Method of evaluation the current state of municipal infrastructure for investment planning purposes

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Abstract. Nowadays the problem of the municipal infrastructure state is extremely important, both for the Russian Federation and for regions. Municipal administrations face deterioration of fixed assets, lack of available capacity and lack of funding for the development of existing infrastructure. The research is relevant because of insufficient elaboration of existing mechanisms of assessing the state of the city's municipal infrastructure and the absence of a general tool for monitoring the current needs of fixed assets in the field of housing and communal services. In order to monitor the current state of the municipal infrastructure of the city and further decision-making on the financing of initiatives to modify it, a mechanism has been developed to assess the current state of the municipal infrastructure. The purpose of the study is to develop a mechanism for assessing the current state of public infrastructure systems. To achieve the objectives of the study were used such research methods as: the study of scientific literature and statistical information on the research topic, the analysis of the information, synthesis of information received, development of economic and mathematical models for assessing the current state of municipal infrastructure. The method of hierarchy analysis (T. Saati) and utility functions were used in the formation of integral performance. The result of the study is integral performance for assessment of the current state of the city's municipal infrastructure. The results may be used in order to improve the quality of decisions in the field of housing and communal services management. In future, the results of the study can be used to develop an economic mechanism for investment planning for the development of municipal infrastructure in the city.

1. Introduction
In the context of the widespread modernization of housing and communal services in Russia, the development of municipal infrastructure is of particular importance. The need to implement measures for the development of municipal infrastructure is determined by a number of factors, such as the current state, prospects for demand for utilities, and regulatory requirements for such facilities [2, 3].

Thus, one of the determining factors in planning the development of housing and communal services is the assessment of the current state of the municipal infrastructure, since depending on the value of this indicator, the industry's need for financing may differ significantly.

The development of a unified approach to assessing the current state of municipal infrastructure will help improve the efficiency of management decisions in the field of city administration [6].
2. Methods
The purpose of the study is to clarify and systematize knowledge about the use of tools for assessing the current state of public infrastructure systems for their further application to investment forecasting.

Research objectives the study of existing approaches to the assessment of municipal infrastructure and their updating in accordance with the need for their application to investment planning.

Municipal infrastructure as an object of assessment has a number of distinctive features [1], such as:

1. The heterogeneity of the evaluated objects;
2. A significant number of evaluation objects;
3. A large number of estimated parameters;
4. Specific numerical values of the evaluation parameters.

Thus, in order to organize a large number of heterogeneous parameters, it was decided to use a hierarchical model that allows you to group the criteria and look at the subject of research with different degrees of detail. The method of analysis of hierarchies and utility functions is used to evaluate the weight coefficients of each of the criteria.

The combination of these methods will allow you to decompose the process of evaluating the current state of public infrastructure into simpler components for further assignment of weight coefficients and calculation of criteria values [11, 12]. The result may be used for decision-making in the implementation of current activities and planning in the field of municipal management of the city.

3. Results

Assessment of the municipal infrastructure of the city

Assessment of the state of municipal infrastructure of the city in industries

Assessment of municipal infrastructure systems in components

Figure 1. Hierarchical structure of criteria for evaluating utility systems
At the top level of the hierarchy is the main criterion, or indicator of the integral evaluation of the city (N_0). The second level consists of four areas of assessment (N_1 - N_4), which are branches of housing and communal services. At the bottom are the industry criteria (N_{11} - N_{44}).

The hierarchy includes the following evaluation criteria:

- N_0 – assessment of the current state of the municipal infrastructure of the city;
- N_1 – assessment of municipal infrastructure in the field of heat supply;
- N_2 – assessment of utility infrastructure in the field of power supply;
- N_3 – assessment of public infrastructure in the field of water supply;
- N_4 – assessment of municipal infrastructure in the field of water disposal;
- N_{11} – state of heat networks;
- N_{12} – equipment status;
- N_{13} – capacity utilization;
- N_{14} – network capacity;
- N_{21} – network state;
- N_{22} – equipment status;
- N_{23} – capacity utilization;
- N_{24} – network capacity;
- N_{31} – network state;
- N_{32} – equipment state at water intake stations;
- N_{33} – capacity utilizations;
- N_{34} – capacity of networks and distribution sites;
- N_{41} – network and capacity state;
- N_{42} – pumping equipment state;
- N_{43} – capacity utilization;
- N_{44} – network capacity;

The main parameters to assess utility infrastructure of the city are: the state of the networks, hardware status, load, available capacity, and network bandwidth [7, 9, 11]. These criteria are selected for evaluation because of their direct impact on the future needs of the industry in financing. The obtained parameters can be used for investment planning of municipal infrastructure systems [5].

Any element of the hierarchy can be evaluated using the formula:
\[ \sum_{i=1}^{n} N_i \times w_i \]  
where \( N_i \) – i-th element of hierarchy; \( w_i \) – the weight of the i-th element in the structure of the previous element.

Due to the equal importance of each of the considered branches for the urban economy, the author decided to assign equal weight coefficients to the elements of the first level. The final formula for evaluating the current state of public infrastructure systems is:
\[ N_0 = 0.25N_1 + 0.25N_2 + 0.25N_3 + 0.25N_4 \]  
where \( N_0 \) – integrated assessment of municipal infrastructure systems of the city; \( N_1 \) – assessment of heat supply systems; \( N_2 \) – assessment of power supply systems; \( N_3 \) – assessment of water supply systems; \( N_4 \) – assessment of water disposal systems.

The evaluation of the weight coefficients of the second-level criteria is determined using the hierarchy analysis method. The weight values of the node parameters \( N_1, N_2, N_3, N_4 \) are determined by the expert evaluation method and calculated in table 1 [8].
Table 1. Matrix of pairwise comparisons

| Industry assessment | $N_{i_1}$ | $N_{i_2}$ | $N_{i_3}$ | $N_{i_4}$ |
|---------------------|-----------|-----------|-----------|-----------|
| $N_{i_1}$           | 1         | 1         | 7         | 5         |
| $N_{i_2}$           | 1         | 1         | 5         | 3         |
| $N_{i_3}$           | 0,14      | 0,20      | 1         | 0,33      |
| $N_{i_4}$           | 0,20      | 0,33      | 3,00      | 1         |

The result of processing the matrix was an equation suitable for evaluating the municipal infrastructure of various areas of housing and communal services of the city:

$$N_i = 0,45N_{i_1} + 0,36N_{i_2} + 0,06N_{i_3} + 0,13N_{i_4}$$  \(3\)

where $N_i$ – the integral assessment of the utility infrastructure systems of the city; $N_{i_1}$ – assessment networks; $N_{i_2}$ – assessment equipment; $N_{i_3}$ – assessment of capacity utilization; $N_{i_4}$ – bandwidth estimation.

A distinctive feature of the second level of the hierarchy is the presence of numeric values in the criteria. Weights are assigned in accordance with the results of the matrix of pairwise comparisons.

The second-level criteria score is calculated based on utility functions. On the x-axis is the value of the criterion, on the y-axis is the value from 0 to 1.

Network state assessment:

$$x_{i_1} = \frac{T_{nf}}{T_{nr}} \times 100$$  \(4\)

where $x_{i_1}$ – the wear rate of networks, %; $T_{nf}$ – the total actual period of use, years; $T_{nr}$ – the total regulatory period of use, years.

Equipment condition assessment:

$$x_{i_2} = \frac{T_{ef}}{T_{er}} \times 100$$  \(5\)

where $x_{i_2}$ – equipment wear rate, %; $T_{ef}$ – total actual period of use, years; $T_{er}$ – total normative period of use, years.

In case of assessing the wear of municipal infrastructure in the city, a general utility function is used to calculate the state of networks and equipment [4]. This function has the following form:

$$N_{i_1,i_2} = 1 - \frac{x_{i_1,i_2}}{x_{min}}$$  \(6\)

where $N_{i_1,i_2}$ – an assessment of the state of the equipment (networks), %; $x_{i_1,i_2}$ – an indicator of the equipment (networks), %; $x_{min}$ – the maximum possible wear of networks in accordance with the standards.
Figure 2. Utility function for assessing the depreciation of public infrastructure facilities

Figure 3. Utility function for assessing capacity utilization and network

Assessment of capacity utilization:
\[ x_{13} = \frac{P_t}{P_r} \times 100 \]  
(7)

where \( x_{13} \) – capacity utilization rate, \%; \( P_t \) – total actual (attached) capacity, units of measurement depending on the estimated resources; \( P_r \) – total project capacity, units of measurement depending on the estimated resources.

Bandwidth estimation:
\[ x_{14} = \frac{P_t}{S} \times 100 \]  
(8)

where \( x_{14} \) – the indicator of network capacity, \%; \( P_t \) – the total actual (connected) capacity, units of measurement depending on the estimated resources; \( S \) – the total network capacity, units of measurement depending on the estimated resources.

The final estimate of capacity utilization and network capacity has a similar form and is calculated using the formula:
\[ N_{13; i4} = \begin{cases} 1, & 0 < x_{13; i4} < x_{\text{max}} \\ 1 - \frac{x_{13; i4} - x_{\text{max}}}{x_{\text{max}} - x_{\text{min}}}, & x_{\text{min}} < x_{13; i4} < x_{\text{max}} \\ 0, & x_{13; i4} > x_{\text{min}} \end{cases} \]  
(9)

where \( N_{13; i4} \) – estimation of capacity utilization (throughput), \%; \( x_{13; i4} \) – indicator of current capacity utilization (throughput), \%; \( x_{\text{max}} \) – the maximum level of network utilization or throughput without the need for qualitative improvement of public infrastructure systems; \( x_{\text{min}} \) – the maximum permissible level of network utilization or throughput according to technical standards.

To conclude, by calculating the values of indicators and assigning them weight coefficients, an integral assessment of the region's municipal infrastructure can be obtained from the point of view of further investment needs.

4. Discussion

The main result of this work is the development of the single tool for assessing the current state of the city's municipal infrastructure. Unlike researchers that published their works previously, for example, Sychev, E. A. in the article "Analysis of a condition of engineering networks and constructions of water supply and sanitation in the state programs of Belarus" or Ratmanov I.M. and Gurtovoy O.M.
in the article "Approach to the organization of technical control in the field of municipal heat supply", considered not a separate engineering system for industries, utilities, but public infrastructure of the city as a whole.

The main difference from the article by Bogdanova S. U., Muratshina A.A., Khaliullina A.A. "Assessment of the state of networks and communications in the Russian Federation" is that the essence of the work is not to assess the actual state of municipal infrastructure, but to develop a scientific tool for conducting such an analysis.

Thus, there is no single tool of assessing the current state of communal infrastructure of the city in the articles studied by the author.

5. Conclusions
In the process of making this work, the composition of factors that form the municipal system of the city was studied. The components are combined into the general hierarchical structure, which allows to assess the current state of the utility infrastructure. Each factor is assigned a weight coefficient according to its significance relative to the others. A method for evaluating each element of the hierarchy has been developed.

The result of the study is integral performance for assessing the current state of municipal infrastructure. This mechanism can be used by municipal administrations to check whether engineering systems meet regulatory requirements or not [13, 14]. With further refinement, the results of the study can be used to develop a tool for territorial and investment planning for the development of municipal infrastructure, since the investment needs of housing and communal services largely depend on the current state of engineering equipment [15, 16, 17].

To conclude, the main goal of the study, which was to develop a mechanism for assessing the current state of municipal infrastructure, was achieved.

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