Conceptual modeling to control the quality parameters of the BIM model

Olga Kysil, Sergii Mikhalchenko, Valery Tovbych

Department of Information Technologies in Architecture, Kyiv National University of Construction and Architecture (KNUCA), Povitroflotskyi Avenue 31, Kyiv, 03037, Ukraine

solomyab@gmail.com

Abstract. This study pays attention to the quantitative and qualitative analysis of the project in the BIM (building information model) form, as well as the relevance to this scientific topic. The definition of ETR (Electronic Terms of Reference) is given. The working hypothesis of the research is described, which consists of several main stages. The novelty of the application of quantitative and qualitative analysis to BIM is emphasized and the method of its automation is described. An example of a typical object is chosen, on which the practical stage of assembling the ETR is carried out and an algorithm for quantitative and qualitative analysis on this basis is developed.

Introduction

The purpose of this article is to describe the general method of qualimetric assessment of the quality of the BIM model and general algorithms of the system and integrated approaches in this direction. The general study of the conceptual modeling of the future properties of the BIM project is based on a fairly wide range of works of modern scientists. Typically, the range of interests includes the business effect of BIM technology, analysis of energy efficiency models, improving the management of the design process, and the entire life cycle of the facility. Attention is paid to communication between project participants, data protection, classification of elements, etc. [1, 2, 3].

The authors of this article took a decision to focus on the implementation of theoretical research, which at the time of its appearance (the '80s, '90s) had no prospects for implementation due to insufficient hardware capacity. Despite this, interactive procedures for making design decisions were studied, even aesthetic issues, which are extremely hard to formalize [4]. The mathematical model of the system approach required a lot of time and miscalculations, the complex one mainly used the anthropo-dependent expert method. Thus, the topic of quality in architecture does not have currently implemented electronic control tools and is a poorly structured multicriterial task. In addition, the existing correlations between impact factors require the development of a complex design decision-making apparatus.

Relevance of the study

One of the conclusions of research on the methodology of optimization of the architectural environment was the statement about its complex organizational structure, which is based on various criteria [5]. Multicriterial is a feature of modern architecture. Accordingly, the popular view of the construction site
through the monetary dimension does not always justify itself. The emergence of many energy efficiency and green building certification systems in the last decade underscores this. Finding a balance between influencing factors is an urgent scientific problem.

The founder and ideologist of qualimetric analysis is G.G. Asgaldov [6, 7]. Also, a significant contribution to the development of architectural qualimetry was made by D.N. Yablonsky, G.D. Yablonska [17], etc. Researches of the system approach of an estimation of quality in architecture were engaged in: G.I. Lavrik [8], M.M. Demin. Systematicity in architecture in general is a topical issue [9], which became one of the starting points for the study of the BIM model as a complex system [15].

Modern scientists are searching for the optimal mathematical model to determine the optimal performance of complex structures, which are architectural objects. The method of analysis of hierarchies (MAI) is considered in modern research as one of the most effective methods of decision-making. It allows you to clearly and rationally structure a complex problem of decision-making in the form of hierarchy, compare and quantify alternative solutions, taking into account not only tangible or intangible quantitative qualities of objects but also subjective qualities or processes of a spiritual nature [10]. In addition, some research presents the algorithm of the procedure for determining the weight of property indices of urban quality of life on the basis of qualimetric method expert assessments. An important basis for the formation of ETR as a qualimetric standard is a theoretical algorithm related to the development of a universal method of quantitative assessment of urban quality of life, which allows to assess any object [11].

The study focuses on the possibility of applying a BIM model of qualimetric quality assessment based on two approaches: integrated and systematic. But in modern sources there is no transitional link in the application of these methods in BIM technology. No systematic analysis of the BIM model and its input and output data as an architectural and construction system. There are no methods and means of assessing the quality of the BIM model as a product of architectural and construction design, which must be implemented with maximum aesthetic, economic, technological and environmental effects.

Approval of the concept of BIM implementation in Ukraine at the state level at the end of 2019 made it possible to further work on proposals for changes to DBN 2.2.3 for the implementation of BIM in Ukrainian regulations. In line with this study - ISO 22263: 2008, dedicated to quality management. In addition, amendments were made to the Law of Ukraine "On Building Standards" to improve rationing in construction: added "parametric rationing method in construction - a way to establish requirements for the object of rationing in construction, which provides for the definition of objectives and / or safety parameters, functionality and quality of the object of rationing in construction (criteria, requirements for performance and / or its indicators.) However, it should be noted that according to the analysis of modern research, determining the quality of the model is quite relevant not an issue for the global design community. To date, comprehensive tool of its kind for BIM technology to designers available. The use of survey results can be widely represented in various aspects of construction, architectural and economic fields of activity:

- A tool for improving the public procurement system. It is from this sector that the implementation of BIM at the state level in many developed countries began. Optimizing transparent decision-making helps to improve the economic performance of the construction industry and the return on investment in the public construction sector.
- Application of decision-making meanwhile the public hearings. The clarity of the method helps to compare the performance of different projects and make appropriate independent decisions.
- A method of improving the assessment of private investment risks, which is carried out through the modeling of quality indicators according to the criteria important for a particular business plan.
- Quality control of the project team for both its leader and the investor. Transparency in the adherence to the schedule and the quality of the work corresponding to the ETR improve the economic effect of cooperation for both parties.
Grounds for a legal assessment of actions to change the terms of reference in the design process, which entail iterative revisions of the project, and, accordingly, the financial obligations of the parties.

**Scientific hypothesis**

The algorithm for obtaining scientific results consists of 3 stages:

**Analytical stage:**
- Study of existing methods of multicriterial analysis and optimization of indicators to improve the result;
- Systematization of modern criteria for assessing the quality of architectural and construction object;
- Conducting business analytics of existing BIM software to identify existing automatic means of obtaining indicators from the model;

**Methodical and theoretical stage:**
- Definition of the main groups of quality assessment criteria;
- Description of the BIM model as a system with the interaction of subsystems and over systems;
- Defining the paradigm of the Electronic Terms of Reference as a control system for the input database of the model;
- Formation of the property tree. Development of mathematical and analytical apparatus to obtain research results.

**Practical stage:**
- Block diagram of creating a template of the Electronic Terms of Reference;
- Block diagram of the software module to determine quality indicators, their aggregation, and weight distribution;
- Technical description of the software implementation of the mathematical and analytical apparatus of the study.

The object of research is the BIM model as a system of heterogeneous data types at the input and output.

The subject of the study is a multicriteria l analysis of the BIM model.

The purpose of the study is to develop a methodology for applying automatic multicriterial analysis to the product of construction information modeling to manage the quality of the modeling product.

**Scientific novelty**

The study for the first time describes the analysis of quantitative and qualitative design characteristics of the BIM model. It predicts the economic, aesthetic, environmental and technological properties of the project.

Methods are implemented using the:
1) definition of indicators of 4 main categories of assessment: economic, technical, aesthetic, ecological;
2) obtaining consolidated quality indicators of different categories from the BIM model;
3) comparison of the reference indicators for electronic terms of reference;
4) automation of multicriterial comparison of model indicators with reference values.

It should be noted that there are now several documents governing the quality of certain aspects of BIM processes and information product. These are Employer’s Information Requirement (EIR), BIM Management Plan (BMP), BIM Execution Plan (BEP). But all these documents do not have the requirements of the needed quality of architecture, which reproduces the model.

The paper concludes on the possibility of taking ETR as a qualimetric standard, provided that it determines the values of weights and formulates on this basis the reference indicators of properties. The conclusion is based on the existing modern theses about the numerical values of the characteristics of the reference sample. They are set as accepted reference values, which are used as an agreed reference for comparison and which are defined as:
a) theoretical or established value based on scientific principles;
b) assigned or certified value based on experimental data from certain national or international organizations;
c) agreed (based on consensus) or certified value, based on joint experimental work carried out by a scientific or engineering team [12].

Significance of the study
The practical significance has been studied on the example of designing the residential area of a functional-spatial military cluster using BIM technology. The development of a software tool based on the developed method of quantitative and qualitative analysis of the BIM model will allow managing the qualitative characteristics of the project according to existing regulatory parameters and customer-specified conditions at the initial stage of the life cycle of the object - its project. The tool described in the study improves both the economic, technical, environmental and social efficiency of the product of architectural and construction design.

The application of the method of quantitative and qualitative analysis of the BIM model is appropriate for the introduction of standardization, in particular in the field of design of special structures. The Technical Committee for Standardization TK-320 "Special Purpose Buildings" has expressed its intention to use this method after its final development.

In addition, the application of this method makes it possible to more accurately determine the material consumption and total cost of construction. This saves significant funds and prevents corruption in tenders for the design and construction of buildings and structures to state order. The practical significance of the project exists both at the national level, from the regulation of public procurement and public hearings, and in the private construction sector: to assess business risks and mutual control of the customer and the contractor.

It should be noted that an integral part of the ETR is the regulatory framework, which corresponds to the type of design object. In the example presented in the article, these are military standards that always provide for action within the described framework [13]. It is the initial constraints in the data fields of the ETR table. But according to the modern method of parametric examination of the building, which is gradually being replaced by fixed State Building Standards, it is such a flexible system of setting initial parameters as ETR that allows to combine the wishes of the customer with constant building standards. Besides, the parametric method of rationing is practiced in countries with already implemented at the state level BIM technology.

Method of qualimetric analysis of BIM model
This method in the study is developed on two bases: integrated and systemic approaches. Both options are implemented in the process of forming the ETR according to the request of the customer or investor and the building codes in force in the country of construction. To further assess the design qualities of the model, ETR is taken as a qualimetric standard. It can also be assumed that ETR is a conceptual BIM model [14], which precedes the construction of the design BIM model for further work with related specialists at other stages of the life cycle.

In previous theses, the study defines the following groups of quality criteria: technology, economics, ecology, esthetics. To form such groups of criteria, an analysis of international certification systems DGNB, LEED, BREAM, which reflects the current indicators of environmental quality and sustainable development of architectural objects [15].

At this stage, the study tested the formation of ETR for BIM model of a typical residential military facility. The reason for choosing such an object is its typological and functional features against the background of a clear structure [16]. The composition of the terms of reference in this case has a basic core, which is a description of the constant prerequisites, and additional options that change according to age and status factors. In the process of research, a tree of properties of the residential area was constructed, the data of which were transferred to the ETR spreadsheet. An assumption was made about the similarity of the structural structure of the table data and the property tree, which was confirmed.
during the work. Given the traditional application of the expert method of decision-making, there is a certain problem of automating such a process. In the course of the work, a hypothesis arose as to the possibility of providing expert roles to the architect, project manager and customer, who fill in the ETR table. Also, the "expert" regulator of parameters is a database of standards, which is automatically connected to the table at the time of specifying the typology of the object. It determines the possible valid value ranges in the data fields of the ETR table.

The results of the study and its prospects
The application of the qualimetric method of assessing the quality of the BIM model by an integrated approach takes more hardware resources and time due to a large branched system of indicators for four groups of criteria, each of which has its subgroups. However, the ETR formed by this method allows to describe in detail the needs of the customer and it is easier to harmonize them with the standards.

The compilation of ETR according to the system approach is a fast method of conceptual modeling of business effects from the project. Aggregation of indicators helps to adjust the project more easily to achieve the optimal picture.

In the example given in this article, it is advisable to use a systematic approach to determining the quality of the project. This is especially convenient in the case of developing a typical model. For further application of the model for a specific design task, it is possible to supplement the ETR and recalculate the indicators by a comprehensive method.

During the project, the so-called self-learning BIM model is created. In fact, it can be used as a conceptual template for objects of a similar typology. In the process of developing design solutions and comparing their success with ETR, machine learning can occur [14]. The prospect of such software is difficult to overestimate in the context of the versatility and complexity of modern architecture.

Conclusion
According to the experience of architects involved in BIM technology design, a significant problem is outdated design standards and the application of the rules of paper documentation to modern projects. Design models have in electronic form the whole range of relevant information. But now there is a conflict between new technologies and generally accepted design processes. The terms of reference are an element of such a conflict, as it is one of the initial defining documents for the project. Besides, to achieve maximum economic and social effects, the architect must be able to monitor quality indicators at any stage of design.

The study described in the article is part of a project to develop software tools for all stakeholders of the BIM process. Previous surveys have depicted the high level of interest to such a software shown by the professionals.

References
[1] Olawumi T O and Chan D W M and Wong J K W 2017 Evolution in the intellectual structure of BIM (Taylor and Francis Ltd.) p 1060–1081
[2] Ashworth S, Tucker M and Druhmann C 2016 The role of FM in preparing a BIM strategy and employer’s information requirements (EIR) to align with client asset management strategy 15th EuroFM Research Symposium, Milan.
[3] Succar B and Poirier E 2020 Lifecycle information transformation and exchange for delivering and managing digital and physical assets (Automation in Construction) vol 112.
[4] Tovbych V 1986 Interactive graphic modeling of architectural environment taking into account features of its visual perception (Kiev, Kyiv National University of Construction and Architecture the dissertation)
[5] Myronenko V 1999 Methodological bases of optimization of the architectural environment. Author's abstract. dissertation of doctor of architecture (Kharkiv State Technical University of Construction and Architecture)

[6] Azgaldov G and Kostin A 2012 Quality - as the most important object of quantitative analysis, (Barcelona, Jan. 2012. Accessed)

[7] Azgaldov G 1996 Construction of a tree of indicators of properties of object Standards and quality Vol. 11

[8] Lavryk G 2002 Fundamentals of systems analysis in architectural research and design (Kyiv, KNUBA, Ukrainian Academy of Architecture) p 140

[9] Panova L 2010 Systematics of the architectural environment: monograph, (Kharkiv, Kharkiv National Academy of Urban Economy) p 235

[10] Badyul M and Kramarenko V 2013 Application of the method of analysis of hierarchies in design and construction Construction. Materials science. Mechanical engineering. Series: Energy, ecology, computer technology in construction vol 70

[11] Lisnychenko S 2015 General principles for determining the importance of indicators of urban quality of life (Kyiv, Online).

[12] Motalo A and Stadnyk B and Motalo C 2020 Analysis of methods and types of measurements in qualimetry Scientific journals and conferences, ISTCMTM Vol 78

[13] Base camp facilities standards 2004 URL: https://docplayer.net/29960552-Base-camp-facilities-standards.html

[14] Kysil O and Levchenko O 2018 Software tools for sim analysis and neural networks of artificial intelligence on its basis (Academia.edu, Collective monograph) Vol. 2

[15] Kysil O 2020 Systematisation of BIM data for project quality management International Scientific Conference Topical issues of modern design

[16] Mykhalchenko S 2016 Cluster approach to the formation and development of special areas in terms of approximation to the standards of developed countries Urban Planning and Spatial Planning Vol. 59 p 336

[17] Yablonska G 2013 Economic efficiency and quality of urban and architectural solutions (Kyiv, Kyiv National University of Construction and Architecture) p 120

[18] Knysy V and Yablonska G 2017 Methodical improvement of design as a strategic and tactical means of materializing architecture Urban Planning and Spatial Planning vol 65