The use of "digital twins" technology in the operation of buildings and structures

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Abstract. The article discusses the use of Digital twins technology (digital twin) in the operation of construction projects. Its application contributes to the most efficient operation of buildings and structures. The "digital twin" is constantly updated with up-to-date information: maintenance companies are engaged in updating the needs of residents, conducts diagnostics of the condition of the building as a whole. This technology helps to determine the exact timing of equipment replacement. The operated building and its systems are under constant supervision and control of management organizations. The cost of operating the building is reduced, as the building is under constant monitoring and diagnostics.

1 Introduction

A digital double is a virtual model of an object that accurately reproduces the form and actions of the original and is synchronized with it. The technology helps to simulate what will happen to the building in different operating conditions. The basis of the digital twin is often a BIM model that appears at the design stage. Information about the current state of the object is added to it and a digital double is obtained. Thanks to the technology of digital doubles, a number of key tasks are solved: it becomes possible to design and build buildings at once, taking, into account the times. The use of "digital twins" technology in the operation of buildings and structures of various scenarios of human movement; to test the temperature and humidity in the room in advance; to introduce contactless interfaces and robotics; to detect problems before the building is put into operation; to reduce financial and organizational risks; to increase the competitiveness and profitability of the business; to plan the development of the company; to increase customer loyalty by predicting consumer requests to the building; calculate the possibility of emergency situations, and save other people in time

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2 Materials and methods

2.1 Researching new digital technologiest

Currently, new digital technologies are already playing an important role in the construction sector, which is undergoing a period of significant changes. These developments were initiated by changes in the Urban Planning Code of Russia, which introduced the concept of an information model (BIM) and the adoption of BIM standards of the Russian Federation based on open standards IFC buikldungSmart [1]. In addition, the use of information models (BIM) becomes mandatory throughout the life cycle of buildings and structures. In this process, BIM represents the undoubted protagonist, revolutionizing the traditional way of working at the main stages of work: design, construction and maintenance. However, the presence of all these aspects under a unique methodology can lead to several problems without a solid basis for regulating the entire procedure (**Figure 1**).

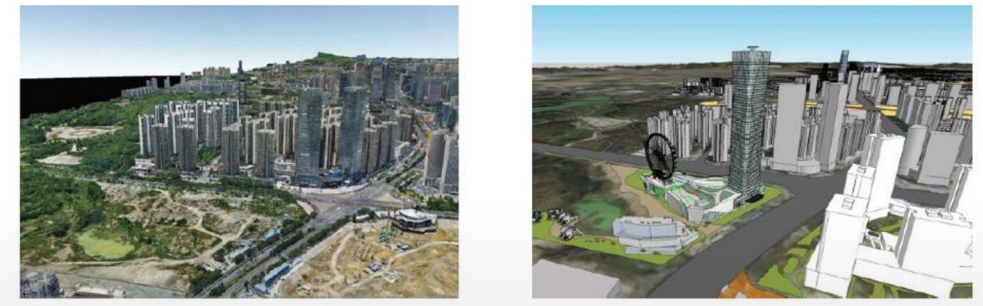

Fig. 1. Digital twins.

A huge amount of information, as well as a large number of people involved, are the main weaknesses that can become the main strengths when the service process or Facility Management is involved in the process [2]. In this scenario, you will need formalized ontologies that can be used to regulate many processes and relationships using the BIM methodology, many of which are described in publications. According to the online publication RB.RU, there are three types of digital twins: DTP — prototype, DTA — aggregated twin and DTI — instance [3].

2.2 Digital Twin Prototype

DTP or Digital Twin Prototype, a prototype is a virtual analogue of an object, it contains information for the production of the original. Such information includes geometric and structural models of the object, technical requirements. Also, the calculation of the cost of construction, design and technological models of the structure are made [4-7].

A DTI or Digital Twin Instance is an instance, a description of a specific physical structure with which the twin will be associated throughout its lifetime. The copy contains data on all the technical characteristics of the object, including its three-dimensional model.

Such a digital double is created on the basis of DTP. It contains the history of the construction of the building, data on materials and components. In this double you will find data on repairs, replacements of system elements. The copy is valid and updated simultaneously with the original.

DTA or Digital Twin Aggregate is an aggregated or combined twin. This is a system that combines a double and an original so that they can be managed from a single centre and exchange data.

The digital twin of the building works in real time. It continuously collects and stores data from all systems, sensors and equipment installed at the facility. The technology analyzes the information received and gives a forecast of the technical condition of the systems, quickly identifies possible breakdowns, sends a signal about the occurrence of an emergency.

In addition to analyzing the technical condition of equipment and systems, the digital twin monitors the efficiency of their work and gives an opinion on the general safety of the building [8].

The digital double sends the data to a special program. Such programs are made by different companies: Siemens, Aveva, Tango, Altec Systems, EPLAN Software & Service Russia, SODIS Lab.

What can be the basis of a digital double [9]:

- the original 3D or 4D graphic model;
- model based on the Internet of things;
- integrated mathematical model for the analysis of engineering calculations;
- holograms and other visualization methods.

The initial model is usually prepared in two ways: a BIM model and laser scanning. The BIM model is formed at the design stage and refined at the stages of author supervision. On its basis, an executive model is made for the completion of the construction of the object. Or the object is scanned by a laser scanner, its digital impression is obtained (**Figure 2)**. The cast is used to model specific elements.

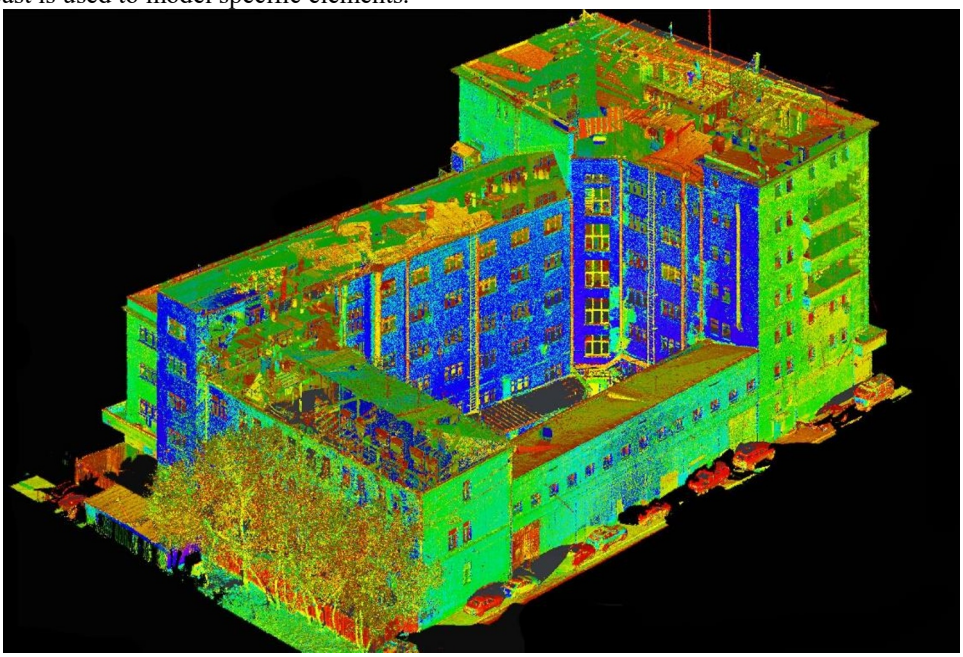

Fig. 2. Laser scanning of buildings.

To create a digital twin, you need to go through the following steps: explore the object, simulate a copy, execute the project and test it, launch the digital twin and debug the processes for the building [10].

Object research is only necessary if the building has a prototype. For example, exactly the same building that has already been commissioned. Then the developers make a detailed picture of this prototype, reproduce all the processes, take into account all the characteristics [11].

If the object does not have a prototype, then modeling a copy will be the first when creating a digital double. A 3D model is created for buildings, and only then the original is erected

At the stage of construction of the project, the developers transfer it to a special platform: Siemens, Dassault Systemes or another. Here the mathematical model is integrated with the interface of the future building, the digital twin receives dynamics [12].

At the testing stage, forecasts are made of how a real building will behave in various conditions. To do this, technical analysts are connected to the process. During the tests, they collect data, and then calculate all possible situations. It depends on this stage how often breakdowns and failures will occur further in the real building, so testing needs to be carried out qualitatively [12].

After that, a digital double is launched. Not all breakdowns can be predicted and predicted, during the launch of the twin, the data collection process continues [12].

Debug processes for the building. The breakdown forecast has been made, now engineers are working with the digital twin as with a real building — debugging processes, making changes to the object to make it as efficient as possible [12].

Before the widespread introduction of this technology in the operation of buildings and structures, it is necessary to calculate profitability. Since one of the most important functions of operation is to ensure safe and comfortable living of people in the building, we will take the time of fire detection as an indicator of efficiency.

2.3 Calculation of the percentage of labor productivity growth from the introduction of digital technologies.

The indicator of the impact of the introduction of digital technologies is the increase in efficiency, therefore, according to the authors, to assess the effectiveness of digital technologies, it is fair to use the percentage of labor productivity growth from the introduction of digital technologies calculated according to formula 1[13]:

$$Z= (((S+ \lambda s)/(T+ \lambda t)-1) \bullet 100\% \quad (1)$$

where

T - the time of fire detection before the introduction of digital doubles;

λt – changing the time for fault detection and troubleshooting due to the introduction of digital solutions;

S - the area of the fire after the time of its location;

λs – the change in the area of the fire after the time of its location due to the introduction of digital solutions.

According to [14], the detection time of the fire is 81 minutes. When using digital doubles, the time for scanning and analysis is 1 minute.

Let's determine the path Lt traversed by the flame front during the free development of the fire (tsv1 = 81 min, tsv2 = 5 min). Let's turn to formula 2 [15],

$$L\tau = 5 \bullet V_1 + V_1 \bullet \tau sv \quad (2)$$

where V_l is the linear propagation velocity of the flame front (fire) is equal to 1.2 m/min, according to the conditions of the problem;

$L\tau 1 = 5 \cdot 1{,}2 + 1{,}2 \cdot 81 = 5 \cdot 1{,}2 + 1{,}2 \cdot 81 = 103{,}2$ m,
$L\tau 2 = 5 \cdot 1{,}2 + 1{,}2 \cdot 1 = 5 \cdot 1{,}2 + 1{,}2 \cdot 5 = 12$ m,

The fire area on can be determined by the following formula 3 [15]:

$$Sp = L\tau \cdot a \quad (3)$$

where a is the width of the room, 10 m.

Sp1 =103.2• 10= 1032 m2
Sp2 =12• 10= 120 m2

3 Results

Fire risk calculation is undoubtedly the most popular fire technical calculation among specialists today. This is due to the fact that this calculation is one of the main criteria for the compliance of the object with fire safety requirements. Risk calculation is also necessary when developing both special technical conditions and a section of the project documentation on fire safety. Based on the calculation of risks, it is possible to significantly revise some points of the regulation of state fire supervision, calculations are necessary for an independent assessment of fire risk, the development of a declaration of fire safety and in a number of other cases.

Based on the calculation results. thus, the efficiency of the introduction of digital technologies improves the indicators of fire detection by almost 23 times.

4 Conclusion

In Russia, digital doubles of the object under construction are also gradually beginning to be used. For example, in 2012, the Etalon group of companies built the Galant residential complex and used BIM: builders applied plan-fact analytics, made a 4D model. Based on the definition of a digital double, it was close to it.

Digital doubles are just beginning to enter widespread use. There is a practice in the mining industry when there is a binding of a digital double to artificial intelligence. A digital double in case of emergency helps to make decisions quickly based on big data. The computer understands how the object is arranged, in what state its components are, and makes the decision itself.

In emergency situations, such as a fire, digital twin technology helps to identify the source of the fire as quickly and efficiently as possible, which, in addition to ensuring safety, also affects reducing the cost of compensation for material damage.

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