Modelling Methods in Solving Research and Design Problems in Architecture Activities

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Abstract. The modern architectural and city-planning science requires combining the efforts of a number of various research teams, including representatives of different branches of scientific knowledge, with the purpose of designing the most rational and efficient methods of research organization. Due to the dynamic nature of architectural and city-planning objects and quick alteration of the parameters of their elements and components, prompt methods of solving research, designing or forecasting problems are necessary. The era of the fifth technological paradigm is characterized with the establishment of such branches of industry as electronics, microelectronics, information technologies. Since 2010ies we live in the phase of the sixth technological paradigm development, in which the production processes are based on cloud infrastructure and virtual services. One of methodological preconditions in the further development of architecture is the search for optimal solutions in the process of research and designing developments, which could be the most quickly and efficiently implemented by means of computers and information models. For this purpose, first of all, the appropriate formalization of architectural objects is necessary – i.e. creating functional mathematical models and software products for implementing the process of research and solutions optimization in computing techniques. Current studies in the sphere of architecture more and more lead to realizing the necessity of system approach to research and designing of architectural objects as complicated systems, having the hierarchic structure. The most promising are the system methods of research, designing and expert evaluation of architectural objects of any degree of complexity.

1. Introduction

The subject domain of architectural research is modeling methods in architecture. For the clearer understanding of objectives, which the architecture researchers and designers face, it is necessary to study the methods of modeling, used in the up-to-date architectural science and practice. Due to the complication of the object of architectural activity and the necessity of solving city-planning, spatial-planning, architectural-structural, compositional, economical and other problems a need arises to determine and classify methods of modeling, used in modern architecture.

The issues of selecting modeling methods, used in various fields of knowledge, and their classification are considered in a number of system studies by the authors [1–5] etc. The questions of architectural design are considered in research works [6–9]. The system methods of research, design and expert's assessment of architectural objects are studied in works by the authors [10–14]. Methods of research and designing of architectural objects in wireless cyber-physical systems are dealt with in
the research works [15–18]. Methods of developing algorithms of 3-D models generation on the basis of drawings were studied in a number of works by researchers and designers of programming modules [19–26]. The peculiarities of using main business applications, used in the modern practice of architectural design (such as SAP2000, ETABS, Abaqus, ANSYS, Rhino, Revit, and AutoCAD), and methods of complex objects modeling, parametric modeling and the methodology of information modeling of buildings are considered in works [26–27].

2. Topicality
At present there is no single approach to rendering object and subject of architectural activity, which inevitably results in significant discrepancies in the sphere of research methods and architectural design of objects, especially at such important levels of solving this problem, as general city development plans and settlement systems in general. The search for efficient ways of modeling complex objects, to which architectural objects belong, is associated with the application of advanced technologies, used in modern construction sector, and methods of information modeling of buildings. The topicality of this problem has determined the objectives of this research.

3. Research objectives
– identification and classification of modeling methods, used in architectural activities;
– substantiation of the used modeling methods in various development periods of architectural science and their interrelation with the development phases of technological paradigms;
– identification of the most promising modeling methods, corresponding to the criteria of up-to-date technologies and manufacturing organization.

The object of research is modeling methods, used in architectural theory and practice in various historical periods of architectural science development. The subject of research is classifying the ways and methods of modeling, used in architectural theory and practice.

The methodology of research is based on the comparative (benchmarking) analysis of modeling methods, used in architectural design.

4. The theoretical part
At present a model is a reflection of certain characteristics of an object with the purpose of studying it. The origin of the concept of «model» is closely related to the architecture (from Latin modus, modulus – measure, image, way) and construction activity. Models in architecture have been traditionally presented in the form of bulking models, made in miniature or life-sized with the purpose of visual demonstration, architectural-constructional creative process, or in drawings. A model is a certain substitute object, which under certain conditions can replace an original object, reproducing the properties and characteristics of the object under study. A model has such advantages as visibility, demonstrativeness, availability for testing and manipulations [3, 4, 5, 10]. Modeling is the abstract, formal reproduction of the structure and functions of an object under study, and a model is an artificial object, the elements of which and their interrelations appropriately (isomorphically) correspond to all main (substantial) and specific elements and interrelations of the modeled system.

In fig. 1 the classification of modeling methods into qualitative and quantitative is presented; and in Fig. 2 the classification of modeling methods (according to V. Venikov) is given, described in [1, p. 63]. Models can be classified by various characteristics. First of all, models are divided into physical (material) and descriptive (mental) [1, 10]. In mental modeling the mathematical, symbolic and appearance modeling is singled out; and in material modeling – mathematical, physical and full-scale modeling. In Fig. 3 the classification of models according to V.A. Shtoff [5] is presented.

At the beginning of the 20th century the studies of structures under load on their scaled-down models came into general use in design practice as an industrial experiment. Since 1950–1960 the only measure of accuracy of architectural and construction solutions in architectural objects, including large-span ones, taken on a model, was the practical experiment. The design experience has demonstrated that a model, tested through practice, can be a reliable way of decision making [28].

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The peak of construction of, for example, large-span shells, was in 1950–1960ies. The only measure of accuracy of architectural and construction solutions of shell structures, taken on a model, was the practical experiment. The design experience has shown that a model, tested through practice, can be a reliable way of taking decisions.

Since 1960–1980ies the concepts of «design model» and «design modeling» have appeared in architectural design methodology [6, 9], due to the approbation of system methods and the general system theory, presented by L. von Bertalanffy [30, 31]. The complication of an object of architectural activities required the system approach and system methods of research and applying models to its functional-spatial structure.

In the period of the fourth technological paradigm development, which extended up to 1990ies [29] and was characterized with achievements in motor industry and aircraft engineering, petrochemistry, nuclear power industry and electronics industry, the design 2d and 3d models were beginning to find application in architectural theory and practice. In the era of the fifth technological paradigm (since 1971) the architectural theory and practice are based on the achievements in the sphere of
microelectronics, informatics, biotechnology, genetic engineering, space exploration, new types of energy and materials, satellite communication. In recent decades, in the era of computers and telecommunications, the new and various ways of addressing to the topic of modeling in architecture have been emerging in architectural theory and practice. Modeling in architecture is understood as a method of studying complicated objects, phenomena and processes by means of their simplified imitation (full-scale, mathematical, logical) by developing special abstract systems – models, reflecting the structure and functions of an object under study [10]. The most widespread types of architectural models nowadays are schemes, drawings, graphs, dummies, numeral dependencies etc. The modern architectural designer has to master not only material, but also mental modeling methods.

![Classification of models](image)

*Figure 3. Classification of models (according to V.A. Shtoff).*

In architecture and construction design the mental modeling includes verbal-descriptive models (appearance models) and mathematical models. Verbal-descriptive models include: technical specifications, explanatory notes to designs and reports, problem statements in the verbal-descriptive form. As a rule, verbal-descriptive models are later transformed to mathematical models for convenience in further operation. The appearance analogies are presented with charts, drafts, designs, drawings and dummies, reflecting visually certain features and properties of a modeled or designed object. Graphic models can be presented as flow charts (flow graphs). The availability of a geometric layout in the form of dummy allows presenting a designed object as a whole before its implementation.
on the construction site, interconnecting all its parts into a whole in a best possible way, and finding an optimal solution. Models in form of flow charts describe visually the logical and functional sequence of solving this or that problem, as well as the structure of various objects, systems, phenomena and processes. Graphic modeling is used for making structural, functional and other models.

A structural model of an object in scientific activities of an architect allows representing the content of a system under study and the hierarchic interrelation of its components. A structural model can be presented with a graphical scheme, showing all the objects and their parts, making up the system, elements and components of the parts etc. depending on disarticulation level of an object under study. A more comprehensive view on the structure of an architectural system is given by an information model or a functional model.

An information model is aimed at describing the states of a system’s elements in the process of their transformation, as well as of informational flows. A functional (ontological) model describes the system nature of an architectural system, bound with interactive relations: the reason and the place of each element in the hierarchical structure are defined and limited with its functioning, its role in the system’s organization. A functional model is also aimed at describing the sequence of elementary operations in the process of taking into account all informational links, existing between the elements of the system and its hierarchical levels. A functional model can be also presented in the form of a network model, representing the sequence of the design process from one operation to another.

5. The practical relevance
The work is aimed at identifying the most sought-after in the nearest future functional and information cybernetic models and the system approach to modeling complex objects. At present we live in the era of active development of the fifth technological paradigm, which began in the 1970ies of the 20th century. It is characterized with the establishment of the following main branches of industry: electronics and microelectronics, information technologies, genetic engineering, software, telecommunications, space exploration. The key factor of the fifth technological paradigm is microelectronic components; the achievements of it are the individualization of production and consumption and the speed of communication and transportation. The development phase of the sixth technological paradigm since 2010ies is associated with such main industries as: nano- and biotechnologies, quantum and cloud technologies. Production organization is based on virtual services and cloud infrastructure. In the architectural practice the information models of architectural objects, based on computer modeling, are gaining development and implementation. The up-to-date computer modeling distinguishes two main types of it: parametric (generative) and kinetic (robotical).

6. Conclusions
As a result of the carried-out research the following conclusions can be made.

1. In solving research and design problems in architectural activities both physical (material) and descriptive (mental) modeling finds application.

2. The development of information technologies and scientific and technological advance in fields of science, related to architecture, has contributed to the approbation of system approach and system methods of modeling in architectural activity. Due to the complication of an object of architectural activity in modern architecture, it is not possible to properly solve research and design problems without system modeling with the use of up-to-date information technologies on the basis of functional cybernetic models.

3. The era of the sixth technological paradigm is based on virtual services and cloud infrastructure. In conditions of this technological paradigm the most promising are numerical methods of research, designing and expert evaluation of architectural objects of any degree of complexity. Such methods require applying the evaluation criteria of architectural objects, which should meet the following requirements:

1) a criterion should include the indices, which influence the completeness and efficiency of a design architectural-structural solution;
2) a criterion should be measurable (the possibility of carrying out quantitative analysis);  
3) universality of criterion (for objects of various complexity and designation);  
4) promptness of criterion (information processing and obtaining results at the stated time).  
Such requirements are met by the system methods of research, designing, forecasting and expert evaluation of architectural objects, which allow the application of electronics and computer technologies.

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