Method for multi-criteria evaluation of urban parks

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Abstract. Urban parks have a positive impact on the environment of our cities and at the same time play an important social role by offering recreational opportunities for everyone. Urban parks provide comfortable environment for visitors to relax and exercise, evoke positive aesthetic emotions when contemplating picturesque landscapes, thus helping people build self-respect and develop pride in their city and unifying different social groups around the common goal of preserving green spaces. Urban park maintenance is an important part of the overall effort to ensure sustainable urban development. The aim of the study is to develop a method for multi-criteria evaluation of parks as a tool for monitoring and management of these objects.

1. Introduction

The continuing territorial and demographic growth in the Republic of Belarus results in dynamic and sometimes very unfavorable changes in living conditions of the urban population [1]. Therefore, one of the main directions of the national urban development policy of the Republic of Belarus for 2016 – 2020 is sustainable development of administrative and territorial units, and specifically through “integrated development of the living environment of the population and ensuring environmental safety of human settlements” [2], which corresponds to the basic principles of sustainable spatial development of the European continent [3]. Among the activities that can help achieve this goal, attention should be focused on renewal of existing parks and creation of new green areas.

2. Another section

Most of the urban parks in Belarus were created during the period of the country’s history as a part of the Soviet Union. Therefore, the characteristics of the parks do not meet the criteria recommended by modern guidelines and other regulatory documentation on park design [4].

Field studies allowed us to identify the following problems: a small area of the parks; nonoptimal spatial configuration of the parks and, as a result, high levels of noise pollution and other negative factors; poor transport accessibility to urban parks for people living far from the city centers; low functional development of parks due to the low number of leisure activities available, as well as due to moral and physical obsolescence of the leisure facilities; often poor maintenance of the parks; spontaneous functional zoning of the parks due to commercial factors; physical and moral deterioration of green infrastructure.
These problems have a negative impact on effectiveness of park functions and the role they play in ensuring the urban sustainability. In order to make administrative decisions, local authorities need a method to evaluate the current state of parks in terms of their compliance with the requirements of modern regulatory documents, which would allow making well-grounded decisions on the order of priority of their renovation or reconstruction. There are a number of known methodologies for evaluating parks based on the results of sociological surveys conducted among park visitors [5]. In contrast, the aim of our research is to develop a method based on objective characteristics that can be measured or calculated. The method will allow evaluating parks by comparing their characteristics with the characteristics recommended by the guidelines for park development currently in force in the Republic of Belarus [6,7], and if they are not available, with the characteristics of the parks chosen as reference ones.

3. The study
The first point of the study was the problem of the most important benefits parks bring to people, which must be included in our evaluation. This would allow us to build a model to visualize the internal structure of the park evaluation. Since parks are created with the aim to perform functions beneficial to people, it can be logically concluded that we need a model of park functionality. And since the regulatory documents currently in force in Belarus define the functionality of an object as a synonym for its quality [8], we decided to build a model of park quality. The study of literary sources [9-18] allowed us to identify four main functions of urban parks that are most important for people: recreational, ecological, ergonomic and aesthetic ones. On the basis of the identified functions, a model of urban park quality has been built, which is presented in figure 1.

![Figure 1](image)

The next stage of the study was to develop a set of criteria for park evaluation, which is presented in Table 1 [19].

The set of criteria revealed the hierarchical structure of park quality. To describe this structure, a hierarchy was built. A fragment of the hierarchy (upper levels) is shown in figure 2. The lower level of the hierarchy contains 60 primary indicators recommended by the guidelines for the park development currently in force in the Republic of Belarus which can be measured or calculated. The required integrated quality of the parks is placed at the top level.
Table 1. The set of criteria for evaluating the integrated quality of the urban park.

| Park Functions       | Criteria for evaluating the park functionality                                  |
|----------------------|---------------------------------------------------------------------------------|
| Ecological function  | Protection of the park from external negative factors                           |
|                      | Park benefits provided by its natural features                                   |
| Recreational function| Leisure opportunities for individuals                                           |
|                      | Opportunities for holding public events                                         |
| Ergonomic function   | Safety of parks for visitors                                                     |
|                      | Park accessibility                                                               |
|                      | Park convenience                                                                 |
| Aesthetic function   | Landscape design of parks                                                        |
|                      | Design of pedestrian areas                                                       |
| Park security        | Security factors of park functioning                                            |
| Park legal protection| National legislation on park protection                                          |
| Financial security of parks | Public financing of parks                                               |
|                      | Involvement of private capital in servicing the needs of park visitors          |

After creating the hierarchy, possible tools for achieving the aim of our research became apparent. Most often, the hierarchy analysis method [20] or the qualimetric method of quality assessment of objects [21] developed in the USSR are used as tools for solving multicriteria problems. Both methods have been compared and we have come to the conclusion that the qualimetric method is relatively less labor intensive and has found a wider application in many branches of manufacture, as well as in tasks of building design [22]. For these reasons, to evaluate the quality of parks, the qualimetric method was chosen.

This method can be used to obtain estimates of varying accuracy: according to a rank-order scale, an interval scale or a ratio scale. For the purpose of the study, the task was to develop a method that allows measuring the quality of parks using a rank-order scale. In this regard, by using the expert evaluation method, we determined the weighting factors of indicators included in the hierarchy. A survey algorithm (figure 3) was developed and a group of 25 experts was formed, who have determined the weighting of the park indicators in two steps.

The results were organized in a table and subjected to statistical analysis. For each indicator, the coefficient of variation was calculated according to formula (1). The value of the coefficient of variation equal to 33% was as the boundary of the expert opinion consistency.

\[ V_{ij} = \frac{\sigma_{ij}}{\bar{x}_j} \]  

(1)

where \( V_{ij} \) is the coefficient of variation for the \( j \)-th indicator, \%; \( \sigma_{ij} \) is the mean square deviation of expert estimates for the \( j \)-th indicator; \( \bar{x}_j \) is the expert average estimate of the indicator.

Here, the mean square deviation of expert estimates determined by formula (2) is used:

\[ \sigma_{ij} = \left( \frac{1}{n} \sum_{i=1}^{n} \left( x_{ij} - \bar{x}_j \right)^2 \right)^{1/2}, \]

(2)

where \( x_{ij} \) is the estimate of the \( j \)-th indicator made by the \( i \)-th expert; \( n \) is the number of estimates of the indicator (the number of experts).
The expert estimates with coefficients of variation less than 33% were used to calculate the average weighting factors for park characteristics and their normalization. As a result, all indicators acquired their own weighting factors $L_j$. A fragment of the histogram showing the weighting factors of primary indicators of parks is given in figure 4.
At the next stage of the study, we selected methods for determining the values of primary indicators of park: analytical method, documentary method and instrumental method of measurements.

In addition, it was decided to use the values recommended by regulatory documents on park development or, if these documents are not available, the best indicators among the parks being compared as reference values.

To calculate the values of indicators placed at higher levels of the hierarchy, formulas (3), (4) were used:

\[ K_{ij} = P_{ij}^{st} / P_j^{st}, \quad P_{ij} \leq P_j^{st} \]  

\[ K_{ij} = P_{ij}^{st} / P_j^{st}, \quad P_{ij} \geq P_j^{st} \]  

where \( P_j^{st} \) is the reference value of the indicator; \( P_{ij} \) is the value of the primary indicator (indicators of the lowest level); \( K_{ij} \) is the value of indicators of higher levels (except the lower level).

To organize and process the data, a Microsoft Excel table was created. A fragment of this form is presented in table 2.

To determine the integrated indices of park quality \( I_{int} \), we suggest using the weighted arithmetic mean formula (5):

\[ I_{int} = \sum_{j=1}^{n} K_{ij} \cdot L_j, \]  

where \( L_j \) is the weighting factors of the \( j \)-th indicator; \( K_{ij} \) is the calculated value of the \( j \)-th indicator.
Table 2. Form for calculating the composite indicators of the quality of the parks being compared.

| Sequence number of the indicator in the hierarchy, \( j \) | Park A | Park B | Park C | Park D |
|-----------------------------------------------------------|--------|--------|--------|--------|
| \( L_j, \% \) \( P_{jL}^i \) | \( K_{jA} \) \( L_{jA} \) | \( K_{jB} \) \( L_{jB} \) | \( K_{jC} \) \( L_{jC} \) | \( K_{jD} \) \( L_{jD} \) |
| 1 | \( \sum = 100 \) | \( \sum = \ldots \) | \( \sum = \ldots \) | \( \sum = \ldots \) |
| 2 | | | | |
| \( \ldots \) | | | | |
| n | | | | |
| Sum | Ranking | \( \ldots \) | \( \ldots \) | \( \ldots \) |

4. Testing of the method
The developed method was tested in four parks of cities (district centers) of Belarus. To perform a comparative analysis, the Bobruisk city park, Baranovichi city park, Lida city park, Borisov city park were chosen. Using the developed method, we calculated integrated quality indices of these parks, which were used as the basis for their ranking needed for making an administrative decision on the priority of financing park renovation.

To present the results of the park evaluation, we used a stacked bar chart. Figure 5 shows five bars corresponding to columns 2, 6, 9, 12, 15 of table 2. The bars are arranged in descending order of calculated integrated quality indices of the parks. The first bar on the left (the highest bar) corresponds to the ideal park. Its value is equal to the maximum possible value, 100 points. The remaining four bars correspond to the real parks chosen for evaluation and comparison. Each bar of the diagram consists of 11 segments of different heights; each is associated with a sum of indicators grouped by criteria and reliability factors of the park. The height of these segments corresponds to the numerical values of the quality criteria and the reliability factors of the parks being compared.

A testing experiment was conducted at the last stage of the study. During the experiment the indicators of two selected parks with the best and the worst estimates were changed to reference values. The hypothesis of the experiment was the assumption that the integrated quality index of the best park would change by a smaller amount than that of the worst park in the rating. The assumption proved to be correct.

5. Conclusion
The developed method for urban park evaluation is a tool for ascertaining the conformity of characteristics of old urban parks with the requirements of modern guidelines on park development, which gives local authorities the opportunity to identify parks that are in dire need of funding and prioritize their renovation or reconstruction.
Figure 5. The chart presenting the quality evaluation criteria values of each of the parks being compared.

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