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Methodology for assessing the comfort of an urban environment in terms of availability analyzing

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Abstract

Creating a safe and comfortable environment, developing a human, is a priority of urban development. One of the important stages of the solution to such a problem is the actualization of the regulatory base in the field of city-building, which should lay the principles of a city, developing a human and promoting better health.

The work shows the feasibility for quantitative analysis of safety and comfortable spatial environment when creating general plans of cities and their territorial entities. So, using the method of calculating the integral index of spatial-temporal accessibility of objects that implement the functions of the city, we suggest performing a comprehensive quantitative evaluation of planning decisions in terms of placing of socially significant objects. A key prerequisite for the calculation of this index was the inclusion of the time parameter provided to a person to realize his/her rational needs. This approach is based on the principles of creating biosphere compatible cities that develop a person, and allows not only more fully appreciate the quality of urban planning decisions, but also to consider the interests of groups with different mobility.

As an example, we determined the level of implementation of the city functions “Knowledge” (components - pre-school and general education) and “Entertainment and leisure” (component – recreation open urban green spaces) for different groups in a new micro-district in Orel. The calculation of the indicator was carried out for children aged 3-4 years, 7-8 years, healthy young people, people in old age and residents with disorders of the musculoskeletal system. For the latter, the obtained values differ from the maximum possible. The analysis noted the insufficient capacity of educational institutions, reflecting a defective personal availability.

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Keywords: aged people, built environment, open space, people with disabilities, urban planning;

Introduction

Creating a safe and comfortable environment, developing a human, is a priority of urban development. Along with the development and improvement of general plans of cities and districts it is necessary to include activities to balance the results of anthropogenic activities and the life potential increase of the Biosphere. One of the important stages of the solution to such a problem is the actualization of the regulatory base in the field of town-building, which, according to the academician V. A. Il'ichev and his followers, should lay the principles of a biosphere compatible city, developing a human [1,2].

Cities, being developed in accordance with the statements of this concept are characterized, in the first place, with a level of a symbiotic relationship with the biosphere and the degree of implementation of opportunities for human development. The latter, in turn, is determined by infrastructure, the quality of the functional organization of the territory, safe and comfortable ways of moving. Because of the complexity and multidimensionality of the concept of

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human potential for its quantitative determination from these positions the integral index ξ, which reflects the realization of the city functions, is introduced. In this case, the functions of the city according to the structure proposed in [1-3] are sustenance, entertainment and recreation, the organization of the structures of power, mercy, knowledge, creative realization of human needs, strengthening its relationship with nature.

In the first approximation, the quantitative analysis of the levels of implementation of city functions is suggested being conducted on the basis of statistical data for the regions, taking as criteria the average or normative values [3, 4]. Using the named index it is possible to assess the safety, accessibility and comfort of the various facilities, e.g. transport infrastructure [5, 6]. Here, by calculation the coefficients of the implementation and availability of the city functions based on the analysis of the state of the production environment of car service stations were obtained.

The article [7] shows the calculation of the level of implementation of the education functions based on qualitative and quantitative assessment of the indices characterizing the degree of accessibility, security and comfort of the educational environment in universities. The paper [8] gave the recommendations to the quantitative evaluation of urban planning decisions of new micro-districts based on the concept of biosphere compatibility. The analysis of biosphere compatibility and level of implementation of the city functions in relation to the needs of the disabled population is given in the articles [9-11]. Here, without an analysis of the territorial accessibility, attention is paid to functional planning factors determining the accessibility of facilities for groups of people with limited moving abilities.

A more detailed assessment of planning solutions of the micro-districts with the help of this index is relevant for objects of everyday services. A key requirement to their location is to provide pedestrian accessibility which reduces the time for obtaining the necessary services and limits the use of road transport. It assists to person's healthy way of life and his or her social integration, and has a positive effect on the safety and availability of transportation, acoustic comfort, air quality and soil in the residential neighborhood [12]. Besides, it is impossible not to agree with the author of the article [13] that the orientation of urban quarters, micro-districts to ensure short distances between facilities of daily service and housing, jobs will make the activity more sustainable in terms of its spatial-economic transformation. Specific quantitative indices mainly determining the capacity and service radius are regulated for such objects (Fig. 1).

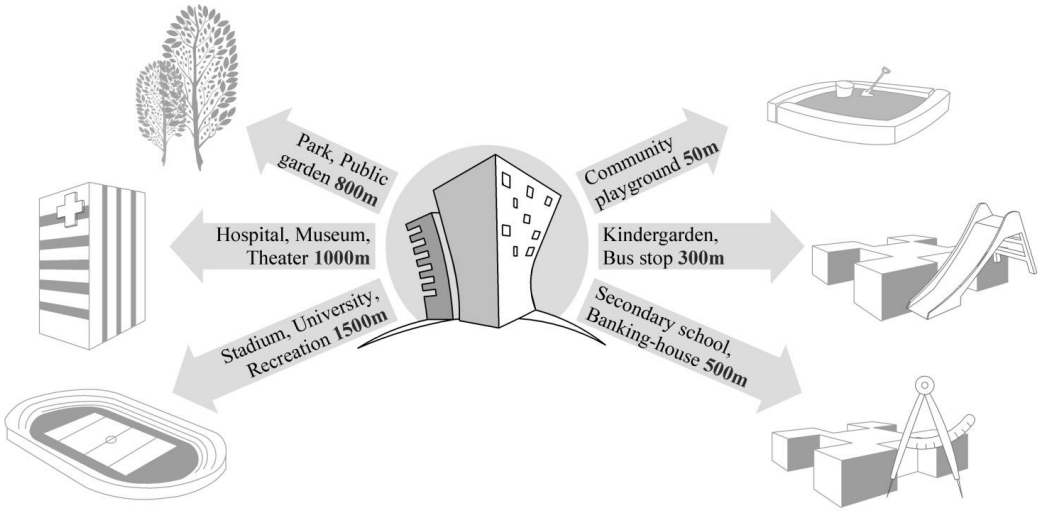


Fig. 1 Some recommended distances from places of residence to public buildings and structures

A disadvantage of the assignment of the distances to constant numerical values is the inability to take into account the characteristics of movement of different categories of the population fully. In this context, in order to quantify the walking availability it is recommended to measure distance between the objects of the infrastructure with the time needed to meet rational human needs [1]. Thus, evaluation of the safety and comfort of the urban environment in the specified statement using the index ξ will allow to consider interests of children and the elderly, pregnant women, persons with disabilities and others.

This approach was applied in determining the spatial and temporal availability of educational facilities [14]. In the

present work it is proposed to extend the developed methodology to assess the availability of urban open spaces designed for walking with children, communication, sports, recreation for residents with special movement abilities. Unlike most of European countries, Canada [15-17] and the United States of America, in Russia the availability of public parks and parks planning areas is estimated by the time of their accessibility by public transport [18]. However, increasing the radius of accessibility to a few kilometers will lead to the need to organize a large number of parking spaces and increase of environmental load on the territory adjacent to the park.

Methods

The method of calculating the implementation index of the city functions (i=1..7) in the socially important objects at the level of planning districts is reduced to determining the integral index of the territorial-personal availability ξ_i:

$$\xi_i = \sum_{j=1}^{m} N_j \xi_{i,j} \Big/ N, \quad (1)$$

where N_j, N – respectively, the population of the j site and the district under consideration as a whole. This division of the planning area on m (number) of j sites can be done by separating residential groups or radial zones of accessibility.

Here $\xi_{i,j}$ is an indicator of the implementation of the i city function for the j site of a residential zone and an index of territorial (pedestrian) or space-time accessibility for residents of this area. It is defined by the ratio of time $\bar{t}_i$ spent by a person of a certain group of mobility to overcome the comfortable distance $\bar{S}_i$ to the object, to the time actually spent $t_{i,j}$:

$$\xi_{i,j} = D_i \cdot \bar{t}_i \Big/ t_{i,j} \text{ или } \xi_{i,j} = D_i \cdot \bar{S}_i \Big/ S_{i,j}, \quad (2)$$

where D_i is the coefficient that indicates the proportion of the population with the possibility of obtaining service of the i city function P_i , in the total number of inhabitants $\overline{P_i}$ of the territorial:

$$D_i = P_i \Big/ \overline{P_i}, \; D_i \leq 1. \quad (3)$$

Then the values $\xi_{i,j}$ can be equal to:

– within the service area of the facility at a distance not exceeding the maximum comfortable distance, and with sufficient capacity object – ($\xi_{i,j} = 1$);

– on the territory located outside of the comfortable safe distance – ($0 < \xi_{i,j} < 1$).

In Eq. 2 $S_{i,j}$ – the actual distance between the object that implements the i city function and the j site is determined by the length of the trajectory path, taking into account its non-linearity:

$$S_{i,j} = R_{i,j} \cdot K_{i,j}, \quad (4)$$

where the nonlinearity coefficient of the pedestrian connection will be equal to:

$$K_{i,j} = S_{i,j} \Big/ R_{i,j}, \quad (5)$$

where $R_{i,j}$ is the shortest distance between the object and the j site, which is the actual radius of the object accessibility.

Included in Eq. 2 $\bar{S}_i$ the parameter defines a comfortable distance which is to overcome in time $\bar{t}_i$:

$$\bar{S}_i = \bar{t}_i \cdot V, \quad (6)$$

where V is the average speed of a man with a certain mobility, depending on age and health state.

Table 1 presents the values of comfortable distances defined by values of the average speed of pedestrians moving rapidly or calmly in the autumn-winter period (according to the Leningrad scientific research laboratory of forensic examinations and [19]).

Table 1. The distances covered by pedestrians with different movement speed for the estimated time

Pedestrians' age or their moving abilities	Calm pace				Rapid pace			
	V, m/min	Distance S, m			V, m/min	Distance S, m		
		5 min	7 min	10 min		5 min	7 min	10 min
3-4 years	51.0	255.0	357.0	510.0	72.0	360.0	504.0	720.0
7-8 years	69.3	346.5	485.1	693.0	88.8	444.0	621.6	888.0
21-25 years	82.2	410.9	575.2	821.7	106.3	531.5	744.1	1063.0
over 70 years	48.3	241.5	338.1	483.0	65.6	328.0	459.2	656.0
with a prosthetic leg1	51.0	255.0	357.0	510.0	67.5	337.5	472.5	675.0

In this formulation, the quantitative indicator of the safety and comfort of the urban space, and everyday pedestrian connections should be determined, in the first place, for socially significant objects, and it is suggested referring intra-district parks to these objects.

So, to assess the level of implementation of the function i=3 "Knowledge" it is recommended to take as initial data the distances corresponding to five minutes of walking rapidly. In addition, for pre-school educational institutions (i=31) we take the speed of pedestrians at the age of 3-4 years, and for educational institutions (i=32) – at the age of 7-8 years. The level of implementing the function i=2 "Entertainment and leisure" in relation to its component – leisure on the open urban green spaces (i=21) – can usefully be measured at a comfortable distance corresponding to the seven-minute walk at a slow pace. For residents with disorders of the musculoskeletal system a five minute walk is considered to be comfortable to overcome the distance.

As example we will perform a quantitative evaluation of planning decisions of district "Botanica" which is located in the Zavodskoi district of the city of Orel in the area between the floodplain of the Oka river and the railway line (Fig. 2). The area of the district is 40.2 hectares. The residential construction is represented by apartment houses with

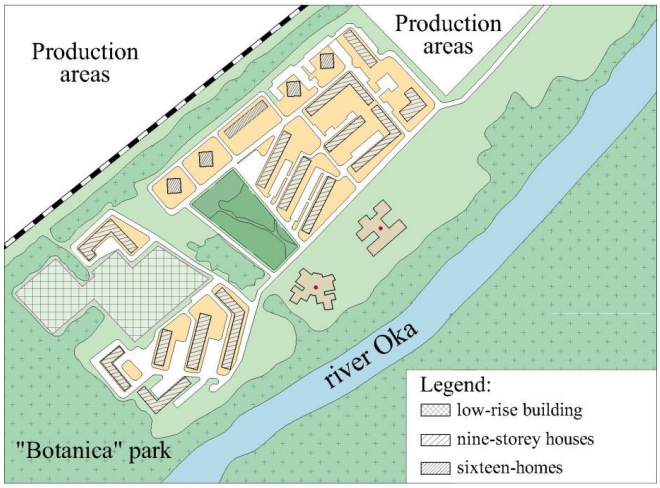


Fig. 2 The scheme of development of the micro-district "Botanica" in the city of Orel

a height of 9 and 16 floors. There is a park area of about 1.8 hectares in the center of the micro-district, and a

[1] the value of this speed is a guideline when assessing a comfortable distance for people with disorders of the musculoskeletal system

building of the preschool educational institution (PEI) for 280 seats and a secondary school (SS) for 550 seats in the south-eastern part. In the west the micro-district borders the Park “Botanica”.

Results and Discussion

Fig. 3 graphically presents comfortable distances to the facilities for pre-school and general education and to the intra-district park for people with different moving abilities.

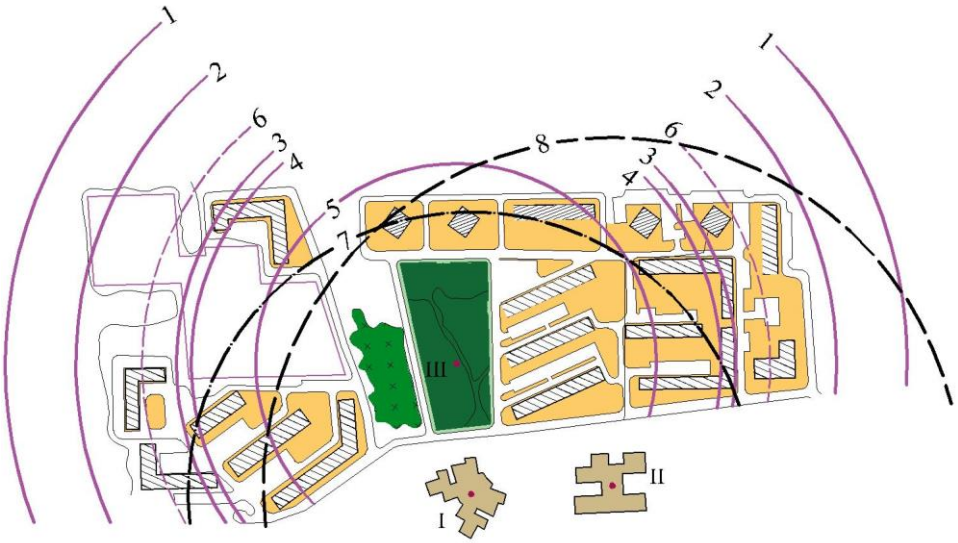


Fig. 3 – The radii of the accessibility of pre-school educational institution I, secondary school II and the intra-district park III in the micro-district “Botanica”, corresponding to comfortable distances: 1 - for healthy people aged 21-25 years, 2,8 – 7-8 years, 3,7 – 3-4 years, 4 – over 70 years, 5 – for people with disorders of the musculoskeletal system, 6 - for all population groups, in accordance with [16]

As it can be seen from Fig. 3, the radii of the pedestrian accessibility of socially significant objects do not fully cover the territory of the considered micro-district. So, apartment buildings in the north-western and eastern parts of the micro-district are located from educational facilities at distances greater than comfort values. In this regard, and also due to the insufficient capacity of educational institutions, indicators of implementation of preschool and school education in the district are $\xi_{31} = 0.80$ и $\xi_{32} = 0.67$ [14], respectively.

Spatial environment of the everyday pedestrian connections is fully safe and comfortable only for healthy young people. A safe and comfortable environment for persons with disorders of the musculoskeletal system, the elderly and preschoolers is located in the central part. A more detailed analysis of spatial-temporal accessibility of the destination is given in the form of the scheme in Fig. 4. Here the boundaries of the comfortable distances to the adjacent park “Botanica” are marked. The figure shows the radial accessibility zones taking into account the non-linearity of pedestrian connections which as it is stated in the article [14], reduce the value of the desired indicator on the average on 9%.

The values of the indicators of the level of implementation of the function i=2 “Entertainment and leisure” in terms of its component i=21 “Leisure in urban open green spaces” in the micro-district “Botanica”, defined by Eq. 1 for various population categories, are given in Table 2.

Table 2. Values of the index ξ_{21} for residents depending on the individual characteristics of movement

	Pedestrians' age or their moving abilities				
	21-25 years	7-8 years	3-4 years	over 70 years	with disorders of the musculoskeletal system
ξ_{21}	1.0	1.0	0.95	0.94	0.89

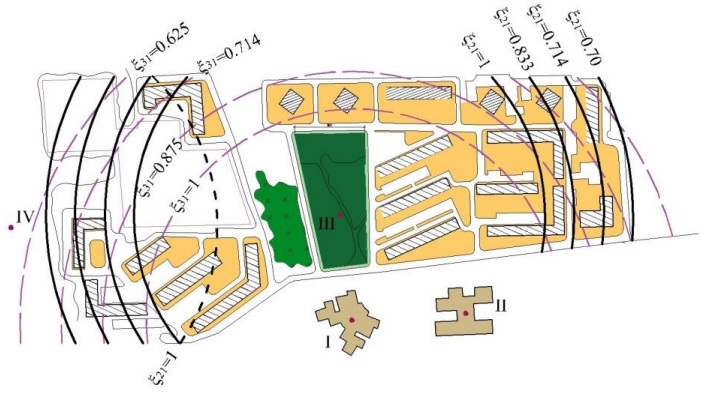
The results of a comprehensive assessment of spatial-temporal and personal accessibility of socially significant objects are considered as safety and comfort characteristics of the micro-district territory as well. According to the values of the integral index ξ it can be determined that the level of implementation of the city functions (the averaged value) within a residential district for children aged 3-4 years is $\xi_{2,3} = 0.875$, for children of primary school age is $\xi_{2,3} = 0.835$. The obtained values indicate low quality of planning decisions of the micro-district.

A more detailed analysis of the security and comfort of environment of everyday pedestrian connections may be adjusted by taking into account the quality of pedestrian communications between the object that implements the i city function, and place of residence (j site). This index depends on the following factors [14]:

- the number of crossings performed by a pedestrian in the same level of city streets with heavy traffic and driveways;
- length of the pedestrian way passing through the busy intra-quarter driveways;
- the availability of recreational areas and the distance between them;
- predicted thermal comfort [20-24];
- predicted level of acoustic pollution;
- aeration mode;
- insolation;
- the extent of landscaping, etc.

a)

b)



c)

d)

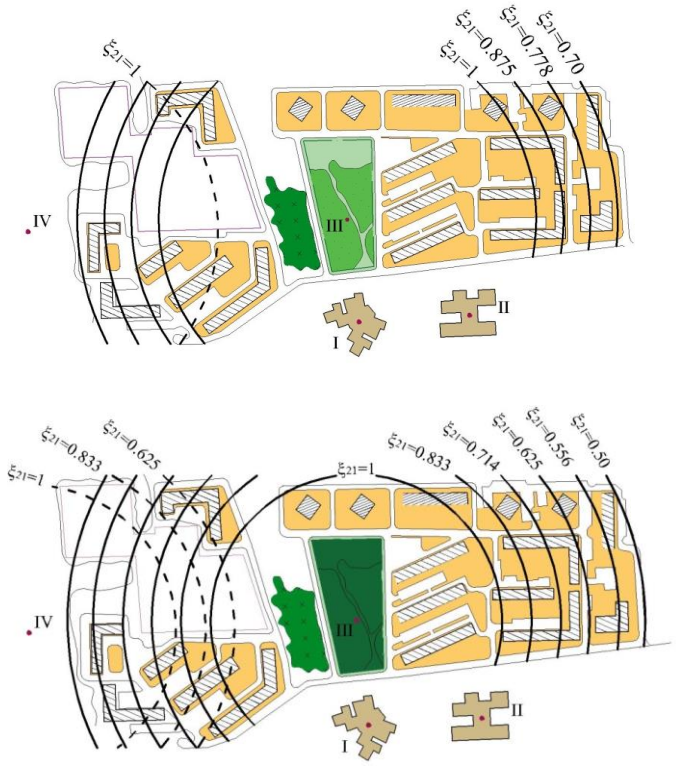


Fig. 4 – the division of the territory of the micro-district "Botanica" into the zones of space-time accessibility to the social facilities for children of school age (a), preschoolers (b), people of old age (c) persons with disorders of the musculoskeletal system (d)

Conclusions

For quantitative evaluation of the safety and comfort of the spatial environment in the analysis of its territorial personal accessibility it is proposed to use the integral index of the level of implementation of the city functions ξ_i. With regard to the location of the objects of everyday service this index will be an indicator of the effectiveness of urban design decisions from the standpoint of ensuring not only the functional adequacy of the territory, but the temporary accessibility.

The method for quantitative evaluation of planning decisions tested on socially significant objects of everyday services and recreational areas enables numerical justification of the location and capacity of new construction projects, and the feasibility of renovation of existing buildings, the organization of pedestrian paths and their improvement. Thus, the results of a comprehensive assessment of the quality of planning decisions of a new residential district in Orel have demonstrated a high degree of accessibility of the spatial environment for healthy young people. At the same time, for residents of old age, preschoolers, and disabled persons with disorders of the musculoskeletal system the space of everyday pedestrian connections is not fully safe and comfortable.

The graphic division of urban areas based on the values of the integral indicator of territorial and personal accessibility in the form of maps and schemes will allow to visualize the sufficiency of the levels implementation of the city functions. The results of the complex assessment of planning project areas and general plans performed with the help of this indicator will be useful for analyzing program effectiveness of long-term strategic planning in urban development.

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