

PAPER • OPEN ACCESS

## Automation identification of construction work and structural elements in BIM development

To cite this article: I A Tyurin 2020 *IOP Conf. Ser.: Mater. Sci. Eng.* **913** 042010

View the [article online](#) for updates and enhancements.

You may also like

- [Implementation of Building Information Modeling \(BIM\) in Sarawak Construction Industry: A Review](#)  
N Zaini, A Ahmad Zaini, S D Tamjehi et al.
- [Increasing the economic efficiency of design and construction solutions due to the automated identification of construction works and structural elements of information models](#)  
I A Tyurin and A V Ginzburg
- [Automated assessment of information models for compliance with "green" standards](#)  
Elena Makisha and Angelina Rybakova



**ECS**  
The  
Electrochemical  
Society  
Advancing solid state &  
electrochemical science & technology

**DISCOVER**  
how sustainability  
intersects with  
electrochemistry & solid  
state science research

# Automation identification of construction work and structural elements in BIM development

**I A Tyurin**

National Research Moscow State University of Civil Engineering, 26, Yaroslavskoe highway, Moscow, 129337, Russia

E-mail: TyurinIA@mgsu.ru

**Abstract.** With the massive transition of construction projects to information modeling, the question of the design work automation arises. For decades, design engineers together with design automation engineers, have improved the two-dimensional drawing system, automating all possible routine operations, but with the widespread introduction of information modeling technologies, most of the developments in the field of automation cease to be relevant. The main objective of the study is to determine the priority tasks of design automation using the information modeling technologies. As a result of the study, the automation tasks were identified and a methodology for solving them at the design stage using the information modeling technologies, was proposed. The research results described in the article allow the identification of construction work and structural elements, increase the information model elements' detail level and perform the resource calculations in an automated mode.

## Introduction

The first successful results of design automation were obtained in the distant 70s of the last century. At that time, automated drafting systems were used, and taking into account the fact that the computer equipment of that time had significant dimensions with rather primitive computing capabilities, the acquisition and use of such devices was carried out only in research and production associations or the country's leading design organizations.

Computer-aided design systems in construction (CADS) actively developed and found widespread use when computer technology became quite compact, affordable and used everywhere. At this time, AutoCAD (Autodesk developer) and ArhiCAD (Graphisoft developer) became the mass design products.

The AutoCAD software product replaced the traditional drawing, and was an "electronic" panel board with primitive automation tools (calculating sizes, areas, generating callouts). CADS development in the AutoCAD environment was carried out by developing such ready-made blocks of two-dimensional images as: axes, rolling profiles, normative tables. Catalogs of all possible elements repeating from project to project were massively developed. Further CADS two-dimensional drawing development, affecting the area of the variable part of the drawings, and software (SW) was developed for each section of the project, and in some cases for a specific project.

ArchiCAD software product, already at that time, was implemented as a design system using information modeling technologies (IMT). Design was carried out using such elements as "wall", "ceiling", "roof". It was also possible to load the element databases containing information about the



Content from this work may be used under the terms of the [Creative Commons Attribution 3.0 licence](https://creativecommons.org/licenses/by/3.0/). Any further distribution of this work must maintain attribution to the author(s) and the title of the work, journal citation and DOI.

material, weight, components, and so on. The use of such element bases significantly accelerated the work of architectural design engineers.

In April 2000, the first release of Autodesk Revit software (version 1.0), an analog of ArchiCAD, but with more IMT features, was released. It could be used for all the areas of construction design, starting from the engineering preparation of the territory and ending with the project estimates.

Despite the IMT powerful design tools available 20 years ago, still the vast majority of engineers prefer to use “electronic” panel boards. This is due to several factors, the main of which are: IMT regular support, educational program of training and readiness of practicing specialists for retraining. For example, the state program for the construction industry digitalization started in 2018, and since 2019 the state bodies of examination started accepting the information models (IM) for verification, created using IMT.

It is also worth noting the following factors that impede the widespread transition to the implementation of design work using IMT: IMT incompatibility with developed by the CADs for planar (two-dimensional) drawing, lack of data transmission formats integration CADs IMT among themselves, even when using the specially developed IFC standard described by the standard ISO 16739-1:2018 “Industry Foundation Classes (IFC) for data sharing in the construction and facility management industries - Part 1: Data schema”.

### **Formulation of the problem**

For the formulation and solution of the project activities automation tasks, it is necessary to consider the legal support of the project documentation development processes. The main regulatory documents in this area are the Government Decree No. 87 “On the composition of sections of project documentation and requirements for their content” [1] (GD №87) and BC 333.1325800.2017 “Information modeling in construction. Rules for the formation of an information model of objects at various stages of the life cycle” [2] (BC IMT). GD №87 establishes the requirements for the project documentation composition for submission to the examination of project documentation, and BC IMT sets the IM content requirements.

As a result of the GD №87 and BC IMT analysis two design systems can be distinguished, traditional - design using “electronic” pockets, and modern - design using IMT. Recently, more and more works are devoted to IMT development [3-11], rather than improving the traditional design approach.

In a traditional design system - the ultimate goal GD №87 is defined, that is, design engineers, knowing the finite number of drawings required, in the design process do the job of filling them with two-dimensional information.

In a modern design system, BC IMT sets the goal, and this is IM containing the elements with the (LOD) LOD 300 development level (IM elements presented in the form of an object or assembly, with exact fixed dimensions, shape, exact spatial position, orientation and necessary attribute information). But in modern realities, BC IMT existence does not cancel the obligation to apply GD №87, that is, organizing the design processes using IMT, as a result anyway in addition to IM, it is necessary to form a set of project documentation in accordance with GD №87, which in turn sometimes puts the design institutes using IMT, in an unfavorable position.

This issue is resolved by applying CADs aimed at generating a set of project documentation using IM data, which at the moment have reached a high level of development and considering them in this article does not seem advisable.

Returning to the modern design system study using IMT, as a result of studying BC IMT, we can conclude that the process of modeling a capital construction object is reduced to a phased transition from LOD 0 to LOD 400+. According to BC IMT, at the “project documentation” stage IM should contain the elements with a level of development LOD 300. Also, BC IMT regulates the list of information (features) that should be assigned to the IM elements. Based on this, it can be concluded that the design process using information technology is the process of transition from the lowest to a given level of detail (LOD) of elements IM. As a result, it is possible to establish the task of

automating the modern design process using IMT – it is the detailing elements IM automation from the current to the set level.

The problem is solved by using the databases containing elements or information about the elements of the simulated building. For example, to design a sanitary point, it is enough for the designer to find in the pre-installed base of elements, the corresponding sanitary point, which, in addition to the sink geometry, contains the information about the fastening details, the type of hydro seal, and installing it in the appropriate place in IM, rather than redrawing and assigning the identification features as new each time.

The situation is different with the supporting structures and other variable elements of the designed object, for example, when designing a concrete base, in IM data on waterproofing, anchors, main and related reinforcing products should be entered. The options for these features' application are so great that when combined, the designed element can be represented by an infinite number of options, which in turn makes it impossible to create the databases of such elements.

When setting the tasks for the design processes' automation using IMT, it is advisable to consider the situations when IM information on the geometric characteristics of the elements is entered in manual mode IM and the attributes are assigned for further identification by machine or human means.

For the machine identification, the main feature is the classifier code used, which is used in the classic Boolean search model [12]. That is, in automatic mode, it is possible to search for a given code in a specific information base and such requested properties are returned to the model, as: element weight, type of material, thermal conductivity, and so on. This method is usually used to generate various specifications - volumes of materials, air exchange tables, etc.

To identify IM items by a person, for example, when drawing up the budget estimates by an estimate engineer, as a rule, it is not always possible to use the classifier codes that he assigned to the IM elements, this is due to the use of various information databases, and for the individual structural elements of the simulated object, as described earlier, such codes cannot be in connection with the infinitely large variability of design decisions.

Among software IMT for automated identification of construction work and structural elements, the following are most often used in Russia [13]:

“Hector: 5D Estimate” (developed by Ltd “Scientific and Technical Center “Hector”);

“ABC-4” (developer of Scientific-Production Enterprise “ABC-N” LLC);

“Estimo.Connect” (Aibim Developer);

“ITWO 4.0” (developer “RIB”).

SW specified work is carried out in addition to SW development IM, in the so-called “re-composers”, in which the construction work and structural elements' identification is carried out with the subsequent return to IM estimated properties of the elements under consideration. Algorithm for the construction work and structural elements' identification of these SW implemented on the classic Boolean search model. At the slightest deviation from the Boolean search model, the direct participation of the decision maker is required (DM).

Returning estimated properties does not increase the detail level of IM elements, since to obtain the estimated calculations it is necessary to transfer the specified estimated properties to an additional SW for performing the estimated calculations, that is, the properties assigned to the elements are not supported by internal (native) software for unloading volumes, for example, it is not functional in conjunction with Autodesk Revit Material Takeoff. As a result of the study of existing solutions for the automated construction works and structural elements' identification, we can conclude that the currently available developments are the complex that do not meet all the tasks of design automation when using IMT and do not have a sufficient level of practicality for mass implementation.

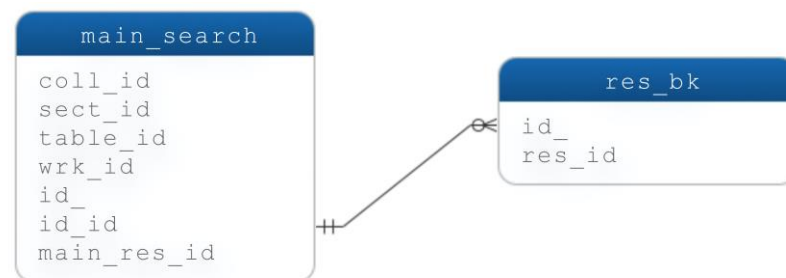
Summing up the study of modern design tools, the task of their automation comes down to finding the solutions to automate the identification process elements IM, both for the construction work and the structural elements of the construction site.

## Methods and techniques

To solve the problem of the construction works and structural elements' identification, it is proposed to carry out a search using fuzzy logic and the subsequent return of the estimated properties, detail properties of IM elements and a list of resources necessary for the construction works' implementation.

The search using suffix array [14-15] is based on textual data, as a result of which an array of conditionally suitable features is created for the IM element in question. The search itself is carried out by forming an array of suffixes from the known text data of the IM element (class name, material, labeling, description) with intermediate fragmentation [16], subject to zero errors. As an example, the identification of a structural element was carried out - an external brick wall 380 mm thick, with an array of suffixes: walls, brick, wall, 380, external, without facing.

The state elemental estimated norms for construction and special construction work were used as a search database [17] (State elemental estimated norms for construction work (SEEN) compilations). State elemental estimated norms for construction work collections were converted using the basic operations of relational algebra [18] to the database with the following structure:



**Figure 1.** Structure of the developed DB

The database is based on the main search table containing the generated rows for searching.

- coll\_id – collection title SEEN;
- sect\_id – section title SEEN;
- table\_id – table name SEEN;
- wrk\_id – list of works;
- id\_ – SEEN code;
- id\_id – table column name SEEN;
- main\_res\_id – main resource name;
- res\_bk – return table in IM data;
- res\_id – list of support resources.

For example, for the masonry exterior brick walls, the search bar is as follows:

- coll\_id – “Structures made of bricks and blocks”;
- sect\_id – “Brick and stone structures”;
- table\_id – “Masonry walls made of bricks”;
- wrk\_id – “Masonry of brick structures. Installation of niches for heating, ventilation and smoke ducts with grooves for grooves, sedimentary and temperature joints, architectural and structural details”;
- id\_ – “08-02-001-01”;
- id\_id – “Masonry walls of brick exterior simple with a floor height of up to 4 m”;
- main\_res\_id – “Brick ceramic, silicate or hollow”.

As a result of the search, proposals were formed in a relevant order for the DM selection pattern “d\_id **from** main\_res\_id”:

- masonry walls of brick exterior simple with a floor height of up to 4 m **made of** ceramic, silicate or hollow brick;

- masonry walls of brick exterior simple at a height of over 4 m **made of** ceramic, silicate or hollow brick;
- masonry walls of brick exterior of medium complexity with a floor height of up to 4 m **made of** ceramic, silicate or hollow brick;
- and so on.

Upon confirmation DM a particular type of work comes back in IM (assignment of characteristics to the IM elements) estimated characteristics from the res\_bk table in the form of a cipher (id\_) and a list of resources (res\_id) from the database with the help of which the identification is carried out. The assigned new characteristics can be used to perform the resource calculations, draw up the calendar plans, both for the entire object and for its individual elements, when calculating the purchases volume, and so on.

A feature of the SEEN collections use, is expressed in the volumes return of the materials necessary for the design structures' manufacture taking into account difficult to eliminate losses and waste, for example, for a device of 100 m<sup>3</sup> of concrete preparation, 102 m<sup>3</sup> of concrete is required. That is, in fact, the volumes of materials calculated by the design engineer and the construction engineer are different from each other, since the design engineer calculates the volumes of finished structures, and the construction engineer calculates the volume of the materials needed to make the structure. This is a very important point that is often overlooked when calculating the construction cost using the "quantity take off" or "bill of quantities" system.

The elements were filled with specified properties by searching the main\_search table in the confirmed rows DM. To set the search criteria the "Appendix A" BC IMT was used for the detail levels LOD 100 - LOD 300, for example for a "wall" these are the types, conditional dimension (LOD 100), exact dimension, position, room boundary (LOD 200), external image / appearance, construction, material, slopes, marking, fire resistance. As a result of the search, the following results were obtained:

- construction - "laying of brick structures. Installation of niches for heating, ventilation and smoke ducts with grooves for grooves, sedimentary and temperature joints, architectural and structural details";
- material - "ceramic, silicate or hollow brick";
- according to other criteria - "null".

To further fill the information model, the building resources classifier (BRC) was used. [19] The suffixes array for BRC search is formed by decomposition main\_res\_id from the lines confirmed by DM. As a result of identification using BRC, for the IM items with main\_res\_id assigned in general form (e.g. "concrete"), the corresponding building material was selected (eg "concrete mixes of heavy concrete (CMH), the class B25 M350").

Further IM filling was carried out by seeking the regulatory compliance. An array of search suffixes was similarly formed by decomposing main\_res\_id from the lines confirmed by DM or from the materials selected by BRC. The search base was the base of state standards (GOST) for building materials. Therefore, the IM elements' signs of regulatory compliance were returned, for example, for "concrete mixes of heavy concrete (CMH), class B25 M350" was obtained according to GOST 26633-2015 Heavy and fine-grained concrete. Technical conditions.

## Summary

As a result of the study, the main task of design automation using information modeling technologies at the current development level was formulated: it is necessary to search for the solutions to automate the process of identifying IM elements, as the construction work and structural elements of the construction site. The solution of the automation task will allow to provide the information models elements with a higher level of detail and assign their additional properties (estimated features, regulatory compliance, etc.).

To solve this problem, a technique for the IM construction work and structural elements' identification, was proposed by forming an array of suffixes from the known text data of the IM

element (family name, material, labeling, description) with intermediate fragmentation, provided that the number of errors tends to zero. To verify the proposed methodology, as an example, the identification of the structural element was carried out - an external brick wall with a thickness of 380 mm.

As a result of checking the methodology, the element under study was identified in an automated mode, automated assignment of estimated properties was performed, automated selection of the appropriate type of material was performed, the level of the information model detail element was partially increased.

The proposed method has several advantages over the existing CADs IMT and has a high development potential. For the full-fledged widespread introduction of the proposed methodology, it is necessary to refine the existing classifiers of building information, in terms of those returned to IM signs.

## References

- [1] Government Decree of the Russian Federation of 16.02.2008 N 87 (as amended on 04/28/2020) "On the composition of sections of project documentation and requirements for their content".
- [2] BC 333.1325800.2017 Information modeling in construction. Rules for the formation of an information model of objects at various stages of the life cycle 2018 (Standartinform).
- [3] Kagan P 2018 Monitoring of the development of urban areas with the use of information technology *MATEC Web of Conferences* **193** 05031.
- [4] Braun A. and Borrmann A. 2019 Combining inverse photogrammetry and BIM for automated labeling of construction site images for machine learning *Automation in Construction* **106** 102879.
- [5] Heaton J, Parlikad A K and Schooling J 2019 Design and development of BIM models to support operations and maintenance *Computers in industry* **111** 172-186.
- [6] Cavalliere C, Dell'Oso G R, Favia F and Lovicario M 2019 BIM-based assessment metrics for the functional flexibility of building designs *Automation in Construction* **107** 102925
- [7] Chan D W M, Olawumi T O, Ho A M L 2019 Critical success factors for building information modelling (BIM) implementation in Hong Kong *Engineering, Construction and Architectural Management* **26(9)** 1838-1854.
- [8] Baik A 2017 From point cloud to Jeddah Heritage BIM Nasif Historical House – case study *Digital Applications in Archaeology and Cultural Heritage* **4** 1-18.
- [9] Tango P, Huber D, Akinci B, Lipman R and Lytle A 2010 Automatic reconstruction of as-built building information models from laser-scanned point clouds: A review of related techniques *Automation in construction* **19** 829-843.
- [10] Barazzetti L, Banfi F, Brumana R, Gusmeroli G, Previtali M and Schiantarelli 2015 Cloud-to-BIM-to-FEM: Structural simulation with accurate historic BIM from laser scans *Simulation Modelling Practice and Theory* **57** 71-87.
- [11] Pilyay, A., Shilova, L. 2018 The use of normative basis for the construction cost for introduction of 5D BIM in Russia *IOP Conference Series: Materials Science and Engineering* **365(6)** 062009.
- [12] Sharapov R V, Sharapova E V, Merkulova T E 2008 Some questions of using the extended Boolean search model *Bulletin of Kherson National Technical University, Kherson: KhNTU* **2 (31)** 504-508.
- [13] Davydov N S, Pridvishkin S V, Belkevich A V 2018 Automation systems for the production of budget documentation for the BIM model *Materials of the Twelfth Conference with International Participation "New Information Technologies in the Study of Complex Structures"* 55-56.
- [14] Takaoka T 1994 Approximate pattern matching with samples *Proc. 5th Int'l. Symp. on algorithms and Computation* **834** 234-242.

- [15] Gonnet G, Baeza-Yates R, Snider T 1992 Information Retrieval: Data Structures and Algorithms *Prentice-Hall* 66-82.
- [16] Muthukrishnan S and Sahinalp C 2000 Approximate nearest neighbors and sequence comparisons with block operations *In Proc.of ACM Symposium on Theory of Computing* 416-422.
- [17] State elemental estimated norms for construction and special construction works, approved by order of the Ministry of Construction and Housing and Communal Services of the Russian Federation of December 30, 2016 M 1038 / pr (On approval of estimated standards).
- [18] Miroshnichenko G 2015 Relational databases: Practical methods of optimal solutions (Publishing house BHV, M.).
- [19] Classifier of building resources approved. By order of the Ministry of Construction of Russia from 02.03.2017 N 597