Neural network algorithms optimizing the development of residential neighborhoods

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Abstract. Modern urban planning involves the creation of a comfortable living environment. The success of new neighborhoods depends on factors such as size, location, services, and transport accessibility. However, issues such as project cost and feasibility often limit innovative urban development projects. A systematic analysis, including a morphological approach, can reveal the complexities of such projects. To optimize the efficiency of construction, the project documentation contains input parameters for calculations. Calculations of economic efficiency should take into account the phasing of the project and the stages of the life cycle. To evaluate the effectiveness of a neighborhood, fuzzy logic is used to process parameters such as the attractiveness of the neighborhood. This research focuses on creating a model of a residential neighborhood using neural network algorithms to optimize economic efficiency by adjusting the parameters of design, construction and operation, taking into account the specifics of the life cycle of a construction and investment project. The article suggests the use of neural network algorithms to improve the development of residential neighborhoods, presenting the appropriate model and discussing its features. The relevance and possibilities of developing this approach in the context of planning new neighborhoods are highlighted.

1 Introduction

Modern urban planning is a complex task that combines the creation of a comfortable environment, social and cultural zones, infrastructure and much more. The attractiveness of new areas is determined by the size, location, quality of services, transport connectivity, as well as the uniqueness of the technologies used [1-4].

All innovative urban development projects should be economically justified and effective. New construction technologies expand the capabilities of specialists, but the issues of cost and payback of projects often go beyond these technologies and become limiting factors. [5 – 7].

Projects covering entire neighborhoods with complete social infrastructure are considered promising [8-10]. Taking into account the features of such projects can occur through a system analysis [11], including a morphological approach describing the elements of the system and their interrelationships. Despite the complexity of this approach [12], it is acceptable for microdistricts [13-15]. Most of the data from the project documentation is not

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required to calculate economic efficiency. This information serves as input parameters for building optimization in order to maximize efficiency.

All construction projects have a certain phasing [16-18], including stages from project preparation to its liquidation. For accurate calculations of economic efficiency, the microdistrict model must take into account the features of these stages. The primary results of the calculations will be related to the stages, but the final performance indicators will cover the entire project - from the idea to the liquidation, or through the specified stages of the life cycle.

From the approaches of the theory of system analysis [11] to describe developing systems, the genetic-prognostic approach becomes recommended, since it complements the morphological description, taking into account the temporary state of the objects of the system and their mutual connections [12].

When creating a model for evaluating the effectiveness of a microdistrict, there are disadvantages of initial formalization in many parameters, such as the attractiveness of the area for future residents. Therefore, it was proposed to use fuzzy logic [19], which allows you to create appropriate fuzzy models. The advantages of fuzzy logic include a convenient description of the conditions for solving problems in natural language and the possibility of approximating any mathematical system through fuzzy logic - the fuzzy approximation theorem [20]. The disadvantages associated with some freedom in the formation of fuzzy rules and membership functions are compensated through adaptive algorithms, the parameters of which change as they are used. Such algorithms based on fuzzy logic are usually called neural networks and are used in intelligent systems, also known as artificial intelligence systems [21-23]. This work is aimed at creating a model of residential neighborhoods based on neural network algorithms to optimize their economic efficiency indicators by changing the parameters of design, construction and operation, taking into account the specifics of the life cycle of construction and investment projects.

2 Proposed model

Within the framework of the proposed model, the objects of the microdistrict are divided into several types, $T = \{t_0, t_1, t_2, \ldots\}$: residential properties (t_0), medical, educational, sports facilities, shops, restaurants, recreational areas, parks, pet walking grounds, elements of transport infrastructure, etc. Each of the types of objects is generally divided into types (t_i: $K_i = \{k_{i1}, k_{i2}, \ldots\}$) depending on the features of the functioning, the scale, the target group of the population for which it is designed. For example, educational facilities can be divided into kindergartens, schools, universities.

Each object of the microdistrict in the first approximation is also characterized by the coordinates of its location (x, y) on the map of the neighborhood, the projection area (S_n) and a total area of (S_t), and it is also possible with some additional characteristics, depending on the type and type of object. This representation of the microdistrict is as simplified as possible, however, it allows you to form the necessary relationships and relationships between objects that determine the general characteristics of the microdistrict in the future, including its economic efficiency. It is also important to note that the listed parameters of objects can be easily obtained from information models (for example, BIM), project documentation for individual construction projects and the neighborhood as a whole.

Figure 1 shows a conditional image of a microdistrict made within the framework of the proposed approach. The boundaries of the microdistrict play the role of restrictions in changing the coordinates of objects.

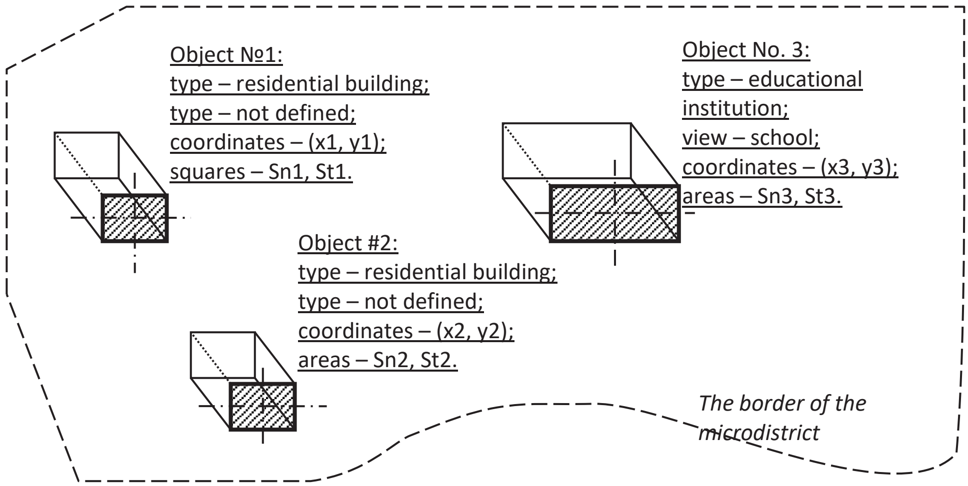

Fig. 1. A conditional image of the neighborhood.

Capital (one-time) costs for the construction of a microdistrict can be very precisely determined in advance if the total area, the technologies used, the features of the decoration of buildings, etc. are known. However, these costs at each stage of the life cycle turn out to be their own and make a certain contribution to the total cost of the project. To account for the share of costs at each stage, it is appropriate to introduce an appropriate weighting factor w_i such that the sum for all w_i equals 1, where i – denotes the stage of the project (see, for example, Table 1).

Table 1. An example of the distribution of the weighting coefficient of capital expenditures by stages of a construction and investment project.

Weight coefficient	**Construction and investment stage (number/name)**						
	1	2	3	4	5	6	7
	Preparation of an investment project	Designing	Approvals and access to the site	Construction	Initial operation	Exploitation	Liquidation
w_i	0,03	0,05	0,01	0,80	0,01	0	0,10

To obtain absolute values of costs in the first approximation, it is quite sufficient to take into account only the total areas of objects and the corresponding calculation coefficients. These calculated coefficients can be reliably obtained from the data of state monitoring systems and statistical accounting of construction activities. So, to estimate the cost of 1 square meter of housing in the region, it is sufficient to attribute the total cost of the construction of known objects for the studied period of time to the volume of the area of the commissioned housing for the same period. The remaining features of the erected buildings (classiness, features of engineering and design solutions, etc.) can be taken into account later, using their own correction coefficients for each feature.

When implementing the proposed model within the framework of neural network algorithms, all weight and correction coefficients will be adjusted in the process of training these networks on real examples and cases implemented in the relevant development regions. Due to the fact that the average statistical data are selected for the initial values of the coefficients of the model, the results of its calculations before training will also correspond to the average statistical data, which ensures the mathematical stability of the computing apparatus used, and subsequent training of the model will help reduce the calculation error by taking into account the specific features of the development of specific neighborhoods.

Regular costs for the construction and maintenance of the microdistrict will primarily depend on the duration of a particular stage of the construction and investment project. For such regular costs, it is no longer possible to introduce normalized weighting coefficients, as in the case of capital expenditures. Nevertheless, within the framework of neural network calculation, it is possible to introduce binary coefficients b_i, where i – denotes the stage of the project, which are able to take into account (turn on/off) certain cost mechanisms at different stages of the project. As an example, Table 2 shows the value of such a binary coefficient for the regular costs associated with the land tax allocated to the microdistrict.

Table 2. An example of the behavior of the binary coefficient of regular costs associated with the land tax, according to the stages of the construction and investment project.

Binary coefficient	**Construction and investment stage (number/name/duration)**						
	1	2	3	4	5	6	7
	Preparation of an investment project	Designing	Approvals and access to the site	Construction	Initial operation	Exploitation	Liquidation
	1 month.	6 month.	3 month.	18 month.	2 years	48 years	6 month.
b_i	0	0	1	1	1	1	1

Binary coefficients can also be adjusted when setting up the model. The calculated parameters of regular costs, as well as in the case of capital (one-time) costs, can be determined from statistical data, or for example from regulatory documents and rulePp.

The approaches embedded in the proposed model are fully suitable for implementation within the framework of neural network algorithms, which makes it possible to form an intelligent system for evaluating the effectiveness of a neighborhood project and optimizing its development at the early stages of design, and also ensures its integration with existing information models of buildings and the neighborhood as a whole.

3 Demonstration of the proposed model

Below is a demonstration of the proposed model implemented using spreadsheet technology. The model is maximally simplified, takes into account only capital costs, contains only two objects, one of which is a residential building located at the origin of coordinates, and the second is a conditional social object with coordinates (x, y), the proximity of which to a residential building increases the attractiveness of a residential object.

The parameters of the model objects used for the calculation are shown in Tables 3 and 4. The author draws attention to the fact that all the values entered in Table 3 are hypothetical, and the calculation itself in its current form was created only to demonstrate the principles of calculations according to the proposed model

Table 3. Model parameters.

Model Parameters	**Parameter value**
Construction cost, rub/sq.m	90 000
Cost of implementation, rub/sq.m	120 000
Object No. 1 – residential building: • coordinates • area, sq.m	 (0;0) 4 800
Object No. 2 – social object: • coordinates	 (x, y) – vary

Table 4. Weight coefficients of the model.

Weight coefficients	**Construction and investment stage (number/name)**						
	1	2	3	4	5	6	7
	Preparation of an investment project	Designing	Approvals and access to the site	Construction	Initial operation	Exploitation	Liquidation
Cost weighting factor (costs)	0,03	0,05	0,01	0,80	0,01	0	0,10
Weighting factor of sales (income)	0	0	0	0,4	0,58	0,02	0

In the model example shown, neural network training was not carried out. In real conditions, training is carried out by conventional methods, such as back propagation algorithmPp.

4 Conclusions

The paper presents the application of neural network algorithms for optimizing the development of residential neighborhoods, proposes an appropriate model, discusses its features, shows the relevance and prospects for the development of the proposed approach when planning new neighborhoods.

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