Creating protected areas in the urban environment, corresponding to the "Smart City" formation concept. The way to sustainable development of urban ecosystems

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Abstract. This article considers the information system of territorial planning of urban development which corresponds with the “Smart City” concept. Article summarizes the results of studies of the state specially protected natural areas of Moscow in, which allowed to identify negative factors that impede their sustainable development. It addresses the recreational pressure build-up on anthropogenic natural regions (ANR) and its dependence on the city's planning structure. It also shows the usefulness of a map set development, including: inventory maps, land-use planning maps, recreational pressure maps, which serve as a good tool for ANR territory development pattern projects, also for recommendations preparation aimed at improving the ecological status of the territory, taking its recreational capacity into account. A prerequisite for the adoption of land-use and development rules for the purpose of regulating population density in the bordering natural areas is the need to develop zoning schemes for the territory according to the level of recreational pressure (subzone) and the development of urban planning regulations for the use of land and real estate. To ensure the sustainable development of cities, there is a need for urban planning aimed at creating a safe and qualitative living environment that meets the needs of the modern human community, while not infringing on the opportunities of future generations of mankind. The number of these measures will ensure the sustainability of the city's natural skeleton while the functional zoning of anthropogenic natural regions (ANR) will allow regulation of anthropogenic pressure level and will ensure the sustainability of these systems which are aimed at the formation of the “Smart City” concept.

1. Introduction

In connection with the globalization process increase, the most developed and demanded territories of highly developed countries are the mega-cities that meet the "Smart City" formation concept. Megapolis is the largest form of settlement, resulting from the unification of a large number of neighboring urban agglomerations into a single array. To date, cities that meet the "Smart City" formation concept, is a complicated production and territorial complex, aimed at solving certain tasks of the labor process [1]. As a part of the city, objects of different functional purpose are connected, such as city-forming, city-serving and town-providing, the formation of which is aimed at comfortable living conditions of the population (figure 1). In the context of the aggravation of environmental problems, the disturbance and degradation of the city's natural ecosystems are revealed, as well as the need to conserve parts of the earth's surface and water surface. [2]
Establishment of a network of specially protected natural areas (PAs) at various levels, from regional to international, with the formation of a system of town planning regulations that should perform the legal support tasks of the ecological framework, and individual PAs – to perform the role of nuclei in some way that allow preserving the most valuable natural complexes in their natural state, as well as contribute to the successful restoration of ecosystems that are subject to anthropogenic impacts of the “Smart Cities”. Today, there is a change in the function of urban protected areas, which reflects the overall global trend. Conceptual continuation of the idea of sustainable use of natural resources was received in the decisions of the V IUCN World Parks Congress (2003, Durban) [3]. At the national level, the problems of PAs were recognized in 1995 with the adoption of the "On Specially Protected Natural Territories" Federal Law. To date, the formation of a network of protected areas, including the protection of the natural area, is one of the priority areas of developing cities. The formation of a national parks network in Russia is almost complete (figure 2).

On the territory of the city of Moscow, 119 protected natural areas are registered according to the Department of Nature Management and Environmental Protection of the City of Moscow. The inadequacy of financing and state control over observance of the PA use regimes, lack of a legal
mechanism leading to increased anthropogenic impact are the main problems in the organization and functioning of PAs. The current principles for creating a network of PAs, taking into account the city's development, need a new approach to identify areas that require special environmental protection, and the integrated system should be aimed at ensuring conditions for sustainable development and improving the environment of the region. In the course of its implementation, it is necessary to gradually create and introduce the following special nature management regimes:

- conservation of biological and landscape diversity;
- maintenance of ecological balance and the most important natural processes;
- saving unique natural objects located on the territory of the region;
- protection of territories of traditional nature management in the prevailing conditions;
- creation of recreational areas.

A comprehensive assessment of the city's ecological and town-planning situation is possible with the use of a scientifically grounded method, which at the legislative level is defined as a "Town planning forecast" or top-down planning development of the territories, which at the legislative level should be fixed by the same set of town-planning documents. Composition and content of town planning documents, as well as the order of their development, are determined by the Urban Development Code of the Russian Federation.

The most valuable areas in the ecological and aesthetic sense are chosen for the city-planning sphere of activity, and this leads to the destruction of the city's ecological skeleton. The factors by which the territory is selected, can be grouped into two groups: natural, anthropogenic. Figure 3 shows the model of the system "technogenic source - the natural environment" from the position of the ecological approach.

![Figure 3. Scheme of anthropogenic impacts on the natural ecosystems of the city](image)

Anthropogenic factors determine the criteria for planning restrictions on the use of anthropogenic natural regions (ANR), and the structure of planning restrictions forms the functional zoning of the urban area, aimed at ensuring a favorable environment for the life of the population and protecting the territories from the adverse effects of natural and man-made disasters. Taking into account the established restrictions on the use of territories, it becomes necessary to determine the intensity of the ANR use. For Moscow, there are high recreational loads that negatively affect the state of the city's natural skeleton, so there is a need to design accessible recreational areas aimed at meeting the needs of district residents.

In the general system of functional zoning of settlements territory, recreational zones are among the mandatory functional zones that provide an optimal habitat for the population, designed to organize and conduct various forms of mass recreation of citizens and compensate anthropogenic impacts on residential areas with a high population density.

As an analogue object, the Losiny Ostrov National Park was defined, its distinctive feature being its location: part of the territory is within the city limits, and part of the territory is in the Moscow...
region. At the same time, the boundaries of the Moscow part of the territory are blurred, the placement of courtyard territories within the boundaries of the park is observed.

The protected zone of the PA "Losiny Ostrov" is 47% of the total territory. Objects of cultural heritage located on the territory and access to which are free and not regulated, are the points of gravity of the population. Absence of zoning and regulatory norms and rules for the use of zones subject to recreational loads lead to the spontaneous use of territories under protection and environmental disturbance. Based on the results of the conducted studies, it was revealed that for the preservation and maintenance of the territory, functional zoning is necessary with the identification of the main zones, including a number of restrictions aimed at preserving the park itself:

- **specially protected area** - designed to conserve natural ecosystems in the course of their natural development, preserve the entire diversity of local plant and animal species. Designed depending on the size of the PAs, the recreational impact of a potential number of recreants living in the proximity of residential development;

- **zone of educational tourism** and visitor services is designed for environmental education and tourism, recreation in nature;

- **recreational zone**, designed for recreation and sports. It is aimed at the perspective development of scientific activity with the aim of carrying out scientific research work on the study of natural and resource functions, recreational sustainability. In the recreational zone, traffic and parking should be prohibited, except for the driveways and equipped parking lots, the bonfire kindling in unacceptable places, the violation of vegetation and soil cover, cluttering and contamination of forest areas and reservoirs.

2. Methods

To assess the degree of anthropogenic impacts, the concept is used - the ecological capacity of the territory or the ecological norm, which corresponds to the limiting values of anthropogenic loads established on the basis of data from long-term field observations. The ecological norm characterizes the ability of adaptation of organisms, populations and plant communities to adverse impacts, which indicates that the ecosystem is in equilibrium. Areas adjacent to the boundaries of NP "Losiny Ostrov" do not have reserve recreational areas. A distinctive feature of them is that in these territories urban development activities are allowed within the framework of the approved design plan, if there is a positive conclusion of the state ecological expertise [6]. As a result of the studies, three main groups of objects were identified: objects aimed at ensuring and maintaining the territory; objects to ensure the recreational function of the city; objects of third-party users. A significant change in the ecosystem of forests and forest parks occurs under the influence of a recreational load, which can be determined:

\[ R = \frac{N_i}{S_i} \]  

(1)

where \( N_i \) – number of visitors to recreational objects, \( S_i \) – area of recreational territory.

Determination of the actual recreational load and the number of visitors to recreational facilities can be carried out by various methods, but they only allow to reflect the existing situation, therefore the main objective of the research was aimed at developing a method for determining the potential number of visitors in the current urban development situation. Of the materials presented (figure 4), the territory of microdistricts and residential areas falls within the zone of walking distance (500 m), this is understandable from the position of the currently accepted principles for the formation of residential buildings. The potential number of visitors depends on the density of the population within walking distance of 500m, and limited walking distance within 1000m of the park boundaries. Areas of the park territory that do not have borders are used for recreational purposes.
Determination of the potential number of visitors can be conducted according to the actual housing stock located within these limits, or based on the indicator of population density characterizing the development of each district using appropriate inventory cards.

To do this, determine the area of residential development at a distance of 500 and 1000 m (A500, A1000) from the border of the ANR. Knowing the density of the population within each “i” territory, the potential number of visitors to the “Ni” park can be calculated:

\[ N_{i500} = A_{i500} \times P_{i500} \]  

The values of the number of potential visitors thus obtained will determine the boundary conditions for estimating the recreational distribution of holidaymakers.

3. Implementation

The construction of hydro technical facilities located outside the urban agglomeration without preliminary analysis also leads to negative consequences, therefore, it is necessary to carry out an assessment of environmental factors that adversely affect livelihoods at the planning stage of the territory. On the example of the complex for rowing slalom (figure 5), located in the urban village of Bogorodskoye, Moscow region, it is possible to identify adverse effects affecting the environment during the construction period [7].

![Figure 5. Computer model of the construction of a complex of rowing canal buildings in the Bogorodskoye village](image_url)
To estimate air pollution, it is necessary to calculate in accordance with the OND-86 procedure [8]. According to paragraph 5.21 of this procedure, a significant effect on atmospheric pollution is exerted by those substances for which the following inequality holds: $M / \text{TLV}_{DA} > F$, where $M$ is the pollutant mass emitted; $\text{TLV}_{DA}$ - daily average threshold limit value of pollutant; $F$ is a parameter. The parameter $F$ in this inequality depends on the weighted average height of the emission sources of the substance and is determined from the following relations: $F = 0.01 \times H$ at $H > 10$ m; $F = 0.1$ at $H < 10$ m. If the inequality $M / \text{TLV}_{DA} < F$ is satisfied, a dispersion calculation is not required, if not, the dispersion is calculated. The calculation of the parameter "F" and the list of substances for which the calculations were performed can be presented in the form of table 1.

**Table 1.** The result of calculating the emission of pollutants into the atmosphere during the construction of the complex

| Name of pollutant     | Actual emission, g/s | TWA accepted for calculation, mg/m³ | Emission height H, m | M/TLV | F parameter | Note                            |
|-----------------------|-----------------------|------------------------------------|----------------------|-------|-------------|---------------------------------|
| Nitrogen dioxide      | 0.26                  | 0.2                                | 2                    | 1.3   | 0.1         | Calculating the dispersion      |
| Nitrogen oxide        | 0.04                  | 0.4                                | 2                    | 0.1   | 0.1         | Calculation is not needed       |
| Petrol                | 0.07                  | 5.0                                | 2                    | 0.01  | 0.1         | Calculation is not needed       |
| Kerosene              | 0.096                 | 1.2                                | 2                    | 0.08  | 0.1         | Calculation is not needed       |
| Carbon monoxide       | 0.80                  | 5.0                                | 2                    | 0.16  | 0.1         | Calculating the dispersion      |
| Sulfur oxides         | 0.03                  | 0.5                                | 2                    | 0.06  | 0.1         | Calculation is not needed       |
| Carbon black          | 0.04                  | 0.15                               | 2                    | 0.27  | 0.1         | Calculating the dispersion      |

The intensity of pollutants dispersion in the air of the territory depends on the climatic and meteorological conditions of the area. The intensity of pollutants dispersion in the atmosphere is affected by the absence of dense high-rise buildings, which helps maintain the pollutants at the background level.

As a result of the calculations, the maximum concentrations of pollutants created by the source of pollution in the surface layer of atmospheric air are: nitrogen dioxide - 1.3 TLV$_{DA}$, carbon monoxide - 0.16 TLV$_{DA}$, sulfur oxides - 0.27 TLV$_{DA}$.

The collection and processing of the information received was carried out in accordance with a rule that provided for three stages: a visual examination; calculations; geo-referencing. Calculation of the dispersion of the pollutants discharged was carried out using the Prisma software package. Based on the results of the calculation of dispersion at the border of residential development, the concentration of pollutants does not exceed the TLV.

Classification of objects, determination of boundaries, coordinates of topographic survey, allowed to substantiate the composition of cartographic information. As a result, the composition of the actual natural and anthropogenic objects of the territories was established, and their ecological status was assessed. Taking into account the large amount of collected information, it became necessary to store, process and output raster and attributive data. One of the modern software products in urban planning can be environmental mapping based on a geographic information system (GIS) (figure 6), which allows to work and solve a wide range of issues.
Currently, geographic information systems allow you to work in three-dimensional space, where the value of Z is attributively linked to a point with coordinates along the axes (X, Y). The importance and benefits for regions, individuals and nature in the creation of reserves and national parks are obvious. For the regions, this is an advantageous investment in infrastructure, and their activities will make it possible to maximize their environmental and recreational potentials in the interests of the region. At the same time, it is necessary to pay attention to the legal basis on the basis of which it is possible to build any PA system, to control the operation mode and to legislatively protect its facilities from improper use of the territories for profit.

4. Results
To implement the basic principles of sustainable development of the "Smart City" formation concept in the conditions of high urbanization, the development of town planning documentation should allow implementing the basic principles of environmental protection aimed at preserving natural areas. In turn, when developing project documentation for the development of new territories, it is necessary to form a planning structure, taking into account the requirements of permissible recreational impact, and inventory of objects and maintenance of databases using ecological mapping facilitates the forecasting, conservation, restoration of natural areas. For a comprehensive assessment of the state of the components of the environment it is necessary to carry out periodic regular monitoring during the entire technological period of the construction and operation of the facility.

5. Discussion
Functional zoning of the ANRs, consisting in the allocation of zones within the territory, with different levels of anthropogenic impact, is aimed at preserving the core of the ecosystem and reducing anthropogenic impacts on it to the normative values, which is especially important in the context of functional transformation of natural areas. Relevance is justified by the need to develop a methodology for the functional zoning of natural-anthropogenic territorial complexes to ensure the sustainability of natural ecosystems based on the rational development of urban areas of “Smart City” basic concept. Elements of scientific novelty consist in the identification and justification of the results of field observations of the functional transformation of protected areas located in the city; establishing the relationship between the density of population distribution from the borders of the ANR and the recreational load; the development of a methodology for the functional zoning of the territories of the ANR, which makes it possible to implement the principles of sustainable urban planning in conditions of increasing anthropogenic impact of the cities of the “Smart City” concept.
The article is of considerable interest, since it offers a unique approach to solving the scientific problem of ensuring sustainable development of the ANR through functional zoning using GIS.

6. Questions for discussion
1. The method of functional zoning of ANR, aimed at ensuring the sustainability of urban natural ecosystems, allowing to regulate the distribution of recreational load in accordance with permissible normative values.
2. Classification of objects located in the territories of the ANR, performed on the basis of three main groups of functional purpose.
3. Program of research, methods and means to achieve the goal.
4. Method of ecological mapping for urban planning and functional zoning of ANR.
5. Method of determining the potential recreational load on the ANR, based on environmental mapping.

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