Building information model verification at the lifecycle stage of construction

Elena Galkina and Olga Kuzina

Moscow State University of Civil Engineering, Yaroslavskoe shosse, 26, Moscow, 129337, Russia

E-mail: kuzinaon@mgsu.ru

Abstract. The article contains the BIM-models cycle, background and basic principles of verification system with tools for performing the rule check, sequence of C-BIM model check. The validation algorithm of the information model with peculiar properties of C-BIM model (at the construction stage). Verification of the C-BIM model open problems when testing the model. Description of reliability analysis of solutions during verification. The task to control the compliance of the object with the specified design parameters.

1. Introduction

The need for automated BIM models verification for finding errors and for conformation to the rules and regulations arose almost simultaneously with the starting the technology of information modeling. However, most of the research on this topic concerned the models developed at the design stage of lifecycle, and expertise of the data models.

Building information model (BIM) is a well-coordinated, coherent and interconnected model of the object, having the ability for calculation and analysis, geometric reference, working with computer, using specific software, allowing necessary updates of numerical information about already existing object or still under design.

Now, when distinctly indicated the need of BIM technology application at all stages of the building or structure lifecycle, it is becoming increasingly urgent issue in the development and use of appropriate verification systems. This trend concern obviously and stage of construction. At the stage of construction we use the information model, created at the design stage and adopted by the expertise, supplemented by parts of organization and management processes. For that research it is required to be input the concept of BIM-models at each stage of lifecycle.

Let the model at the stage of pre-project is called Pre-BIM, at the stage of designing – D-BIM, at the stage of execution or construction – C-BIM, at the stage of facility management or exploitation – E-BIM, at the stage of reorganization or waste recycling – Re-BIM (Fig.1).

Application of monitoring and control systems in BIM models during the construction stage of lifecycle will improve the management efficiency of the construction processes and will help to detect deviations from established parameters, thereby allowing to take timely corrective action.
2. Background and basic principles of verification system

The first research in the field of systems for checking rules began two decades ago. During this time, verification methods have been developed, but the technology is still young and continues to evolve. Rules verification systems are just beginning to become known and accessible to a wide range of specialists. At the moment, there are four software platforms that have been developed as rule verification systems, namely Solibri Model Checker (SMC), Jotne EDMModelChecker, FORNAX, SMARTcodes. However, application of that software is local, that is mostly limited by the area it was developed. It is wide known, including in Russia, such software products as Autodesk NavisWorks and Bentley Navigator, which, however, is limited in functionality. The main issue is to check for collisions. Russian software has no similar tools, and this is a significant problem, because the adaptation of the above examples to the Russian regulations and standards needs expenses of time and money.

The tool for performing the rule check for the BIM model can be implemented in the form of platforms of various types, such as:
- an application, built into the design tool, for example, a plug-in;
- a stand-alone application that works in parallel with the design tool;
- a web application that allows you to download projects from different sources.

Each of these platforms is applicable for certain purposes. Currently, trends are more concentrated in the field of web versions of such programs.

The validation of the information model can be in general represented as the following algorithm (fig.2):
1. Interpretation of the rules described in the regulatory documents (codes or standards) and logical structuring of rules.

Rules written in natural language in legal documents, in its original form are not suitable for implementation in verification system. It is needed to be formalized as a rule to present them in the form of logical expressions.

Formalized rules are translated into the one of the possible programming languages of rules. An example of such a language can be Prolog.

The language Prolog is concentrated around a small set of basic functions such as pattern matching, tree view structures of data and automatic backtracking. Well-suited for solving tasks dealing with objects and relations between them.

2. Preparation of C-BIM model, which presents necessary information to execute validation rules.

Verification system software usually work with IFC model. IFC is a universal format in the field of information modeling.

IFC was developed by International Alliance for Interoperability, which in 2005 was renamed to buildingSMART to improve the unifying international importance. IFC was created to facilitate communication in the construction industry. It allows to work with the same model in different applications and at all stages of the life cycle of a building or structure.

Usually, the initial object model contains not all information required for verification purposes, if, for example, this information is calculated. In this case, there are two options for providing this information available:

- to present requirements to the designer with accent to the specify information necessary to perform audits;
- to create automatically additional views of the model.

Based on the original IFC model can be generated, if required, additional views from for extraction the information necessary to test, but not presented in the main model.

3. Process of verification of the C-BIM model.

The verification phase combines the prepared model of the building with the rules applicable to it.

Before the immediate execution of the rule, a preliminary verification of the model is required for the presence in it of the information that will be used for verification.

In the absence of any information in the existing model, it may be necessary to generate an additional representation, which will be used for verification.

The received view will be checked before the main check to see if the necessary data was generated in it to avoid errors at the stage of the rule execution.

An additional complication is the management of the received representations of the original model in case when each of them is generated for a separate group of rules and contains changes, based on the results of the performed verification. That is why it is necessary to create methods for ensuring the consistency of the model, which would combine all the received representations with changes to the integrated project.

4. Generating a report upon the results.

The last stage of the test cycle is very important. The results obtained in the process of verification of the C-BIM model should be presented to the professionals in a convenient form for research to find different options for changing detected errors.

It is worth noting also the importance of indicating in the results of the verification the reference to the source of the rule - the regulatory document or standards or codes.

The four verification steps of the BIM model presented are universal and are currently found in all existing systems for checking the rules and the work describing them.

3. Peculiar properties of C-BIM model (at the construction stage)

To understand what checks are necessary for the BIM model during the construction phase, firstly it is necessary to determine what information the model contains at this stage of the lifecycle.
Upon completion of the design phase (D-BIM model), the customer receives a model that has passed the expertise and was approved by officials, which is the basis for the construction. One of the necessary design results is the construction organization project (COP). The construction organization project is the documentation which reflect the issues of optimal organization decisions of the entire complex of the given construction site.

However, as a rule, before the start of construction, the COP is undergoing some changes, such as:

1. Complex elements are decomposed into structure components, for erection.
2. Temporary structures and devices for assembling add to the project.
3. Some construction equipment is added.
4. Determine for all elements the stage of erection.
5. Define the capture.
6. Adding element-wise pricing.
7. Elements are completed with logistic information.

During the construction stage, C-BIM model is required for:

- Adopting specific design decisions and planning work on the construction site;
- Creation of high-quality executive documentation;
- Calculation estimates and monitoring the compliance of performed volumes with them;
- ordering and manufacturing of materials and equipment;
- management of building construction processes;
- facility management and operation of the building, technical equipment during the work on the construction site;
- other objectives related to a particular object / project.

The information model of a building today is a specially organized and structured set of data from one or more files that allows both graphical and any other numeric representation, suitable for subsequent use by various software tools for designing, calculating and analyzing the building and all its constituent parts, components and systems.

Obviously, that tasks that BIM-model allow to accomplish on the enlarged stages of the life cycle (preproject, design, construction, operation, demolition) are different, and this determines the essential differences in the requirements for the structure and the filling of the information model. The situation is even more complicated when in some cases complex projects can be designed, built and operated almost simultaneously.

Thus, at each stage of the building's life cycle, its information model obtained from the previous stage is modified and supplemented taking into account the specifics of the new activity, and the process of information modeling continues.

4. Verification of the C-BIM model
The main purpose of construction is the erection of an object, that is, a consistent increase in its volume. Therefore, the main purpose of BIM technology at this stage of the life cycle of a building or structure is the planning and organization of this process.

4.1. Problems when testing the model.
It is possible to check the validity of the model in several ways: to compare the results obtained during the simulations with real observed data.

Creating the BIM model, you can begin to investigate its behavior under different combinations of influencing factors. For this need it is necessary to find out what kind of and how many combinations of factors you need to take to solve the problem.

In real conditions at each point of time can be interact many factors. If we set aside invalid and improbable collision and combinations of factors, the complexity and validation time reduces. But sometimes it is necessary to approximate the model to real conditions. If you don't consider important combinations of factors, that is, the risk of getting distorted results and do not solve the problem.
Another problem is to assess the accuracy and reliability of the results. For example, how to evaluate the validity and accuracy of the findings when assessing execution of taken specialized operation.

4.2. Reliability analysis of solutions during verification

In General, the task is formulated so: during the creation of C-BIM model it is estimated dependence parameter (e.g., deadline) of the test object from the influencing factors.

Let the value of the parameter for a given combination of factors will be called the response. By predicting results formed the hypothesis about the influence of the factors, allowing to predict the response for each combination of factors.

Let \( n \) be the number of forecasts, \( x \) is a number of factors, \( R_i \) is the response on the \( i \)-th forecast, \( V_i \) – evaluation of response influencing factors for the \( i \)-th forecast, \( V_m \) is the mean value of the response.

The diversity of response values is determined by a variety of numbers, caused by the influence of factors or variety of numbers, not associated with the selected factors.

Complete dispersion (the variance) of response \( D_{\text{result}} \) can be shown as the sum of the factor variance \( D_{\text{factor}} \) during diversity of response assessments and residual dispersion \( D_{\text{residue}} \):

\[
D_{\text{result}} = \sum_{i=1}^{n} (R_i - V_m)^2 = \sum_{i=1}^{n} (V_i - V_m)^2 + \sum_{i=1}^{n} (R_i - V_i)^2 = D_{\text{factor}} + D_{\text{residue}} \quad (1)
\]

The higher proportion of the explained dispersion, the more reliable the behavior of the object.

It is important to note that the more factors are taken into account in the model, the more possible to obtain the explained dispersion, but the effect of each factor is evaluated statistically. The more factors you need to take into account, the less accurate is the assessment of the influence of each factor.

The perfect model of an object at the construction stage is a compromise, in which with a small number of factors can explain most of the changes in the object.

Factors can be external and internal. These are the parameters of the object state and its components, as well as the relationship between these parameters.

4.3. The task to control the compliance of the object with the specified design parameters.

It is possible to allocate following basic directions that need to be monitored using the C-BIM model:

1. Control of construction time, i.e. the correlation of the actual state of the object with the projected time results of construction (accordance the executed amounts of works with regulatory/estimated deadlines).
2. Monitoring the expenditure of funds, that is, the correlation of the actual costs of construction with the planned costs for each type of work in the specific or the object operation.
3. Control of materials delivery (volume, timing, location in the warehouse).

The implementation of the described control action is to not perform visually but automatically, using the appropriate software or plugin validation.

Use the earlier shown algorithm for checking rules and update each of the stages in relation to inspections at the stage of construction (Fig. 3)
At first, interpretation of the rules, described in the regulatory documents (codes) and logical structuring of them. The basic rule in this case would be the actual results with the reference design model. When they mismatch, you need to determine the difference in time or cost.

Secondly, creation of C-BIM model, which presents necessary information to execute validation rules. Preparatory activities will be: definition of the last process steps, the definition of all the elements present in the model, the calculation of the cost of these items. The obtained data will be used to perform the comparison. Then the process of validation rules is generating.

Within the report in addition to the identified deviations should be reflected suggestions for corrective actions – changing the schedule or budget.

5. Conclusion
The availability of a model verification tool at the construction stage for the customer is a powerful management tool that will allow solve collisions and find decisions that affect the further course of construction and its successful completion. Creating Pre-BIM, D-BIM, C-BIM, E-BIM, Re-BIM models, you can create operation description of system data and analyse the reality of upcoming improvements, changes, range of the necessary expenses of all types of resources, as well as the most well-coordinated work of the subsystems

Acknowledgments
This work was financially supported by Ministry of Education and Science of the Russian Federation (#NSh-3492.2018.8).

References
[1] Ginzburg A 2016 Information model of the construction project lifecycle Industrial and civil construction 9 61
[2] Ginzburg A 2016 BIM technology throughout the life cycle of construction object Information resources of Russia 5 28
[3] Eastman C, Lee J-M, Jeong Y-S and Lee J-K 2009 Automatic rule-based checking of building designs Automation in Construction 18 1011
[4] Porwal A and Hewage K N 2013 Building Information Modeling (BIM) partnering framework for public construction projects Automation in Construction 31 204
[5] Ciribini A L C, Mastrolembo Ventura S and Paneroni M 2016 Implementation of an interoperable process to optimise design and construction phases of a residential building: A BIM Pilot Project Automation in Construction 71 62
[6] Kerrigan S and Law K 2003 Logic-based regulation compliance-assistance Proc. of the Ninth Int. Conf. on Artificial Intelligence and Law (ICAIL 2003) (Edinburgh, Scotland, UK)
[7] Makisha N 2016 Procedia Eng. 165 1087-91
[8] Makisha N and Gogina E 2017 E3S Web of Conf. 22 00109
[9] Kuzina O 2016 Components of functional information model of city environment reorganization in interactive mode Matec web of conf. 07013
[10] Volkov A and Kuzina O 2016 Complementary assets in the methodology of implementation unified information model of the city environment project life cycle Procedia eng. 153 838
[11] Galkina E 2017 Prospects for the use of information model verification systems in Russia Science review 21 155
[12] Galkina E 2017 BIM prospects in spatial planning Science review 8 131