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Article

BIM for Construction Clash Detection Process after Design stage

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Abstract. The construction industry is one of the most unpredictable and human-dependent sectors of production. This is due to the large flow of information during construction, which requires clear organizational activities. Traditionally established methods of communication on construction sites require modernization. That is why the concept for practitioners "Building Description System and Construction Product Modeling" was developed in 1970. The building society supported this concept and called it "Building Information Modeling" - BIM. The new wave of digital design required a strong material and technical base, the analysis of existing documentation and the creation of design tools began. The authors of the article use the highly specialized NavisWorks software to analyze possible losses as a result of combining the existing design documentation into BIM models on the example of one of the Nur-Sultan projects. The residential complex located in Nur-Sultan was chosen as case study. The residential apartment building was chosen because of the scale of the project and its full implementation in the BIM system. The article makes a comparative analysis on finding the intersections on the principle of combinatorics. The section of structural and space-planning solutions is checked for intersections with the sections of heating and ventilation, water supply and sewerage, then the logic is repeated. Exceptional combinations are selected to check for conflicts (collisions).
Keywords: BIM, NavisWorks, 3D, Management, Clash Detection, Collision.

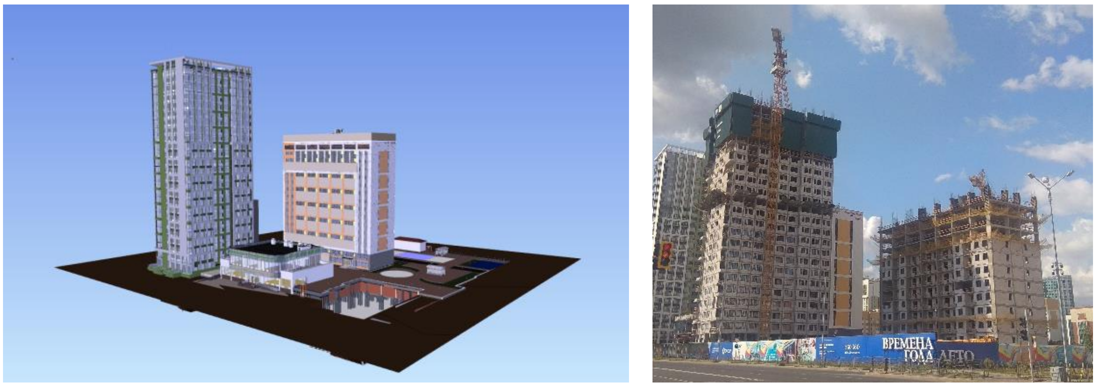
1. Introduction

The construction industry is one of the most unpredictable and human-dependent sectors of production. This is due to the large flow of information during construction, which requires clear organizational activities. Traditionally established methods of communication on construction sites require modernization. Because maintaining a paper-based document flow can lead to errors, which can result in unforeseen costs for the project, which will affect the quality of construction, as well as the overall profit of the company [1]. For this purpose, various digitalization tools are being implemented. One of the latest innovations in this direction is BIM technology. The advantage of the introduction and use of BIM technology is an increase in productivity from the development and design stage to the operation and complete destruction of the building [2].

The first practical guide in this direction is [3], where Charles M. Eastman conducts his early research in the field of information design. This led to the development of a concept for practitioners "Building Description System and Building Product Modeling" in 1970. The building society supported this vision of the author, which contributed to the renaming of the concept into the generally accepted term "Building Information Modeling" - BIM [3]. The new wave of digital design required a strong material and technical base, the analysis of existing documentation and the creation of design tools began. All this leads to the creation of the first two- and three-dimensional computer-aided design and drafting systems. So, the first version of AutoCAD software by Autodesk is released 12 years after the publication of the early studies described in [3]. Further review of the effectiveness of BIM technology is comprehensively considered in [4]. Much attention is paid to the existing literature in order to determine the current status of the development and implementation of BIM. The interviews with key experts in this area are noted separately. The points related to future opportunities, resource needs, existing barriers and general potential of user interest are touched upon [4]. It is worth noting that the development of the functionality of the tools allowed some of them to become separate software, thereby determining the specifics of the work. For example, the emergence of highly specialized software, such as NavisWorks, 3ds Max Design, Civil 3D and others, are widely used in the architectural and construction industry, both in combination and separately. The use of BIM technology in, speaks not only about the technical possibilities but also about the methodology of their use, as another positive side is the interaction with generally accepted standards, which should be adhered to [5]. The virtual model reconstructed in this way in BIM, correlates well with the construction documents in terms of determining the preliminary and final scope of work, as evidenced by two case studies [6]. Based on the above, it can be assumed that the relevance of the implementation of project analysis is significant not only for developed countries, but also for developing countries [7,8]. Thus, the authors of this article made a comparative analysis of possible losses received as a result of combining the finished design documentation in BIM models on the example of one of the projects released in Nur-Sultan.

2. Methods

The residential complex located in the city of Nur-Sultan was chosen as the object under study. The residential multi-storey building was chosen because of the scale of the project and its full implementation in the BIM system (Figure 1).



a) BIM model b) Construction area

Figure 1 – Residential complex in Nur-Sultan

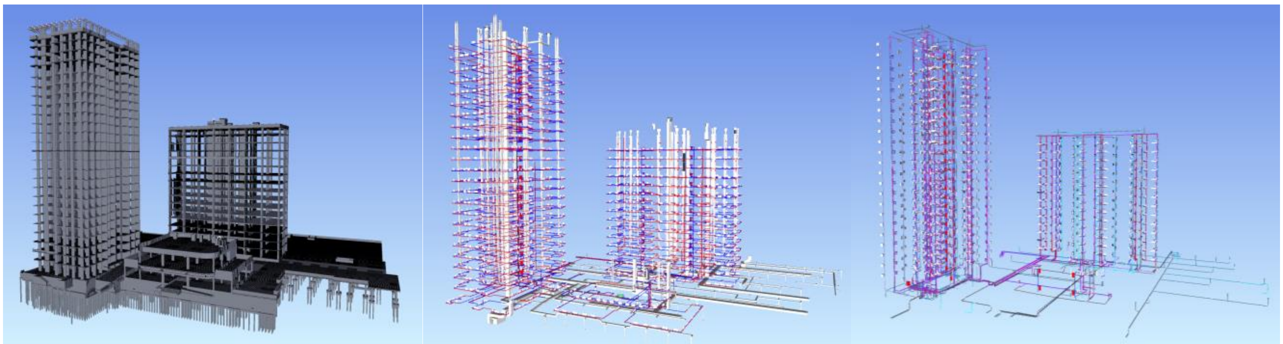
Digital analysis requires powerful software and when choosing a personal computer, it is worth paying attention to the system requirements (Table 1), because the speed of data processing directly affects the speed of decision-making, which is an important factor for the successful completion of the project [9,10].

Table 1 – Single Installation Requirements for NavisWorks

№	Requirements	Descriptions
1	Operating System	Microsoft® Windows® 10 (64-bit) on the Semi-Annual Channel servicing option. See Autodesk's Product Support Lifecycle for support information.
2	CPU	3.0 GHz or faster processor
3	RAM	2 GB RAM or more
4	Disk Space	15 GB free disk space or more
5	Graphics	Direct3D 9® and OpenGL® capable graphics card with Shader Model 2 (minimum)
6	Display	1280 x 800 VGA display with true color (1920 x 1080 monitor and 32-bit video display adapter recommended)
7	Pointing Device	Microsoft Mouse-compliant pointing device
8	Browser	Microsoft Internet Explorer 11, Google Chrom etc.

A key analysis tool is NavisWorks Manage software from the company's AutoCAD family of assembly investigation and verification software. The built-in tools for publishing reports make it possible to open collision objects in the source application.

It is generally accepted to analyze the conflicts that appeared when the 3 main sections of the design documentation were combined (Figure 2 a, b, c).



a) CS b) HVAC c) WSS

Figure 2 – Sections of the design documentation

For this purpose, a comparative analysis for finding intersections on the principle of combinatorics. That is, one section is compared with others and vice versa, for example, the section of structural and space-planning solutions (CS) is tested for intersections with the sections of heating and ventilation (HVAC), water supply and sewerage (WSS). Such sections as low-current networks (LPN) or electricity supply (ES) are not taken into account in the analysis of conflicts for the reason that the flexibility of installation allows to avoid moments associated with them. It is also possible to compare the sections with each other, if necessary. Exceptional combinations are selected to perform a conflict (collision) check (Table 2).

Table 2 – Combinations of sections of the project documentation to find a collision

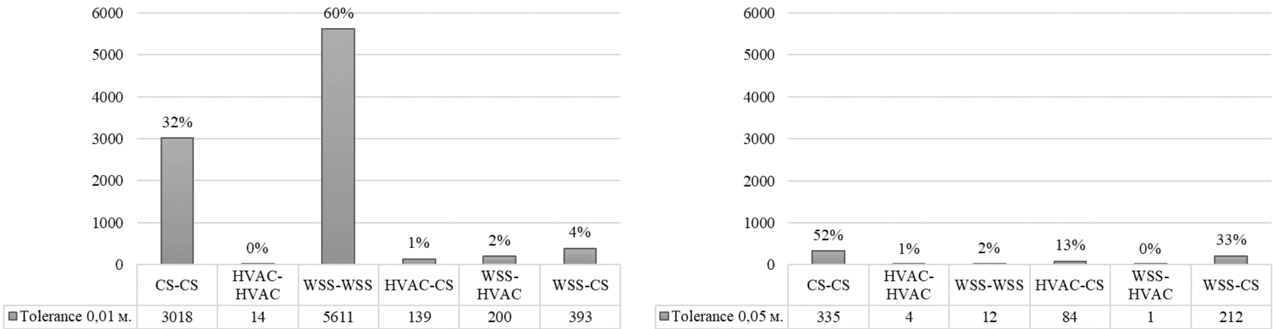
Sections of project documentation	**CS**	**HVAC**	**WSS**
CS	CS-CS	CS-HVAC	CS-WSS
HVAC	HVAC-CS	HVAC-HVAC	HVAC-WSS
WSS	WSS-CS	WSS-HVAC	WSS-WSS

Combinatorial configurations are based on the simplest technique of combining and categorizing the detected collisions: geometric collisions, technological collisions, empty objects and substrates.

In the case of geometrical collisions identify 2 types: detected by a simple visual inspection of the three-dimensional model and based on the rules in the presence of an informative three-dimensional model. Technological collisions relate to system malfunctions that are often encountered in the design of piping systems. The last category of blanks and substrates are of an auxiliary nature and are not used in the analysis. Two values of 0.01 and 0.05 m were used for tolerance, respectively, to check for conflicts in contact surfaces, faces and angles. In general practice, a value of 0.05 m is often accepted [11].

3. Results and Discussion

The analysis of the virtual model revealed the number of conflicts that occurred after merging the three sections of the design documentation into the BIM model. The figures below show the number and percentage of conflicts at different tolerances. A 0.01m tolerance revealed a total of 9,375 and a 0.05m tolerance of 648 conflicts (Figure 3).



a b

Figure 3 – Combinations of the main sections of the design documentation to find conflicts: a) number of conflicts with a tolerance of 0.01 m; b) number of conflicts with a tolerance of 0.05 m

Most of the identified conflicts fit the description in [10], if we take into account a tolerance of 0.01 m. This is justified by the increased requirements for BIM model, which do not take into account the possible changes made in the project on the fact of work, as often the sections are developed and approved by design organizations in parallel, which leads to future deviations.

The conflicts detected when comparing the CS-CS sections relate to intersections due to joints and adjacencies of monolithic concrete structures and do not pose a threat (Figure 4). In such cases, it is often common to ignore conflicts that lie on the same layer. This is done by assigning them a status type, such as active or accepted.

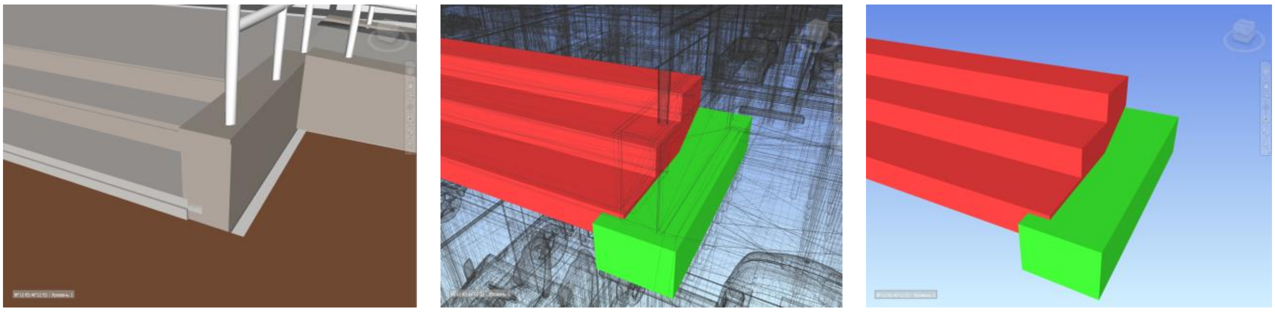


Figure 4 – Example of a conflict when comparing sections of the CS-CS

The HVAC-HVAC section has the fewest conflicts in the two tolerances. This is due to the different heights at which ventilation ducts and heating pipes are installed. Most often, difficulties are encountered with the installation of equipment at the ventilation outlets. This arrangement of several baffles occurs when saving space allocated for the ventilation ducts (Figure 5).

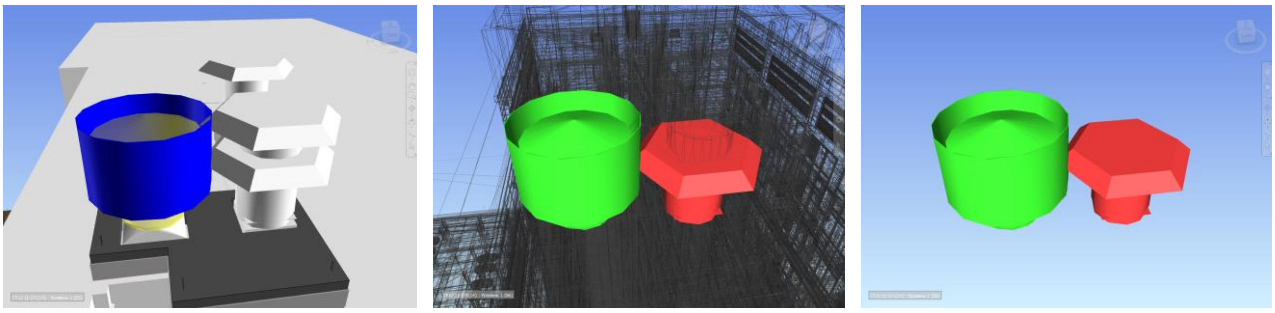


Figure 5 – Conflict when comparing HVAC-HVAC sections

In the section WSS-WSS predominantly conflicts related to the equipment of the toilet, bathroom or other sanitary equipment. The solution of these conflicts is individual in nature, since the use of standard solutions contained in the library, do not take into account the peculiarities of the structure of the equipment and their components (Figure 6).

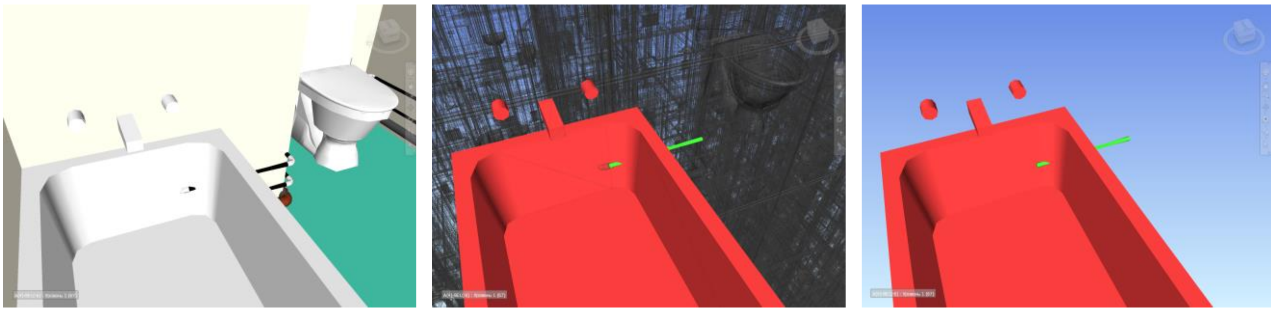


Figure 6 – Conflict when comparing WSS-WSS sections

Conflicts found in the sections HVAC-CS and WSS-CS are associated with the location of technological openings. Due to the use of materials with different dimensions, the difficulty of their marking at an early stage of design is reflected in the fact of construction (Figure 7, 8). As a rule, conflicts of this kind are the most labor-intensive and costly.

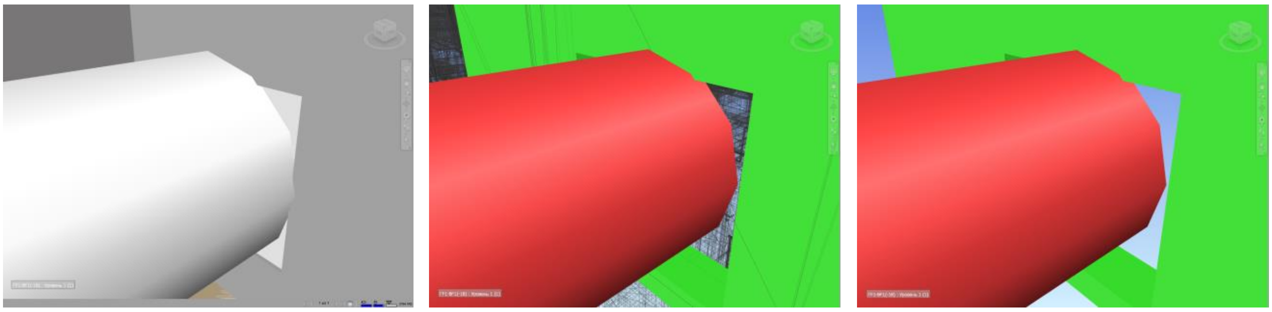


Figure 7 – Conflict when comparing sections of the HVAC-CS

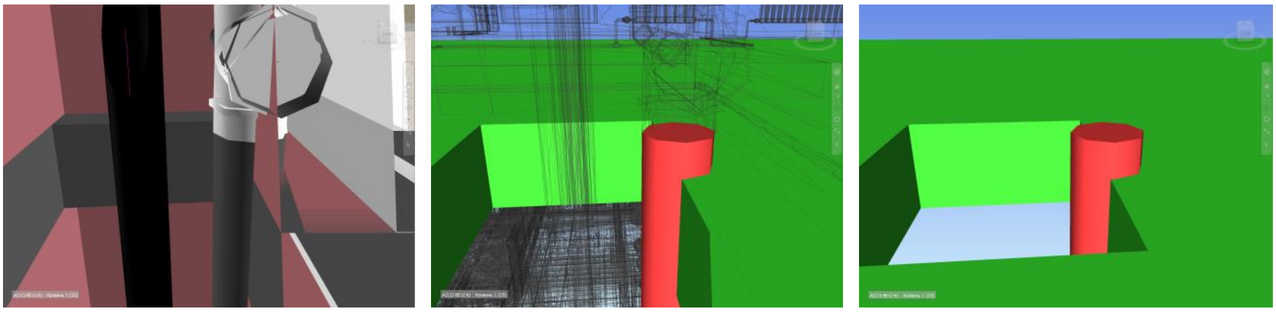


Figure 8 – Conflict when comparing the sections of the WSS-CS

The smallest risks are conflicts related to the WSS-HVAC, because of the ease and convenience of installation of ventilation ducts (Figure 9). In practice, the conflicts of comparison of sections of the WSS-WSS, which were described above, prevail (Figure 6)

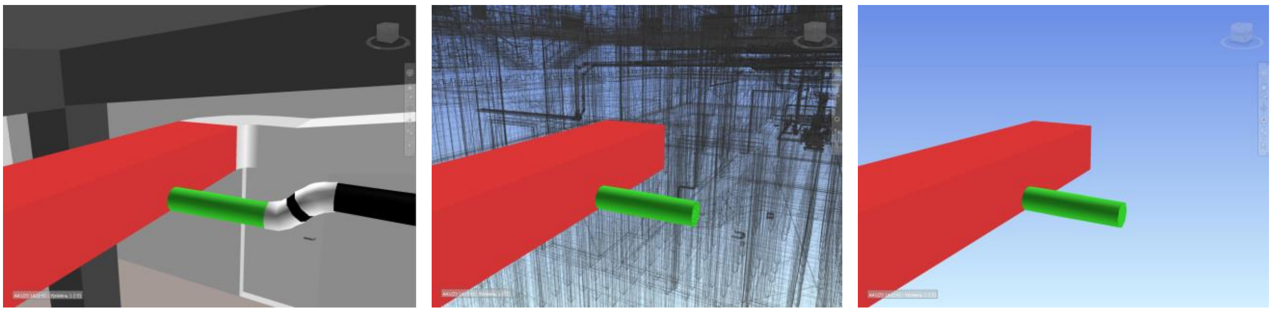


Figure 9 – Conflict when comparing WSS-HVAC sections

4. Conclusions

BIM technologies are part of the digitalization of the construction process. This is confirmed by the growth rate of construction, which requires versatile tools for the control of project documentation. The introduction of such tools helps to detect deviations in the design phase.

The analysis of the residential complex using AutoCAD NavisWorks showed the number of conflicts detected after the design documentation was merged into the virtual model. During the conflict analysis, attention was paid to the tolerance of deviations with respect to various combinations of the main sections of the design documentation. A review was made of some of them. It was noted that the process of finding conflicts is not yet so independent and requires improvement. To avoid possible errors, the virtual model should not be developed in parallel, but one at a time, to warn the designer of the inconsistency in the development of the subsequent section of the design documentation. This methodology will avoid disputes, reduce rework costs and save labor costs.

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