LE IM: Living Environment Information Modelling

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Abstract. The article deals with the information models in construction. The models of different levels are reviewed: flat 2D drawings, 3D volume models, models including time indicators - 4D, models supplemented by financial indicators - 5D, models containing information on a wide range of resource and other indicators – N-D. The importance of an integrated approach to the formation of the information model of the building - BIM was noted. To date, BIM-technologies are used only at the design stage and partially at the construction stage. However, the greatest return can be obtained from the operational phase. The author proposes the introduction of the concept of an information model of the building life cycle - BLC IM. The analysis of the reasons predetermining the problems of mass introduction of BLC IM into construction practice is carried out. The contradictory nature of the interests of the participants in the construction process, the lack of common goals does not allow them to form and use a unified information model. The mathematical description of the information model of the building object is presented.

1 Introduction

The environment of life is a broad concept that encompasses all the diversity of the surrounding space. Creating a comfortable living environment is one of the most important tasks, the solution of which is possible if we create a formalized description of the object we want to manage.

The description of any object, any activity can be considered as a description of a set of dynamically changing indicators. Such an approach, based on working with the Information Model - IM object or process, on the one hand, provides universality, the ability to formalize and use a single mathematical apparatus for a wide variety of activities. But, on the other hand, a serious analysis of the composition of the information model is required from the point of view of the representativeness of the data included in it, from the point of view of the correctness of their interpretation and use.

Consider the environment of life based on the fact that the largest number of objects surrounding a person are building objects: buildings, structures, infrastructure objects whose parameters form specific conditions of life and work. Therefore, in order to talk about the information model of the life environment in general, it is advisable to start with the information model of a separate building - BIM.

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The development of information modeling is inextricably linked with the development of automated systems, with the capabilities of computer technology for the effective search and processing of large data sets [1]. That is why, initially information modeling was developed in those areas where computerization was more actively used. In construction - this is the sphere of design, in which quite a long time began to apply software packages, focused on automation of routine drawing processes.

2 Evolution of information modeling in designing

It is possible to trace the evolution of information processes in building design - Figure 1.

Fig. 1. Levels of information models in the design.

The first systems of design automation (CAD) worked as an electronic culm, allowing to reproduce the work on the creation of a classical flat 2D drawing [2,3,4].

The rapid development of the capabilities of computers to display high-quality graphics allowed software developers for building CAD to take the next step - to automate the formation of a 3D model of the object [4]. This stage quite clearly reflects the complex interaction of programmers and users (in this case, the designers). Often, not users set the prospects for the development of their own industry, but programmers actively dictate the introduction of those technologies that are determined by the capabilities of hardware and software [2]. In fact, a qualified civil engineer must be able to read a flat drawing and no additional information is needed to understand the design characteristics of the facility to the specialist.

Of course, the 3D model is more visible than the classical drawing. It can be effectively used to present the object to investors, customers, potential consumers of construction products [5,6]. The possibilities of using color in the drawing in especially complex cases allow us to detect at the design stage a variety of collisions related to errors in the interconnection of various, primarily, building engineering systems. Nevertheless, the active use of 3D models is determined, first of all, not by serious engineering needs, not by the possibility of reaching new classes of tasks, but by the possibility of modern software without significant additional computing power and time spent drawing the corresponding figure [7].

Any drawing already carries a significant amount of information about the object. A drawing made on a computer can be easily transferred, copied, and corrected. In fact, it is an information model or, what is called BIM (Building Information Model) [1]. However, is such an information model exhaustive? - Of course not. It is clear that the project documentation is not limited to the description of the geometric shapes and dimensions of the building or structure. Unlike the first years of the implementation of BIM-technologies, no one now identifies the BIM-model with the usual 3D-drawing [8,9].

A fairly natural development of modeling a building object is an attempt to describe the process of its erection [10,11]. One of the most important sections of organizational and technological design is scheduling. That is why the next indicator, taken into account in the information model, was time. By analogy with multidimensional models in classical physics, they began to be called four-dimensional or 4D-design [12].

In modern conditions, construction, like other industries, cannot be considered in isolation from a comprehensive consideration of economic factors [13]. Accordingly, there were projects that consider not only the duration of work, but also the corresponding cash flows, which allowed talking about 5D-design (3D + time + finance).

Modern software products, oriented to architectural and construction design, allow you to work not at the level of graphic primitives, but at the level of building products, structures, modules. The object is formed not from ordinary lines, but from images that already contain information about the type of the object being built, the necessary resources (materials, machines, mechanisms, working frames, equipment used), etc. [14,15]. In fact, the information model of the object includes a set of (N) indicators that characterize both the object itself and, to a certain extent, the processes taking place on the construction site. In general, we can talk about N-dimensional or about N-D design.

At the same time, an unambiguous, generally recognized understanding of what exactly should include a full-fledged BIM-model has not yet been formed [16]. This is determined by the many problems associated with the practical implementation of BIM-technologies. Many of these problems are not technological, but organizational and ideological [17].

3 Problems of BIM-technologies introduction. Building life cycle information modelling – BLC IM

The simplest problems are associated with the adaptation of information originally embedded in the software product to the requirements of national standards, the parameters of the products of national manufacturers, the characteristics of the equipment used, etc.

Much more complex is the solution of formalization of data processing, which in general characterizes not only individual works or constructions on the site, but also their aggregates (modules, blocks, sections, complexes, etc.). Many indicators cannot be tied to those lines-constructions, from which the designer draws a drawing.

Modern understanding of construction is not limited to purely technical characteristics. To date, we are talking about the project as an object of management. BIM-technologies are designed to work with data that ensure the effectiveness of process control. In fact, the functionality of the ERP (Enterprise Resource Planning) system is required, i.e. automation of planning, accounting, control and analysis of all major business processes and solving problems of optimization of the project.

The transition to a qualitatively higher level of project management on the one hand allows to get the most out of the use of BIM-technologies, but, on the other hand, it encounters serious organizational contradictions between the goals and tasks of information modeling and the established practice of urban development.

Information modeling of construction should extend to the entire life cycle of the facility (pre-investment stage, design, construction, operation, including repair and reconstruction,

demolition and disposal) - Figure 2. Proceeding from this, it is advisable to introduce the concept Building Life Cycle Information Modelling - BLC IM.

Fig. 2. Building Life Cycle Information Modelling - BLC IM.

To date, BIM-technologies are used at the design stage and in a small amount at the construction stage. From the point of view of information modeling, these are the stages of data accumulation for further use at the main, the longest stage of the object's existence - the operational phase. However, in practice it turns out that the information model generated with such considerable efforts (costs for the appropriate software, training of personnel, collection and processing of additional data) simply does not reach the next stages of the life cycle.

Causes that hinder the widespread use of information modeling in construction practice are quite numerous. But among the main ones it is necessary to name the following: the disunity of the stages of the life cycle of the object and the absence of common interests among participants in the realization of the life cycle.

For designers, the advantage of using BIM-technologies is, as already noted, in the possibility of early detection of various violations, in the possibility of automatically processing large amounts of information (for example, automatic replacement of any structure or material at once in all design documentation), in the ability to automatically generate statements of materials, equipment, estimates, etc. At the same time, the cost of "entering" in information modeling is very high. Especially at the early stage of implementation, when the cost of project development is significantly increased. At the same time, it is important to take into account that it is necessary to lay down in the information model not only the data that designers need for the current work, but also those data that builders and, first of all, specialists in the operation of the facility may need. For designers, this is a waste of time and energy, and no one is paid.

In holdings, where designers and builders work together, it is possible to provide incentives for designers to create an information model for builders. But in the general case, this task is not completely solved now. Moreover, a number of technical, organizational and even legal issues arise concerning the transfer of the information model from one owner to another (what is the composition of the data, what is the format of their submission, who owns the rights to the information collected, etc.).

It is almost impossible to interest builders in acquiring a BIM-model for themselves. The task of the builders, rather, is not to use it for their own needs, but rather to enter into the

model specific data on the materials, technologies, equipment used for their further use at the stage of operation. Some information useful to builders can arise when using reusable standard projects, but few will agree to pay it out of their own profit.

In the current structure of the relationships of participants in the life cycle of an object, the number of barriers to the dissemination of information modeling to all stages is such that BIM technologies simply do not reach the stage of operation. Even so-called smart houses do not work with information models formed at the stage of feasibility study and subsequent design and construction, but with data collected, as a rule, in the process of monitoring the state of an already exploited facility. This cuts off a huge layer of information that allows efficient planning of repair and replacement of equipment, controlling not the whole range of object characteristics, but choosing, according to BLC IM data, only critical parameters, etc.

A significant influence on how information modeling is implemented is provided by the interests of the investor. If the object is being prepared for sale, there is usually no interest in investing in further efficient operation (and therefore in BLC IM), as a rule. Equally, this applies to the costs of energy efficiency, resource saving, environmental friendliness, etc.

Even if there is an investor ready to finance the creation and use of the BLC IM model, which, of course, will pay off in the process of exploitation and even with demolition and disposal, there are still problems associated with the unavailability of specialists to provide a complete description of the composition of such a model. To date, there is no unambiguous understanding of what data may be needed in a few decades, and which, on the contrary, will be superfluous. In addition, there is no full spectrum of mathematical and physical models that allow to accurately interpreting the collected data characterizing the object i.e. make an unambiguous conclusion about the need for certain operations to maintain the life cycle.

4 Mathematical description of the informational model

In general, the object is conveniently viewed as a set of processes characterized by the duration and set of indicators (resources, etc.).

Let there be N processes ($n = 1, \dots, N$) of duration from t_0^n to t_1^n .

The processes are described by a set of indicators $P: p_i^n(t)$, where $i=1, \dots, I$ is the index number of the indicator related to process n . $p_i^n(t)$ - the dependence of the value of the indicator on time - a function determined on a time interval $[t_0^n; t_1^n]$. In case the indicator is specified not by a functional dependence, but by separate values (pairs of points), one can go to the function, using different variants of approximation (as a rule, the accuracy of linear approximation is quite enough).

During the lifetime of an object, processes can be accelerated or slowed down, accordingly, the type of functions describing these or other indicators can vary. In this case there is a transformation of the time of existence of the process: $[t_0^n; t_1^n] \rightarrow [v_0^n; v_1^n]$ and the function describing it: $p_i^n(t) \rightarrow p_i^{n*}(t)$.

In general, the new function $p_i^{n*}(t)$ can be arbitrary (determined depending on the physical meaning of the indicator). However, the condition of invariability of the total amount of the indicator involved in the process is often met (for example, regardless of the duration of the construction of the wall, the total demand for the brick remains constant). In this case, we can write down the condition of constancy of the volume of the indicator in question:

$$\int_{t_0^n}^{t_1^n} p_i^n(t) dt = \int_{v_0^n}^{v_1^n} p_i^{n*}(v) dv \quad (1)$$

Let $\gamma(v)$ is the function that defines the mapping $[v_0^n; v_1^n] \rightarrow [t_0^n; t_1^n]$. Then, by the theorem on the replacement of a variable in a definite integral, expression (1) can be written in the form:

$$\int_{\gamma(v_0^n)}^{\gamma(v_1^n)} p_i^n(t) dt = \int_{v_0^n}^{v_1^n} p_i^n(\gamma(v)) \cdot \gamma'(v) dv, \quad (2)$$

where $\gamma'(v)$ is the derivative of the function $\gamma(v)$.

If the process changes occur proportionally, i.e. function $\gamma(v)$ is linear, $\gamma(v) = \alpha v + \beta$ and $\gamma'(v) = \alpha$. In this case it can be shown that:

$$\alpha = \frac{t_n^1 - t_n^0}{v_n^1 - v_n^0} \quad (3)$$

If the indicator is involved in several processes Q, then its final value is determined by the formula:

$$p_i^{n \in Q}(t) = \sum_{n \in Q} p_i^n \quad (4)$$

You can consider indicators that relate not to one, but to a group of processes Q (to certain types of work on the site, the building site, the building, etc.): $P^Q : p_j^Q(t)$, $j=1, \dots, J$, where J - number of indicators of this type.

A number of indicators (for example, management information) can relate to an object as a whole, without being tied to one or other of the processes: $P^R : p_m^R(t)$, $m=1, \dots, M$, where M - number of indicators of this type.

Thus, the information model is a mathematical object of the form A:

$$A = A(P, P^Q, P^R) \quad (5)$$

At the same time, the analysis of the change in all indicators over time can be carried out analogously to the analysis of indicators of type P.

Speaking about BIM-technologies as tools for creating BLC IM, it is necessary to keep in mind that serious models are open information systems that can integrate data of different levels, i.e. data not directly related to the object, but directly influencing it.

At present, geographic information systems (GIS) are widely used to process spatio-temporal data based on cartographic information. GIS are designed to provide decision-making on effective land and resource management, urban management, transport, etc. GIS are characterized by a wide range of graphic and digital data collected using different methods and technologies, processed both analytically and expertly.

Given indicators of this type: $P^G : p_k^G(t)$, $k=1, \dots, K$, one can consider the BLC IM model as a mathematical object of the form B:

$$B = B(A, P^G) \quad (6)$$

BLC IM-models of individual objects, of course, should be elements of a higher-level information system designed to integrate indicators characterizing complexes of objects, individual territories, regions, regions in general.

It is proposed to introduce the concept of a complex generalized Living Environment Information Modeling - LE IM. This information model of type C is the union of a wide range of aggregates of objects of the form A and B:

$$C = C(A, B) = C(P, P^Q, P^R, P^G) \quad (7)$$

LE IM is designed to solve the tasks of urban planning and zoning, to be the basis for creating schemes for regional and sectoral development up to the formation of regional and federal target programs for various purposes. Creation of a single information model that comprehensively characterizes the environment of human life is an important step in the way of effective management of this environment, a serious basis and an instrument for making informed, weighted decisions based on a system analysis of a wide range of interrelated factors.

5 Conclusions

On the way to creating LE IM models, a number of problems need to be solved to create lower-level models (BLC IM). First of all, it is necessary to make adjustments at the level of the construction complex. From the point of view of system theory, a system that unites subsystems with conflicting interests simply cannot function in a qualitative way. It is necessary in this way to restructure the goals facing the system as a whole and the subsystems involved at different stages of the life cycle of the facility in order to orient everyone towards the effective achievement of the final result (the formation of a comfortable living environment) rather than solving the local multidirectional problems of numerous participants in the process.

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