urban space and is one of the key indicators commonly used in urban planning practice including land planning projects. In the aggregate of density indicators as an urban planning category, the major indicator is population density which reflects the relationship between humans, city, and biosphere [9]. In urban planning practice density indicators are most important for determining the load on the natural landscape and the spatial boundaries of various urbanized systems (e.g., agglomerations). Since urbanized areas are sources of powerful anthropogenic impact on the natural environment, the study of population density has gained environmental significance. This is how the concepts of “critical”, “permissible” and “maximum permissible” [3] population density emerged. The critical density is defined as that of the maximum saturation of the territory above which qualitative changes occur in the natural environment. V. V. Vladimirov provides such indicators as the “critical density” of the population in a city or within the boundaries of an urban agglomeration from 2500 people/km² in the nuclear of the agglomeration to 300 people/km² in industrial areas of agglomerations [3].

Another indicator for assessing the interaction of the technogenic and natural environment is the building density. This indicator is considered in urban planning practice in two aspects:

1) as a two-dimensional planar characteristic of the development of the territory, i.e., the coefficient of development (K1). It is calculated as the ratio of the area occupied by buildings and structures to the area of the site (quarter). Indicator K1 reveals such an important component of the design solution as the ratio of open spaces and built-up areas of planning formation;

2) as a three-dimensional spatial characteristic of the use of the territory, i.e., the coefficient of building density (K2). It is calculated as the ratio of the area of all ground floors of buildings and structures to the area of the site (quarter). These indicators are standard town planning characteristics that are currently provided in SP 42.13330.2016 Urban Planning. Planning and Development of Urban and Rural Settlements, Appendix B.

The use of the coefficient K1 in urban planning ensures the obligatory preservation on the territory of the land plot of open areas essential for designing green spaces, sports and playgrounds, territories for other purposes catering for the city residents' needs in a particular social infrastructure. The maximum permissible indicator of the coefficient K1 in residential areas under the conditions of the reconstruction of buildings is 0.6 or 60 % of the territory of the site can be built up, 40% remains for open undeveloped areas. While designing a plot of a new residential planning formation with multi-apartment multi-storey residential buildings, K1 is 0.4, in this case undeveloped areas that can be employed for various needs and human development already make up 60%.

The density coefficient K2 is aimed at providing comfortable living in residential buildings. E.g., the density coefficient equals 1.2 as specified in SP 42.13330.2016 for new residential formations can be observed with an average 9-storeyed building.

Based on the importance of the spatial and territorial provision of the population of residential areas, it is proposed that the assessment of residential areas include the following fundamental urban planning indicators:

1. population density (people/hectar);
2. construction density:
 - 2.1. construction coefficient K1 (m^2/hectar),
 - 2.2. construction density coefficient K2 (thousand m^2/hectar).

Variations in the construction density indicators best reflect the conditions for human development: economic, environmental, social properties of the urban environment. Since the adoption of the Athens Charter, the design of residential areas has gone down an extensive path of development when the boundaries of the city are expanded, i.e. "territorial growth due to the development of free territories". In the absence of the latter, the building is compacted. As a result, the structure of the center is undergoing changes in a hypertrophied manner, public spaces are being built up. The transformation of the town-planning form is manifested in the overconsolidation of buildings in the central and middle parts of the city as well as the spread of the urbanized territory along the exit highways and in suburban areas.

5. Assessment of the structural and planning organization of the residential area/microdistrict.

The efficiency of the structural and planning organization of the territory is identified using a number of synthetic indicators reflecting the effectiveness of measures, including considering the urban planning and natural features of the territory, the interconnected placement of residential buildings, public buildings and structures, the street road network, green areas of public use and other objects, the expressiveness of the volumetric-spatial building solutions.

In order to design conditions for human development in residential areas, the well-known and commonly used indicators of urban planning of residential areas can be supplemented with those of the density of urban structures:

- density of public and business infrastructure expressed through the ratio of the number of public and business organizations in the service sector to the total area of the design site;
- density of the road network expressed through the ratio of the total length of roads to the area occupied by the projected area,
- density of pedestrian spaces expressed through the ratio of the area occupied by pedestrian spaces to the total area of the design area.

An important indicator is the availability of public transport to the population calculated as the ratio of the number of individuals residing in the zone of comfortable pedestrian accessibility to public transportation stops (up to 800 m) to the total population of the district/microdistrict.

The assessment of the expressiveness of the volumetric and spatial solution of the building (the presence of houses of different storeys, different types of residential buildings differing in architecture and planning of the object) is proposed to be assessed using the indicator of the monotony of the building which is calculated as the ratio of the number of buildings of the two most common types to the total number of houses. The higher this indicator is, the less the variety of buildings will be and the other way around. E.g., the microdistrict project proposes the use of 100 buildings of 5 types. Among these, the two most common types are comprised by 80 buildings. Hence $P = 80/100 = 0.8$. If the two most common types are 50 buildings, $P = 50/100 = 0.5$. The lower the indicator is, the greater the variety of buildings is.

Therefore the assessment of the structural, planning and architectural organization of the district/microdistrict includes the following indicators:

1. development of social and business infrastructure:
 - 1.1. level of development of public and business infrastructure (units of objects/hectar);
 - 1.2. share of the territory of public and business infrastructure (%);
2. density of the road network (km / km²);

3. share of pedestrian spaces (%);
4. availability of public transport (%);
5. variety of buildings (%);
6. share of green areas (%).

The assessment of the options for these two blocks of urban planning indicators was performed using the example of the project for planning the territory of the microdistrict in the city of Volzhsky, Volgograd region (Fig. 3 and Fig. 4).

Fig. 3. Design of planning the territory of a new microdistrict in Volzhsky, Volgograd region. Variant 1

Fig. 4. Design of planning the territory of a new microdistrict in Volzhsky, Volgograd region. Variant 2

The assessment of each of the developed architectural and planning proposals/variants of the territory planning project was performed based on a comparison of the indicators (Table 2 and

Table 3). As a result, this assessment indicates the level of structural and planning organization of the microdistrict specified by each project option, which helps to make a more accurate choice of the best solution. The methodological foundations for the quantitative assessment of the selected indicators were the technical and economic indicators of the design options.

Table 2

Block 2. Indicators of the spatial and territorial provision of an area/microdistrict

№	Indicators	Variant 1	Variant 2
1	1.1 Population density (people/hectar)	180	140
2	1.2. Construction density:		
	1.2.1. construction density coefficient K1	0.3	0.25
	1.2.2. construction density coefficient K2	1.1	1.0

Table 3

Block 3. Indicators of the assessment of the structural and planning organization of an area/microdistrict

№	Indicators	Variant 1	Variant 2
1	2.1. Formation of public and business infrastructure:		
	2.1.1. level of development of social and business infrastructure (units/hectar)	0.08	0.1
	2.1.2. share of the territory of public and business infrastructure (%)	10.3	21.0
2	2.2. Density of the street road network (km/km ²)	10.2	10.5
3	2.3. Share of the pedestrian spaces (%)	9.8	15.7
4	2.4. Availability of public transportation (%)	75	80
5	2.5. Variety of architecture (%)	52	35
6	2.6 Share of green spaces (%)	5.9	30.0

A comparative assessment showed that the indicators of block 2 (spatial and territorial resources) have similar values, however, the third group of the indicators (structural-planning and architectural organization of the territory) revealed the advantages of the second design option. E.g., the level of development of public and business infrastructure in the second option is higher; it also provides a street-road network and pedestrian spaces and green areas.

Hence the approach suggested by the authors to developing the project methodology of urban planning based on the principles of the paradigm of biosphere compatibility makes it possible to expand the traditional urban planning indicators by including an assessment of the environmental safety of residential areas at the stage of engineering surveys. Construction and ar-

chitectural planning solutions should be developed taking into account the existing and previously assessed ecological situation. Having managed to retain the consistency in the methodology of urban planning and the methods of urban environment employed in urban planning practice, the indicators for assessing spatial and territorial resources, structural planning and architectural organization of the territory should be primarily considered as an urban planning tool for analyzing internal stability and well-being of the living environment, designing conditions for human development in the urban environment.

Conclusions. It is obvious that the public need to organize a comfortable and safe urban environment calls for transformation of the design paradigm towards the environmental imperative of modern urban planning. Therefore the possibility of developing a methodological basis for urban planning at the microterritorial level using the principles of the paradigm of biosphere compatibility aimed at human development in interaction with its environment is discussed.

The methodology for designing residential areas of the city is based on the four blocks of indicators as well as those calculated in a quantitative assessment: environmental safety, spatial and territorial resources, structural and planning organization of the territory, urban functions. The suggested list of the assessment indicators for each block is not exhaustive. The authors believe that follow-up studies should be conducted in order to clarify the composition of indicators and to develop assessment calculation algorithms. The performed experimental calculations to assess options for design solutions at the level of planning projects for residential areas prove to be promising and critical for social orientation of the resulting urban planning methodology in designing essential conditions and social infrastructure objects.

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