UDC 004.9:69.003

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Information models of construction objects during their life cycle

Information modeling has been playing a pivotal role during the last decade in bringing in revolutionary and systematic changes in Civil Engineering. The current paper describes the development of models used by architects and engineers from scale models of the Renaissance to the operative models supporting constructed object throughout their life cycle. The development of Information Modeling concept is described, and the focal role of the engineering data and data management in the information modeling process is introduced. The analysis of the existing OpenBIM concept used by Western vendors shows that although it works well at the design stage, but at the construction site and in operation the data management seriously lacks efficiency. The important property of the interoperability also has not been achieved by the means of Industry Foundation classes that are currently used in most Western software products. Under the existing conditions, Russia has a chance to take a leading position in the development of information models.
The second part of the paper describes the digital ecosystem of software products developed by the Russian Group of Companies CSoft for consistent digitalization of design, construction, and operation of buildings. An extensive description of the functionality of the products, forming the seamless system for the life cycle of construction objects is provided.
Keywords: *information modeling, objects of capital construction, life cycle, data management, interoperability*

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INTRODUCTION

Scientists and engineers have traditionally described systems with models. A model of a system consists of a set of objects and the set of processes which change these objects with time. Both the objects and the processes of the model of a system are images of objects and processes of the original of the system. Scientific methods are used to select the objects and processes of the original in the world, to map objects and processes between the original and the model, and to simulate the original and its behavior with the model.

The use of models in Civil Engineering has a long history. In the Renaissance, architectural scale models played an important role [1]. At that time, models were used by the designers of significant buildings and bridges to gain the approval of their clients for their plans. In addition, the models were used to study architectural effects of the bulk of the buildings and of the use of various materials in the elevations and floors of the buildings.

An outstanding example of an architectural model is the model of St. Peter's Basilica in Rome, which was designed and constructed from 1506 to 1626. Each of the four master builders who were entrusted with the project (Bramante, Michelangelo, Maderno and Bernini) modified the design of his predecessors significantly. Michelangelo created a wooden model of the dome at a scale of 1:15. The model is more than 5 meters high and can still be seen in the Vatican today (Fig. 1). It was used by Michelangelo and by his successors to study the original design of the dome and its modifications.

In the 18th century, Switzerland was famous for large span wooden bridges like the bridge crossing the river Rhine at Schaffhausen. An initial design had a single span of 119 meters. Although a model was built and even stood on it to demonstrate the stability of the design, the clients were not convinced. They may have been familiar with scale effects, or found the design too expensive. The redesigned bridge in figure 2 was built from 1755 to 1758 with spans of 56 and 63 meters. The original models of the initial and of the final design can be seen even today in museums in Switzerland.

The nature of engineering changed fundamentally when the scientific method was introduced to augment the traditional empirical approach. The concept of the design engineer was now presented in

Fig. 1. Wooden Model Dome St. Peters Basilica, Rome

the form of a static model consisting of mathematical calculations, texts and technical drawings on paper. This approach is still well known in engineering practice. The data of static models can only be used and passed on through human intervention.

The computer has completely changed the engineering profession. If we can derive a suitable theory for an engineering project, we can today nearly always apply this theory to realistic models of a system and predict the engineering behavior, even for highly complex systems, by using computers and computer-oriented methods. This trend was already revealed in the earliest efforts to use computers beneficially, for example in the development and application of the finite element method FEM and of computer-aided design CAD. The character of models has changed from static to operative in the digital environment [2]. The digital modelling concept includes both the objects of the system and the processes which occur as the system changes. The models themselves can operate on input data to generate information which is required to design, construct and operate originals and to transfer this information in networks [3]. Models with such properties are called operative models. The change from static to operative models is a measure for the changes in our professions due to the novel digital technologies.

The most representative example of the development of operative modeling in Civil Engineering is Building Information Modeling, which involves the generation and management of digital representations of the physical and functional characteristics of buildings. The concept of BIM has been developing from 1970s, and since that time has experienced important transformations[1, 2, 3] [4, 5]. The Urban Development Code of the Russian Federation provides the following definition: “Information model of a capital construction object is a set of interrelated information, documents and materials about a capital construction object, generated in electronic form at the stages of engineering surveys, design, construction, reconstruction, major repairs, operation and demolition of the capital construction object”. It is obvious from this definition that the key component of the information model is the engineering data. This data must be generated, processed, stored, transferred and operated on, and therefore it should be read and understood by the computer.

Despite some consonance in the names BIM (Building Information Model / Modeling) and IM (Information Model or Modeling), it has to be noted that IM is a logical continuation of BIM, as it moves to the next stage — not “modeling”, but data management. This allows us to divide the areas of IM into two large components, which in Russian legislation are designated by the verbs “formation” and “maintenance” of the Information Model. This separation process is still only at the beginning of its organization, and many people habitually use either the term “BIM”, or “DIM” (Digital Information Model), or “TIM” (Information Modeling Technologies) using the word “technology” in the singular, considering this term, introduced by the President of Russia in 2018, to be a certain knowledge. Moreover, this knowledge is still used as an analogue of BIM, but only in the context of the third version of the letter “M” (Methodology). A typical method of global technological expansion is the creation of a “new science” from the way of designing, constructing and managing structures using specialized software, resulting in the creation of a building information model [6–8].

Before moving on to maintaining the information model, it should be pointed out that the division of the “general methodology or knowledge” designated in some non-legislative sources as “TIM” into separate technologies allows us to make a qualitative leap in the regulation of each of the technologies for forming the information model, which will lead to the so-called competitive turnover. As a result, the consumer will benefit, and the progress of information modeling development will not be constrained by the modern platform approach which is designated in the OpenBIM concept as a shared data environment[4]. Information modeling assumes a broader approach in the form of the information space of the information model. This is indirectly called for by the definition of the information model given in the Urban Planning Code of Russia, and which supporters of the archaic OpenBIM concept do not like.

There is a general opinion in Russia that domestic developments are not at the same level as the developments of Western vendors. This raises a smile and understanding that they are often comparing completely the wrong things and do not take into account the goals of vertical (state) digitalization. The lack of fashionable and convenient buttons on the interface or avoidable difficulties with some functions is elevated to the rank of technological backwardness. This is not true. The work of a designer and an architect is very important and a beautiful information model will also please the eye, but these are passing values. The main thing is the efficiency of data management, and this is not enough in OpenBIM. Although it should be noted that the OpenBIM concept works great, but only at the design stage, but at the construction site and in operation it is either a deterrent in data management or low-efficiency. Moreover, this is a global trend and in the West, there are many publications with reflections on “what to do next” and attempts to find a way out to the effectiveness of data management in the current conditions. But the finances of major global vendors invested in products created under the OpenBIM concept are holding back such development.

Another critical issue that should be addressed while developing information models for the life cycle of construction objects is interoperability. Current standardization of technological objects, such as the Industry Foundation Classes IFC which have been incorporated into many Western commercial software applications for building information modelling (BIM), employs as one option the index table concept. The huge volume of standardization required for the many types of objects in practical applications is a serious drawback. In addition, relations between solids must be modelled by additional objects and are not integral part of the geometry. While interoperability has been reached within the product chains of individual software houses, the original goal of the IFC development, to reach full interoperability [9] between models constructed independently on various software platforms, has not been reached completely.

Therefore, under the conditions of sanctions, Russia has a chance to take a leading position, and sets of software, data architecture formats and necessary regulations will ensure a technological and competitive advantage in the markets of other countries.

What does the so-called and not yet explicitly expressed next step, called maintaining an information model, give us in data man-

1 ERDC SR-12-2. The US Army Corps of Engineers Roadmap for Life-Cycle Building Information Modelling (BIM). Washington 2012. 45 p.

2 Bundesamt für Bauwesen und Raumwirtschaft. BIM Leitfaden für Deutschland. Final report. 2013. 109 p.

3 EU BIM Taskgroup. Handbook for the Introduction of Building Information Modelling by the European Public Sector. 2017. URL: http://www.eubim.eu/wp-content/uploads/2017/07/EUBIM_Handbook_Web_Optimized-1.pdf

4 BuildingSMART. IFC Overview. Retrieved from buildingSMART. URL: http://www.buildingsmart-tech.org/specifications/ifc-overview (accessed on January 27, 2018).

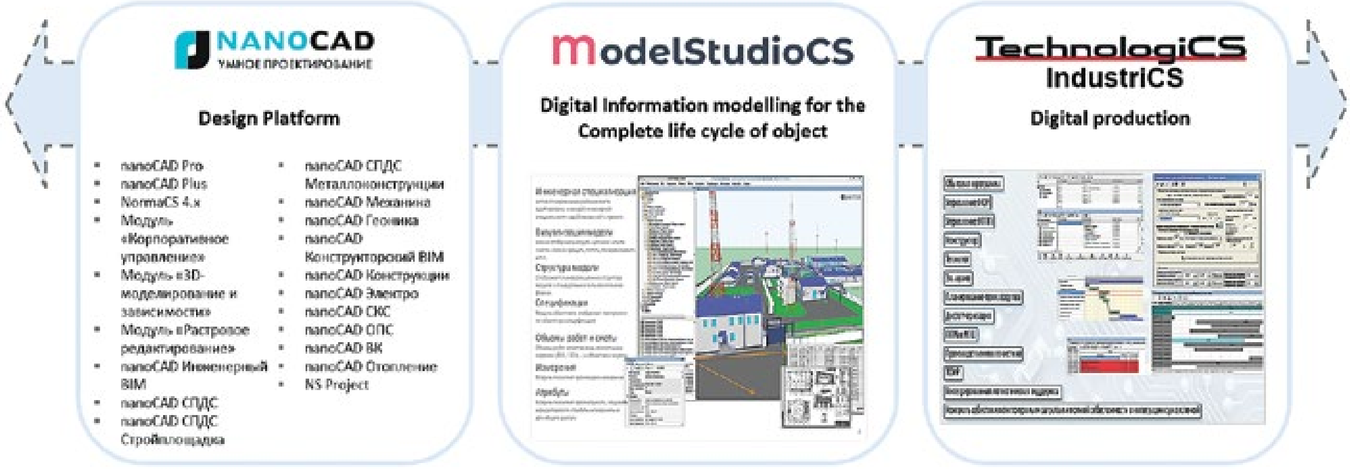

Fig. 2. Digital ecosystem of CSoft software products

agement? Under this term, Russian legislation provides for "…updating of information, documents, materials included in the archival storage…". It clearly follows from this that "someone" or "something" during the life of the information model manages the data of the information model in the way necessary for itself, while the information model itself turns into a "smart database". If by the phrase "something" we mean various software products (technologies) that manage information model data in an automated or automatic mode, then we will get the very division of functions into separate technologies (TIM) and the next step (maintenance) in information model data management. Where the formed information model of the "as built" level itself contains data about the object of information modeling in a convenient structured (machine-readable) form, and the information space of the information model itself adds the functionality of "interconnectedness" to the "structuring", which already refers to the function of machine-readable data or a "smart database"[5]. It is this word (interconnectedness) in the definition of the Urban Planning Code of Russia also does not agree with the archaic concept of OpenBIM. You can learn more about the terminology and concept of the information model life cycle in the standards of the CSoft company.

It is necessary to move from general reasoning to the plane of practical embodiments of information modeling technologies that ensure the maintenance of an information model. At the same time, it is necessary to note an important circumstance — under the term "exploitation" we will understand at least two meanings — the exploitation of the object itself in the form of maintaining its operative condition, for example, to the level of "as built" and the second type of exploitation — for the intended purpose of the constructed object. Let's call this type of exploitation — design or production-technological or socially useful exploitation. Then information modeling technologies, in the context of "management", include such classes of software products as EDA/CAE/CFD/CAPP/CAM/MDM/PDM/MES and others. Or more broadly, the engineering data management system (EDMS) and other management systems — design, financial, sociological, personnel, environmental, etc. [10–15] At the same time, there is absolutely no need to revise the listed and non-listed systems themselves, it is enough to regulate their principles of managing their own input/output data with the principles of data management of the information space of the information model. At the same time, the information model itself plays the role of a "smart database" due to the preliminary preparation of data in its own information space.

In a short article, it is not possible to explain in more detail the principles of building an information space and data management of an information model, but one can only say that the API principle (application programming interface) will not be able to solve all problems. For example, with an avalanche-like accumulation of data and gradation in their management. The logical way out of the impasse of data management is a seamless horizontal, which means the formation and maintenance of an information model throughout its life cycle from a business plan to an archive. At the same time, the technologies for forming and maintaining the information model itself, as a rule, use a common editable format and data architecture [7, 8]. This significantly speeds up data management and eliminates errors and the risk of data loss inherent in following the principles of the OpenBIM concept.

CSoft's solutions for digitalization in the field of design, construction and operation are moving along this path. Moreover, exploitation in two senses is the exploitation of the object itself in the form of maintaining its operative sound condition and for the intended purpose of the constructed object. The basis of the digital ecosystem of the seamless horizontal CSoft are three software products. This is the "nanoCAD" platform, these are complex products "ModelStudioCS" and "CadLib", as well as 14 software products for managing the construction and subsequent operation of the facility — "TechnologiCS" or, in a special case, "NS Project" as a comprehensive "3-in-1" solution for project management, processes, and document management (Fig. 2).

Let's consider typical work organization processes, the life cycle of an information modeling object (capital structures, building or structure), in particular, more for design and construction stages (Fig. 3). At these stages, the main goal of digitalization is to eliminate design errors, optimize the timing of all construction organization processes, and make effective use of material and human resources leading to increased economic efficiency. At the same time, it is necessary to create a significant amount of documentation, usually of a standardized type, and exchange data with government, industry and other information systems.

At the same time, the information model with the help of "CadLib" provides the necessary technologies for organizing a temporary and estimated scenario for organizing construction work and if CadLib

5 Patent of the Russian Federation No. 2686006. Method and system of information modeling of business processes of the life cycle of a production facility. 2018.

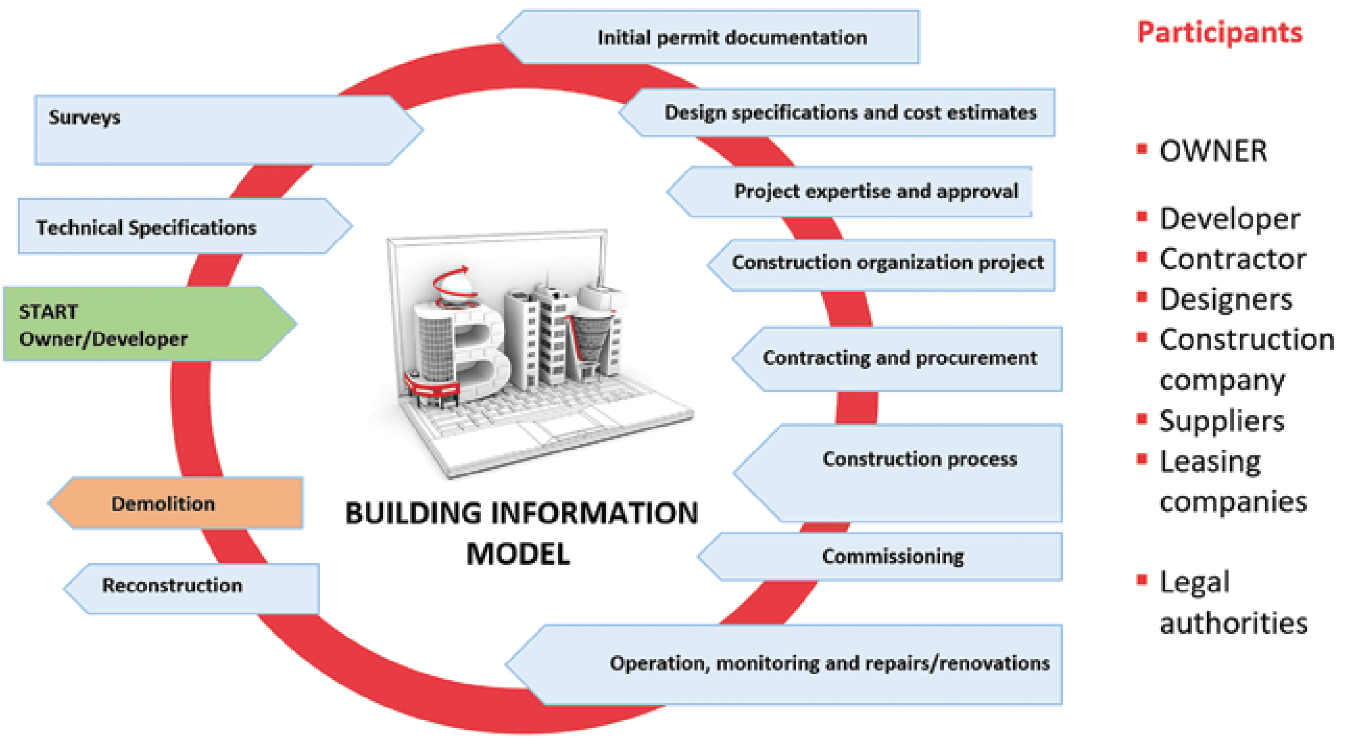

Fig. 3. Organization of information document flow in the ecosystem of CSoft products

performs calendar and network planning on its own. Then specialized software is used to perform the estimated calculations. There are several such software products in Russia and there is automated integration with several main ones[3]. The data required for the estimate calculation is taken from the information model itself and returned after the estimate calculation is completed.

If we return to project management, then from the point of view of automating routine processes, using specialized software products for project preparation and management, it is possible to significantly reduce errors when creating all kinds of documents, for example, at the design and/or construction stages. It is best to do this with the help of specialized technologies, which, as a rule, are combined into specialized platform solutions, for example, "NS Project" — a comprehensive "3-in-1" solution containing modules: Electronic archive and document management, Project and Process management, Construction Management (Fig. 4).

Such technologies simplify the work of leading specialists in many ways, because it allows to avoid large labor costs for correcting errors or, if necessary, reworking ready-made packages of documents. At the same time, there are other possibilities for organizing work. Many people really like the various functions for organizing teamwork, working in various groups and internal chat between employees, regulated and customizable chains of approvals for various documents, electronic signature capabilities, services

Fig. 4. Project Management in NS Project (3-in-1 complex for project management)

for monitoring construction and installation work and much more. And all this is already in a ready-made boxed solution, but customization is not excluded both from the vendor and when using the capabilities of integrators. All these functions work in close data exchange with the information model itself. Features that allow one to implement a construction organization project, determine preliminary construction solutions, model the nuances of production, sequence and alternation of work, taking into account technology, schedules, productivity and resources of contractors and suppliers may serve as an additional tool of such project management platforms, in particular for the construction field.

Digitalization of construction sites, together with the introduction of information modeling technologies, is often a complex process, which primarily encounters the low qualifications of most employees of construction and contracting organizations. Therefore, the main task of digitalization is lower the threshold for digitalization to enter a construction site. One of the best understood mechanisms of digitalization is the technology of visualization of construction works, their organization, sequence, arrangement of construction equipment and emerging collisions. The CSoft software package allows one to make visualizations in various areas of construction work and with customizable visualization parameters, including opportunities for mobile viewing on electronic devices (gadgets) of employees. Full interoperability between technologies is one important factor, which can be difficult to implement for the principles of the IFC transport format. An example of setting visualization parameters is shown in Fig. 5.

Beautiful and colorful visualization of construction is the external aspect of the project management process. The process, which the attribute data undergoes, is much more important. They, as well as the “picture” on the screen, experience changes, ensuring clear document flow at all construction stages and phases. Labor costs are considered, the results of work, performed by executor and contractors, are issued, and recorded, work schedules are rearranged in case of delays or changes, for example, in supplies or other resources, precise and mostly automated work is carried out, which will then allow to restore the construction picture.

Special attention is paid to the increased functionality of the construction schedule, considering the availability of resources. In addition to the standard functions known from certain Western products, several important features are added that, for example, allow to estimate the necessary labor costs to perform a particular job. At the same time, the subjectivity of the assessment of the work performed is excluded and comparison is made with the planned deadlines and standards in the construction organization project. This is in fact the first or even the second step towards a “smart” graph based on machine-readable data. The next step will be using machine-readable data.

The safety and efficiency of the use of construction equipment can be significantly improved with a fairly simple feature such as tracking people and equipment on the construction site. There are many solutions which allow to track the presence of people and technical mechanisms in three-dimensional space, as well as to compare their relative location and even to assess possible future movements, especially when using bulky loads, mechanisms taking into account turning radius, U-turns, dangerous zones, etc. In this regard, people, builders and those temporarily on the construction site, receive sensors for monitoring the location, for example, of a chest mount or inside the so-called “smart” helmets; vehicles and mechanisms are equipped with sensors that allow to control not only their trajectory of movement, but also the trajectory of movement of individual parts, for example, a boom of the crane, a trailer, or a tank of a vehicle Fig. 6. The status of the sensors is transmitted to a special workplace in real time and recorded in separate files, if necessary. Feedback from the object of control is also possible, when a “smart” helmet informs a person about being in a dangerous zone.

The CSoft TechnologiCS product is used to implement the functionality of operation according to the principle of production and technological support of the production cycle. It allows one to provide continuous information support for the main business processes of the enterprise, production planning and management,

Fig. 5. Visualization of the construction process

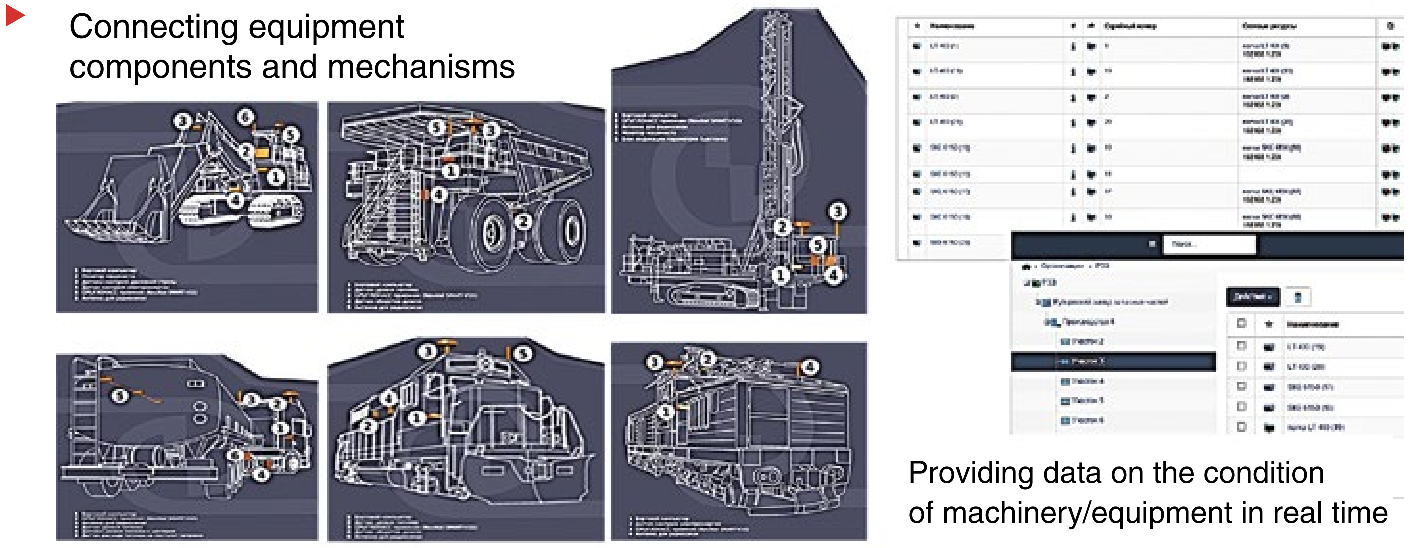

Fig. 6. Monitoring of machinery and equipment

including directly in the workshops and on the sites, as well as quality management and maintenance of manufactured products.

The above mentioned features of the "NS Project" can be used to simplify operation of the construction site itself in the form of maintaining its technically sound condition. In this case, the full functionality of technical maintenance and repair of fixed assets of the task, structure or structure and related equipment, technological and other systems is provided. At the same time, it is possible to connect sensors and dispatching systems like the Internet of Things (IIoT) to visualize an information model on a three-dimensional graph, for example, with coloring of elements and components according to planned and unscheduled maintenance and repairs, or according to the technological principle, taking into account the condition of objects and components of the object in real time (Fig. 7).

The functionality of the software for monitoring maintenance and repair allows to manage and visualize the progress of repair work; to allocate resources, schedule shutdowns and equipment switching, etc. It provides such important instruments as operational monitoring of the progress of the repair program, team-based control of the distribution of work, plan, and fact by stages of work, and analysis of the operating cost of each piece of equipment or subsystem and some other functions.

CONCLUSION

The possibilities of digitalization of the design and construction stage should be fully used for the operation stage. And this is possible under a number of conditions:

- relevance and completeness of the data;

- 3D model of buildings, machinery, equipment, technological and other systems;
- the model allows user to view, create and edit attributes and save them for ublic access;
- the ability to connect data received from the IIoT subsystem for visualization on the model;
- 100 % up-to-date information;
- search by model;
- coloring of the model for scheduled and unscheduled maintenance and repairs

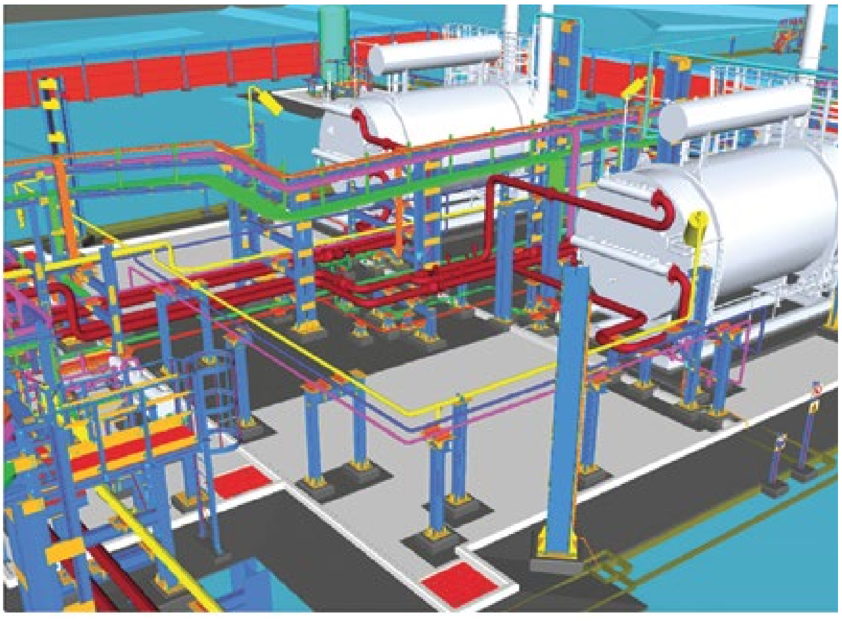

Fig. 7. Creating of digital models for operating services using BIM technologies based on real-time information from objects or/and components status

- full-fledged interoperability of the information model according to the stages of its life cycle;
- the absence of risks of loss, damage and distortion in the data management horizontal due to “white spots” or the use of transport formats;
- the possibility of long-term storage of information model data in an editable format and the transfer of information modeling technologies to a competitive basis with the possibility of replacing them at any point in the information model lifecycle.

REFERENCES

1. Addis B. Physical Models and Innovation in Architectural and Civil Engineering. Nexus Network Journal. 2021; 23(4). DOI: 10.1007/s00004-021-00560-1
2. Kraft B., Huhnt W. Geometrically Complete Building Models. In Proceedings of the EG-ICE 2014 conference, Cardiff University, 16-18 July 2014. DOI: 10.13140/2.1.1702.1123
3. Bilchuk I., Pahl P.J. Three-dimensional Topological Models of Buildings. Vestnik, Moscow State University of Civil Engineering. 2012; 69(10):289-296. DOI: 10.22227/1997-0935.2012.10.289-296
4. Bloomberg M., Burney F., Resnik D. BIM Guidelines, New York. New York City Department of Design + Construction. 2012; 57.
5. 4th European BIM Summit, March 2018, Barcelona : BIM-2018. European Building Summit Barcelona.
6. Bocharov M.E. Is BIM an analogue or a prototype of information modeling in Russia? General Director. Management of an industrial enterprise. 2022; 10. (rus.).
7. Kurbatov V., Rimshin V., Shubin I. Volkova S. Handbook for Information Modelling and AI in Modern Construction & Housing and Communal Services. Publishing House ASV. Moscow, 2023; 420. (rus.).
8. Bachurina S. Information Modelling: Methodology of Usage of Digital Models in the Process of Transition to Digital Design and Construction. Part 1 : a Handbook. DMK-Press, Moscow, 2021; 112.
9. Steel J., Drogemuller R., Toth B. Model Interoperabilty in Building Information Modelling. Software and Systems Modelling, Springer Berlin, 2012; 1:99-109. DOI: 10.1007/s10270-010-0178-4
10. Huhnt W. A Digital Environment for Managing Processes in Civil Engineering. Abstract Volume: 14th International Conference on Computing in Civil and Building Engineering. Publishing House ASV, 2012; 24-25.
11. Pan X., Mateen Kh.A., Eldin S.M., Aslam F., Kashif Ur Rehman S., Jameel M. BIM adoption in sustainability, energy modelling and implementing using ISO 19650 : a review. Ain Shams Eng J. 2023; 15(2):102252. DOI: 10.1016/j.asej.2023.102252
12. Aziminezhad M., Taherkhani R. BIM for deconstruction : a review and bibliometric analysis. J Build Eng. 2023; 73:106683. DOI: 10.1016/j.jobe.2023.106683
13. Zhou X., Ma Ch., Wang M., Guo M. BIM product recommendation for intelligent design using style learning. J Build Eng. 2023; 73(1):106701. DOI: 10.1016/j.jobe.2023.106701
14. Yilmaz G., Akcamete A., Demirors O. BIM-CAREM: assessing the BIM capabilities of design, construction, and facilities management processes in the construction industry. Computers in Industry. 2023; 147(3):103861. DOI: 10.1016/j.compind.2023.103861
15. Gartoumi K.I., Zaki S., Aboussaleh M. Building information modelling (BIM) interoperability for architecture and engineering (AE) of the structural project: a case study. Materials Today Proceedings. 2023. DOI: 10.1016/j.matpr.2023.05.408

Информационные модели объектов строительства в течение их жизненного цикла

В течение последнего десятилетия информационное моделирование играло ключевую роль в осуществлении революционных и систематических изменений в гражданском строительстве. В данной статье описывается разработка моделей, используемых архитекторами и инженерами, от масштабных моделей эпохи Возрождения до оперативных моделей, поддерживающих построенный объект на протяжении всего его жизненного цикла. Описывается развитие концепции информационного моделирования и ключевая роль инженерных данных и управления данными в процессе информационного моделирования. Анализ существующей концепции OpenBIM, используемой западными вендорами, показывает, что, несмотря на результативную работу на этапе проектирования, управлению данными не хватает эффективности на строительной площадке и в процессе эксплуатации.

Важное свойство интероперабельности также не было достигнуто с помощью базовых отраслевых классов, которые в настоящее время используются в большинстве западных программных продуктов. В существующих условиях у России есть шанс занять лидирующее положение.

Ключевые слова: *информационное моделирование, объекты капитального строительства, жизненный цикл, управление данными, интероперабельность*

СПИСОК ИСТОЧНИКОВ

1. Addis Bill. Physical Models and Innovation in Architectural and Civil Engineering // Nexus Network Journal. 2021. No. 23 (4). DOI: 10.1007/s00004-021-00560-1
2. Kraft B., Huhnt W. Geometrically Complete Building Models // In Proceedings of the EG-ICE 2014 conference, Cardiff University, 16–18 July 2014. DOI: 10.13140/2.1.1702.1123
3. Bilchuk I., Pahl P.J. Three-dimensional Topological Models of Buildings // Vestnik, Moscow State University of Civil Engineering. 2012. No. 69 (10). Pp. 289–296. DOI: 10.22227/1997-0935.2012.10.289-296
4. Bloomberg M., Burney F., Resnik D. BIM Guidelines, New York. New York City Department of Design + Construction. 2012. 57 p.
5. 4th European BIM Summit, March 2018, Barcelona : BIM-2018. European Building Summit Barcelona.
6. Бочаров М.Е. BIM — аналог или прототип информационного моделирования в России? // Генеральный директор. Управление промышленным предприятием. 2022. № 10.
7. Курбатов В.Л., Римшин В.И., Шубин И.Л., Волкова С.В. Информационное моделирование и искусственный интеллект в современном строительстве и жилищно-коммунальном хозяйстве : уч. пособие. М. : Изд-во АСВ, 2023. 420 с.
8. Бачурина С.С. Информационное моделирование: методология использования цифровых моделей в процессе перехода к цифровому проектированию и строительству. Ч. 1 : уч. пособие. М. : Изд-во ДМК-Пресс, 2021. 112 с.
9. Steel J., Drogemuller R., Toth B. Model Interoperabilty in Building Information Modelling // Software and Systems Modelling, Springer Berlin, 2012. Issue 1. Pp. 99–109. DOI: 10.1007/s10270-010-0178-4
10. Huhnt W. A Digital Environment for Managing Processes in Civil Engineering // Abstract Volume: 14th International Conference on Computing in Civil and Building Engineering. Publishing House ASV, 2012. Pp. 24–25.
11. Pan X., Mateen Kh.A., Eldin S.M., Aslam F., Kashif Ur Rehman S., Jameel M. BIM adoption in sustainability, energy modelling and implementing using ISO 19650 : a review // Ain Shams Eng J. 2023. No. 15 (2). P. 102252. DOI: 10.1016/j.asej.2023.102252
12. Aziminezhad M., Taherkhani R. BIM for deconstruction : a review and bibliometric analysis // J Build Eng. 2023. No. 73. P. 106683. DOI: 10.1016/j.jobe.2023.106683
13. Zhou X., Ma Ch., Wang M., Guo M. BIM product recommendation for intelligent design using style learning // J Build Eng. 2023. No. 73 (1). P. 106701. DOI: 10.1016/j.jobe.2023.106701
14. Yilmaz G., Akcamete A., Demirors O. BIM-CAREM: assessing the BIM capabilities of design, construction, and facilities management processes in the construction industry // Computers in Industry. 2023. No. 147 (3). P. 103861. DOI: 10.1016/j.compind.2023.10386120.
15. Gartoumi K.I., Zaki S., Aboussaleh M. Building information modelling (BIM) interoperability for architecture and engineering

(AE) of the structural project : a case study // Materials Today Proceedings. 2023. DOI: 10.1016/j.matpr.2023.05.40821

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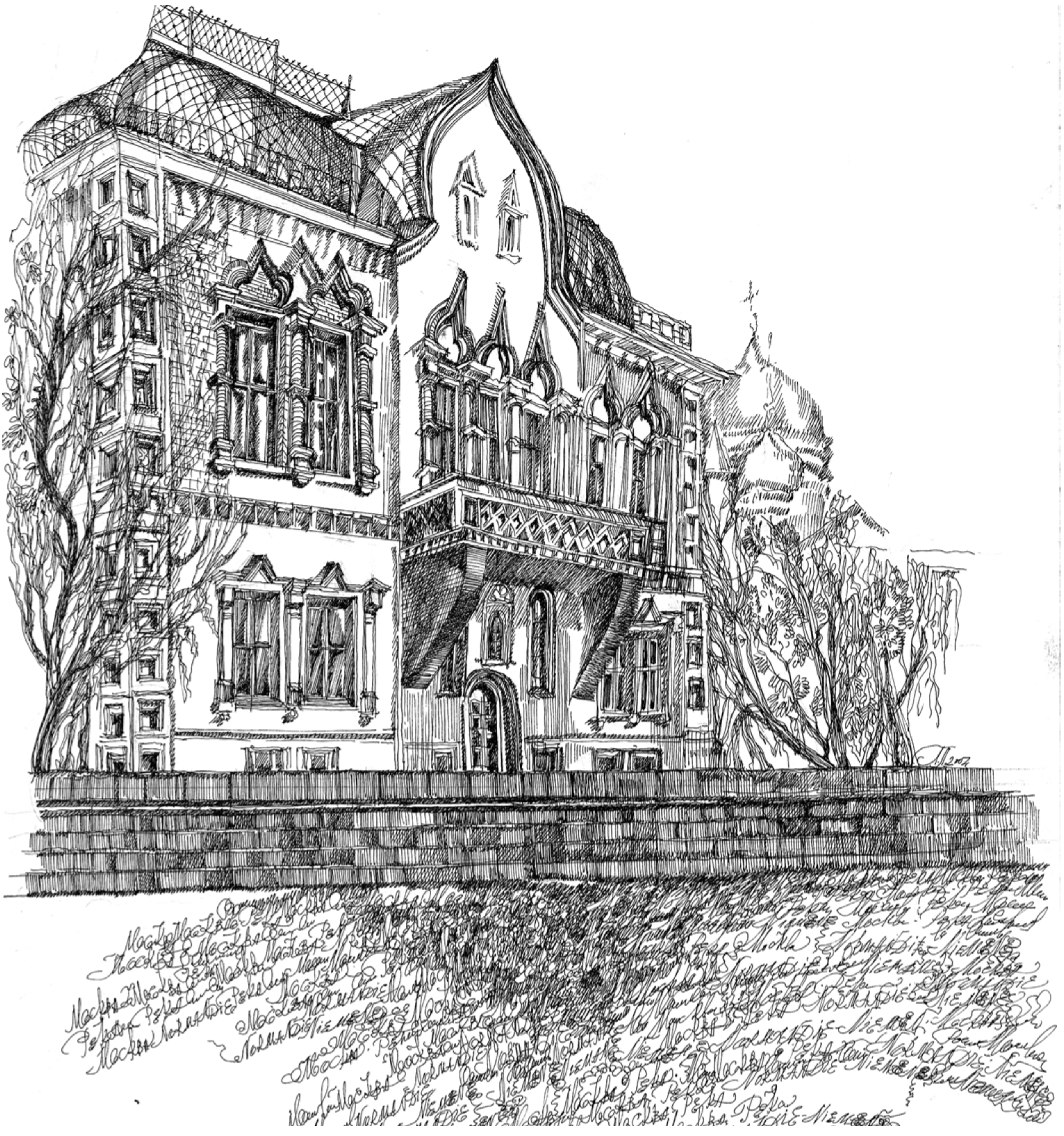
For citation: Galishnikova V.V., Bocharov M.E. Information models of construction objects during their life cycle. *Real Estate: Economics, Management*. 2024; 2:65-72.

Для цитирования: *Галишникова В.В., Бочаров М.Е.* Information models of construction objects during their life cycle // Недвижимость: экономика, управление. 2024. № 2. С. 65–72.



Л.И. Павлова. Москва. Дом Васнецова. Рисунок, тушь, перо.