Advantages of using BIM (BIM-technology) for the design and construction of subsoil use industry buildings and structures

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Abstract. The article provides information about the advantages of using information modeling technologies in the design and construction of facilities for subsoil use enterprises. The data on the state of the art of studying the aspects of the application of information modeling technologies in the field of industrial construction are presented. Recommendations for planning methods and the development of information models of buildings and structures of subsoil use objects are presented on base of the study of existing research. The article also provides information on the test information models of subsoil use industrial facilities which are necessary for the development of recommendations for the choice of levels of the attribute information of elements, for the correct and effective use of models at all stages of the object's life cycle.

1. Introduction

The use of information technology in the design of complex technical objects has already proven its effectiveness in terms of the ability to quickly change and update a large amount of data, the ability of visualizing the final result and assessing the performance of an object. A fairly widespread practice of using information modeling in construction has developed in the world at the same time, which is confirmed by the data of some sociological research [1, 3, 5, 6, 7].

Currently in many countries of the world (USA, Great Britain, France, Nordic countries, Singapore, South Korea, China, etc.), information modeling technologies are being actively introduced in construction. The scale of BIM implementation in these countries is explained first of all by the benefits from the use of this technology. These benefits are acquired at various stages of project implementation and at various levels (at the level of an individual enterprise, industry and the state as a whole) [2].

In 2012, in the United States, more than 70% of construction market participants announced the use of information modeling technologies in their projects (data from McGraw Hill Construction), in the UK in 2016 - 54% (according to NBS, National BIM Report). According to the Singapore State Construction Agency (BCA, Building & Construction Authority) more than 80% of all construction projects are carried out exclusively using BIM technologies since 2015 [2].

According to some foreign analysts, the introduction of information modeling technology can provide a significant reduction in construction costs of facilities financed from the state budget - by 25%, as well as a subsequent reduction in operating costs - by more than 35% [2].

At the same time, the use of information technologies in Russia also does not stand still and begins to have wide practice. A significant number of organizations are beginning to use BIM technologies...
for the design of significant infrastructure facilities, as well as for mass civil and industrial construction. There are also some studies related to surveys of practicing specialists about the effectiveness of the application of these methods in construction practice. So, according to the report on the effectiveness of the use of BIM-technologies by Russian organizations, conducted by NRU MGSU together with LLC "KONKURTOR", the use of information technologies leads [2]:

- an increase in the indicator of net present value up to 10%;
- growth of project profitability by 14-15%;
- growth of the internal rate of return from 14 to 20%;
- reduction of the payback period of an investment and construction project by an average of 15-17%.
  - reducing the duration of the design phase up to 30%;
  - reducing the duration of the process of forming working documentation up to 3 times;
  - reduction of the number of collisions up to 100%;
  - reducing the number of requests for additional information and requests for changes on the project;
  - reduction of the terms for calculating the volume of construction work and subsequent adjustment of the estimate calculations by 2-3 times;
  - increasing the accuracy of estimate calculations, reducing the average error in assessing the total cost of the project to 2%.
  - Reducing costs during the construction and operation of the facility up to 30%;
  - growth of labor productivity up to 30%;
  - reduction of administrative costs up to 40%.

Nevertheless it should be mentioned that the use of information technology leads to an increase in the cost of design up to 30% as a result of the use of more expensive software as well as highly qualified specialists in this area. Also, the achievement of these indicators has many limitations associated with the specifics of facilities, as well as the established practice of their design and construction.

In addition it is important to understand that the use of information technology (BIM technologies) is not the usual use of more modern software that involves three-dimensional design. First of all it is a methodology that describes a collaborative way of working to create and use an information model as a digital twin (digital representation of physical and functional characteristics) of a real physical object at all stages of its life cycle. BIM uses three-dimensional models and a common data environment for effective access and exchange of information between all participants in an investment and construction project.

The use of information technologies in the design of subsoil use objects also encounters difficulties associated with the standard specifics of industrial facilities [4]:

- the need for a feasibility study stage;
- the need to develop a feasibility study taking into account the operation of the facility;
- great dependence of design solutions on production technology and purchased equipment;
- significantly greater number of requirements compared to civilian objects (technological, sanitary, ecological, fire-fighting, architectural, construction and etc.);
- availability of a wide range of on-site structures and networks (overpasses, stacks, pipelines, etc.);
- higher role of production technology, technological schemes, as well as the complexity of technological processes, a large number of technological substance (oil, gas, ore and etc.), high cost of equipment.

The use of information technologies in the design, construction and operation of buildings and structures of subsoil use objects should have a number of differences from standard practice related to the specifics of the facilities. And accordingly the determination of these features and the development of recommendations and methods for the effective use of information modelling in this area is an urgent task [4].

To solve this problem, a number of specific objects were considered and the existing practice of developing information models and their features were analysed.
2. Analysis of typical buildings and structures of subsoil use objects and industry
A number of examples were considered, including single horizontal devices or tanks of surface and underground location when analyzing the existing practice of designing subsoil use objects:

- single horizontal devices or tanks of surface and underground location;
- a fleet of vehicles and tanks of surface location;
- small buildings for the location of technological equipment;
- extended structures such as retaining walls.

2.1. Horizontal devices or tanks of surface and underground location
A typical object, implying the location of a single apparatus or tank, is shown in figure 1.

![Digital model of the object represented by a single horizontal tank.](image1)

The presented structure is a combination of numerous technological service sites with a relatively complex fastening system, as well as auxiliary structures for engineering and technological communications and their maintenance. Thus, the structure itself seems to be relatively difficult to design due to the irregular grid of the arrangement of elements as well as due to the need to fasten the load-bearing elements to the technological equipment, an approximate diagram of the fastening of technological service platforms is shown in figure 2.

![An approximate diagram of the fastening of technological service platforms.](image2)
The existing practice of designing such structures is based on the use of an extensive base of typical design solutions, which are repeatedly applied in practice. At the same time, the implementation of such detailed information models seems to be very labour-consuming, as well as a relatively unreasonable exercise, due to the colossal laboriousness of such digital information models, which can serve as sources of working documentation for an object. This fact is a natural barrier to the implementation of the use in practice BIM for such objects. Accordingly, the use of information technologies for numerous industrial structures should be preceded by the maximum digitalization of the bases of typical design solutions with the development of parametric digital information objects which is the most laborious process but will reduce the routine work on the development of models of individual elements and structures. Without this condition, BIM-design of such structures will remain unreasonably expensive in terms of design. Another option for possible use may be a clear regulation of the level of detailing and information of model elements for solving specific production goals. For example, it can be limiting the level of detail of supporting structures to a minimum for ensuring collision checking with large engineering communications and equipment among themselves, as well as the formation of a general construction plan. In this case, working documentation is developed using standard methods taking into account the agreed sketch and composition of the building and structure received in the process of formation of the building information model. That is, information model is used only at the stage of justifying investments and partially in developing project documentation. The negative side of this approach will be the limitation or absence of the possibility of using the information model of the object at other stages of the life cycle - construction, exploitation and deconstruction.

A similar picture can be seen when considering structures such as a park of tanks and apparatus, only the situation with tightness and saturation with various heterogeneous structures and elements is aggravated which leads to an even greater relevance of the BIM for performing competent distribution of engineering communications and preventing collisions. A general view of a digital model of a structure consisting of a group of tanks or apparatuses is shown in figure 3.

![Figure 3](image)

**Figure 3.** General view of a digital model of a structure, consisting of a group of tanks or apparatus.

2.2. *Small buildings for the location of technological*

Similar conclusions can also be drawn when considering small industrial buildings designed to accommodate technological or material handling equipment, the general view of the digital model of which is shown in figure 4.
Figure 4. General view of the digital model of the building for the placement of technological equipment.

Another important distinctive feature of the structures of these objects can be considered that in fact most of the structures exist with technological necessity; they are needed to maintain engineering communications or to provide access to maintenance of individual elements and units. This means that, in fact, the problem with the placement of numerous objects is complicated by the saturation of technological equipment and communications for which it is necessary to track their position relative to the rest of the components of the structure which objectively can be the cause of various collisions leading to the adjustment of design estimates or additional construction and installation works that may negatively affect the timing of equipment commissioning or completion of its overhaul and reconstruction.

In view of this the development of information models of industrial facilities should be especially carefully worked out within the framework of the display of technological equipment, for example, the minimum set of attributes of model elements should include such data as:

- service and repair area;
- installation space;
- data on fire and sanitary breaks;
- data about the manufacturer;
- data on the used medium for pipelines and tanks;
- operating temperature;
- aggressiveness of the environment;
- controllable or permissible technological parameters;
- the presence of a dynamic impact;
- the presence of hazardous factors of production;
- data on explosion and fire hazard;
- etc.

2.3. Structures of engineering protection of the territory (extended structures)

As a separate part can be considered the structures of engineering protection of the territory which are widely used for the arrangement of subsoil use objects and other industrial facilities. One cannot fail to note the possibilities of information modeling for the stages of approval and examination of design solutions in this case. For example it is proposed to consider the model of an extended retaining wall on a slope terrain. It is possible to significantly reduce the complexity of considering options for the layout of the retaining wall location in height, as well as changing its configuration when changing the
decisions of the master plan with the correct development of the model using parametric objects, which was demonstrated at a specific object. General view of the model is shown in figure 5.

![General view of the information model of an extended retaining wall on a slope.](image)

**Figure 5.** General view of the information model of an extended retaining wall on a slope.

At this object the retaining wall is a monolithic reinforced concrete structure that unites driven wall base piles. Individual sections of the wall are parametric objects in which the placement of piles, the depth of their embedding, the step, the length changes depending on the entered parameters. Thus, a new set of documents, numbering of piles, sections with relief, statements and specifications are obtained almost automatically when the layout of the wall is changing or the layout of the territory.

Thus, we can say that using BIM should be a mandatory integral part which significantly reduces costs for correcting documentation and speeding up the process in case of designing extended engineering structures the configuration of which is largely depends on numerous third-party factors (layout of the territory, technological and other solutions), which can be changed during the design process of the object.

3. Application of BIM at other stages of the life cycle

Another important aspect of using the BIM is the construction process. Currently the software products that allow you to perform 4D-calendar schedules, including the visualization of the construction project are widely used. The process of forming this calendar schedule implies the use of
a project information model and its special processing. During this the individual sets of elements of a model are assigned to the construction process with an appropriate time rate or even cost. And all this information can be used or analyzed during construction or its planning. The development of such solutions in itself is also a laborious process which negatively affects the cost and design time. In this case the strict regulation of the rules for the development of the BIM can also speed up and simplify the process. Each element of the model must be assigned a correspondence to a certain construction process or price by assigning a code at the development stage, which will help in further automatic or semi-automatic data processing. For this the organization must develop its own or adopted an all-Russian or international classifier of building resources and materials. The process of developing such classifiers is now actively taking place all over the world. With the further development of the information model of the object during the construction process the model can be successfully used at the operational stage, as well as imported into specialized solutions for creating digital twins of production facilities for monitoring and analyzing current production activities, that is, filling its information on the actual arrangement of elements, entering the data of the executive documentation and other. The requirements for the development of an information model should be clarified at the stage of forming the terms of reference in order to ensure the possibility of such use.

4. Conclusions And Recommendations
The following conclusions were drawn about the methods and methods of their development of applying BIM based on the results of the analysis of various digital and information models of subsoil industry use objects:

- The main advantages of using information modeling at subsoil use objects and industry are associated with the ability to avoid collisions, "dissolve" all communications at the site, and take into account the relief.
- It should be noted the saturation of subsoil use objects and industry with small details that complicate the model, as well as increase the complexity of developing the model. These facts should be taken into account when forming a methodology for performing work.
- Analyzing the design practice we can conclude that the use of information modeling should be preceded by "digitization" of databases of standard objects for use in design and the development of classifiers of elements for the unambiguous definition of these standard elements at all stages of the life cycle of an object.
- The level of detail of the model elements required to achieve the main objectives of the modeling should be clearly defined. So standard objects can be performed at a sufficiently high level of detail, including such small details as fasteners, etc., and include options for the element model at different levels of development for the stages associated with draft design or feasibility study of investments. At the same time newly developed elements or complex structures consisting of a set of standard elements can be developed in the form of dimensional models with only exact geometric dimensions and appropriate information content (material, manufacturer, etc.). In this case when the model moves in development from sketch to working documentation the development of working documentation can be performed without relying on an information model.
- The significant efficiency of information modeling is associated with the stage of coordinating the route of engineering communications or their possible correction. Since it assumes a relatively automatic change in the design of typical objects or parameterized objects when changing related design solutions. This leads to a significant reduction in the time for making these changes as well as their labor intensity. We can talk about the need for the mandatory use of information modeling in the design of such engineering structures.
- A wide range of BIM applications in activities related to the design, construction and operation of subsoil use objects and industry requires a well-developed system and methodology for the work of all participants in the investment and construction process, which includes a detailed work plan, a scheme of interaction between individual participants and the use of BIM at the different stages of the life cycle.
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