An ontological model for planning urban areas with a given level of economic efficiency

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Abstract. The paper presents an ontological model for planning urban areas with a given level of economic efficiency, the use of which can provide optimal configurations of future neighbourhoods for all participants in their construction and operation. The implementation of intelligent systems based on the algorithms of the proposed model can provide optimal configurations of future neighborhoods for all parties involved in their construction and operation

1 Introduction

Ontological models today are one of the effective tools for describing complex multilevel evolving objects [1-7]. Within the framework of ontological research, conceptual schemes of objects are drawn up, structures of knowledge bases corresponding to them are formed, certain restrictions are established. At the same time, information from various sources with different levels of structuring and formalization is used as input data for creating ontological models, which, on the one hand, increases the objectivity and completeness of the obtained results of describing or simulating an object, but on the other hand requires a special algorithm for ordering, combining, validating, and verifying the data used. The practical value of ontological models is associated with the possibility of creating decision-making systems and management of objects and projects on their basis.

Ontological models find their application in the field of architecture and design for the selection and justification of engineering and architectural solutions and technologies, effective management of construction and investment projects and forecasting the results of their execution [8-15]. A very promising direction of using ontological models in construction is the possibility of assessing the economic efficiency of the functioning of projected urban areas at different stages of their existence for different groups of participants in such projects: investors, builders, residents, operators of socio-cultural and communal facilities, the state. Modelling of new urban areas will allow choosing the most appropriate layout and filling option for each participant of the process at the early stages of design, considering the existing regulatory restrictions and obligations.

Within the framework of this work, the concept of an ontological model for planning urban areas with a predetermined economic efficiency is proposed.

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2 The concept of the ontological model

The proposed ontological model is based on normative and methodological materials concerning the assessment of the efficiency of the use of urban areas [16, 17], as well as scientific work carried out in this direction [18, 19].

The proposed model uses several classes of ontology objects:

• *territories* – the area of housing neighbourhoods. The attributes of territories include geographical location (latitude, longitude), the geometry of the boundaries of the site, relief, natural landscape features (for example, the type and amount of vegetation, the presence of reservoirs, rivers, swamps, etc.), climatic features, soil, and soil features, and more;

• *micro-district* – a complex of residential buildings and non-residential facilities, mainly consumer service institutions, adjacent to transport highways. The formation of micro-districts must comply with the relevant building codes and regulations (restrictions). Planning of an urban micro-district should also consider the specifics of its location and the specifics of nearby (neighbouring) micro-districts. The attributes of micro-districts include geographical location, integral characteristics of infrastructure and containing construction objects, including their number;

• *block* – a block of buildings and urban structures bounded by streets or other boundary objects along the perimeter. Performs a structuring role in the development of micro-districts and the connection of construction objects with streets as elements of the road transport network. The formation of blocks, as well as micro-districts in general, must comply with the relevant building codes and regulations (restrictions). The planning of the quarter should consider the peculiarities of the concept of the micro-district and its road transport network. Attributes of a micro-district, in addition to geographical position, also characterize the integral interaction of its constituent objects with elements of the road transport network;

• *road transport network* - a set of transport lines (paths, roads) of a certain territory connecting its objects. The road transport network ensures the movement of people and goods both without the use and with the use of various types of vehicles. In this regard, the road transport network is a multi-level object that assumes a very deep classification and allocation, for example, of such elements as pedestrian and bike paths, streets, highways, etc. The planning of the road transport network has some regulatory restrictions. Attributes of road transport network elements include their geometric parameters, geographical location, purpose, capacity, regulation features and much more.

• *construction objects* – residential buildings and non-residential urban development objects. Among non-residential facilities, social facilities (educational institutions, medical institutions, shops, cultural and sports institutions, and much more), recreational areas (parks, arboretums, etc.) can be distinguished. Each of the listed objects, in turn, also has a very extensive classification and can vary in size (for example, for educational institutions: university, school, kindergarten, etc.). Important attributes of any construction object are its coordinates, occupied area (on the site), total area of premises, type and related to this type of additional indicators. Some restrictions are also imposed on all construction objects during the design and construction process, due to the relevant norms and rules

• *project participants* are subjects with a designated role in the formation and implementation of the project, as well as the further use of its results. The project participants include investors, designers, builders, buyers and operators of real estate (owners, residents, operators of non-residential premises), as well as the state as a regulator of the construction process and a holder of tax deductions. The attributes of project participants as objects of ontology primarily include their role in the project and the parameters associated with this role (the volume of investments/possessions, etc.).

The restrictions imposed on objects of ontology classes and their attributes are related to the regulations in force on the territory of the micro-district location. Visualization of the object classes of the proposed ontology of the urban micro-district is shown in Figure 1, their relationship is shown in Figure 2.

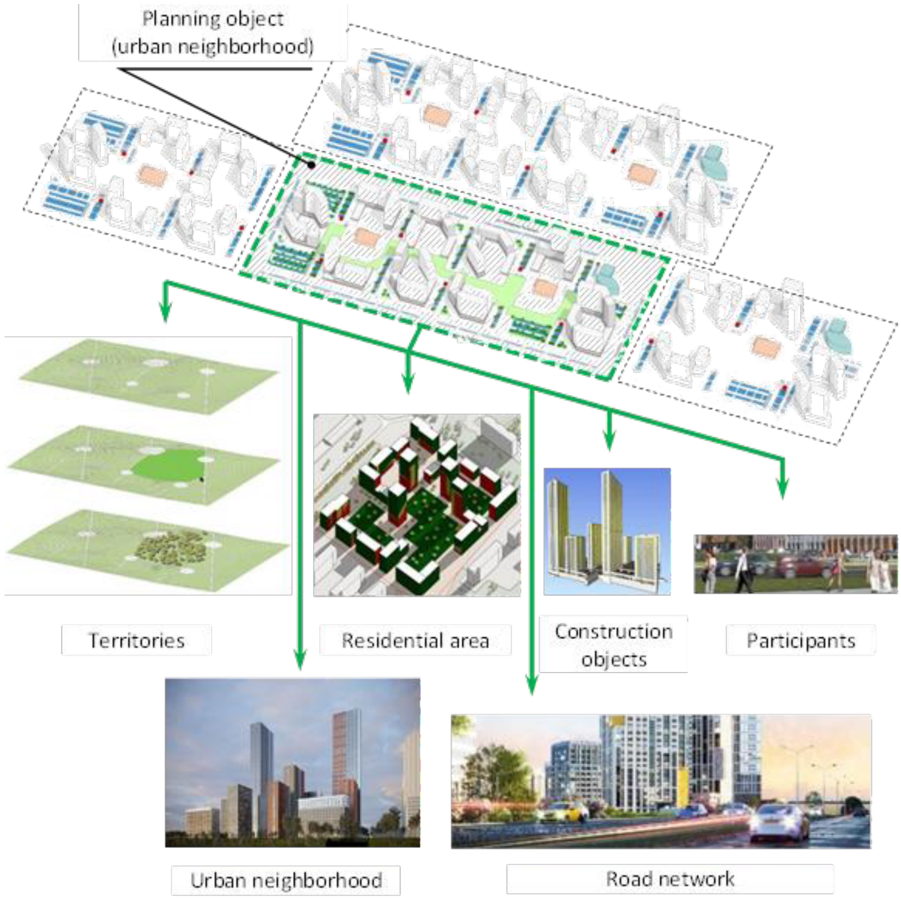

Fig. 1. Objects of the ontology of the micro-district.

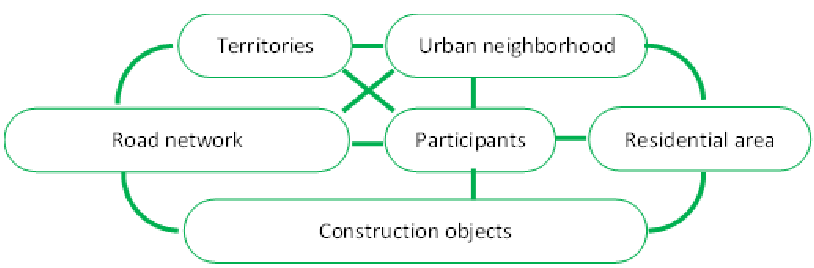

Fig. 2. Connection of classes (graph) of objects of the proposed ontological model.

The actual development of the proposed ontological model provides estimates of economic efficiency (satisfaction, success, economic benefits, etc.) of project participants from participation in an investment and construction project. Due to this, by varying certain attributes of ontology objects available for change, it is possible to obtain various configurations of urban neighbourhoods, and for each such configuration – to obtain a numerical estimate of economic efficiency. Thus, the use of ontology makes it possible to plan urban areas with a given level of economic efficiency for given groups of project participants.

Different classes of ontology objects are related to each other in the relations of descriptive logic, including intersections and unions with each other. At the same time, the attributes of different classes of objects are unique. Attributes of smaller classes that are part of larger objects do not directly follow the attributes of these larger objects. For example, the set of attributes of residential structures is not equivalent to the set of attributes of the micro-district that these structures are part of. Thus, within the framework of the ontological model, the fundamental property of the theory of systems and system analysis is maintained, stating that any system has new properties in relation to the properties of its constituent elements.

It is also important to note that among the many attributes for each class of objects of the proposed ontological model, there are those that show dependence on the stage of the investment and construction project.

Within the framework of this model, the following stages of an investment and construction project are used:

- Stage 1 – preparation of the investment project;
- Stage 2 – design;
- Stage 3 – approval and access to the site;
- Stage 4 – construction;
- Stage 5 – initial operation;
- Stage 6 – operation;
- Stage 7 – liquidation.

The proposed ontological model allows for the expansion of classes of ontology objects, the expansion and detailing of their attributes, and the refinement of relationships.

3 Application of the proposed model

To apply the proposed ontological model, it is necessary to obtain primary information in accordance with the structure of the model object classes (see Figure 1) and their attributes. This information can be obtained from the primary permit, draft, design, or other documentation for the planned micro-district. The extraction of the necessary information can be performed in an automated mode.

Next, the primary configuration of the micro-district is generated, all elements of construction objects and the road transport network are placed in it, that is, the initial values of the attributes allowed for subsequent variation are determined, and the attributes that have values set based on primary documents are fixed.

Considering the interrelationships of the ontology objects (see Figure 2), the calculation of the economic efficiency of the initial configuration of the micro-district is performed for each of the project participants, depending on the stage of the investment and construction project.

Next, the required a priori efficiency value (minimum level, range of values or otherwise) is determined for the project participants (a vector value) and the process of varying the attribute parameters of the neighbourhood objects is started to achieve this a priori value. As a result, such a solution is formed (the configuration of the micro-district), which turns out to be as close as possible to the required values of the efficiency vector. The variation procedure can be implemented by various known numerical algorithms for finding the extremum of a function of many variables.

The described algorithm is shown in Figure 3.

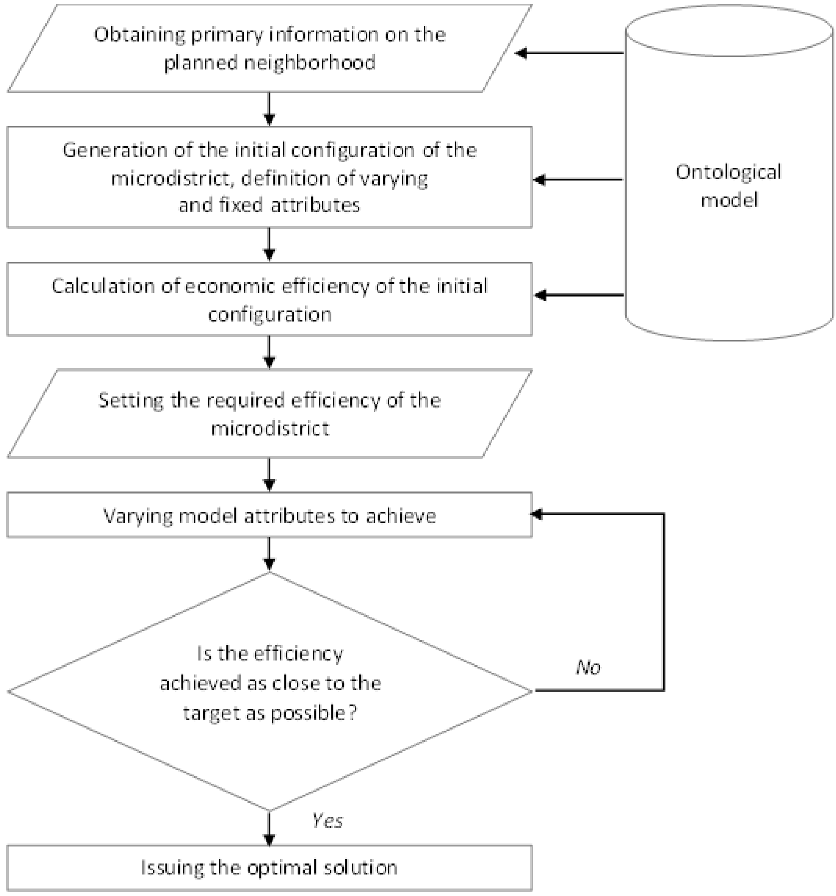

Fig. 3. Algorithm of application of the proposed ontological model.

Thus, at the early stages of planning an urban micro-district, it is possible to obtain recommendations on its configuration to achieve a given level of economic efficiency for the participants of this investment and construction project.

The proposed algorithm is suitable for full automation and can be used as the basis for an appropriate artificial intelligence system that helps in making managerial decisions at the early stages of planning urban neighbourhoods.

4 Conclusions

The paper describes the ontological model and the algorithm of its application for planning urban areas with a given level of economic efficiency. The introduction of intelligent systems based on the algorithms of the proposed model can provide optimal configurations of future neighbourhoods for all participants in their construction and operation.

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