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Construction Project Management with Digital Twin Information System

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***Abstract*—The current stage in the development of the construction industry is its digitalization, which requires the transformation of processes and models based on the use of digital platforms and twins. Datasets in a construction project accumulates quickly and becomes difficult to store and process due to the large file sizes of CAD,GIS and BIM technologies. Managing such datasets is a complex problem, since the usefulness of such data lies in ensuring that it is available and used as needed by all participants in a construction project. The article proposes to develop an information system for creating digital twins of construction project management as an integrator of digital tools based on Big Data Analytics and BIM technology, which is already the standard for the digitalization of the construction industry. The study describes four types of digital twins and ten properties of Big Data required for construction project. Conceptual model of Big Data domains for construction project and BIM-model of Big Data exchange and information transfer for construction project digital twin are considered. The authors propose a framework for creating digital twins of construction project management that uses three main components: BIM-models, Big Data Analytics and Knowledge Base. The results of the study are structure of information system of creating digital twin of territory urban planning project for Design Company and example using a BIM-oriented software product.**

***Keywords*—BIM-model, Big Data, digital twin, construction projectmanagement, digital construction**

I. Introduction

The development of the digital constructionindustry in the modern world is largely due to efficient work with large amounts of data (Big Data), or rather, with meaningful ("smart") data (Smart Big Data). One of the leading positions in the formation of gross domestic product in terms of investment in the economy of any country is rightfully occupied by the construction industry, which must meet the requirements of high labor productivity, economic efficiency and global competitiveness. To meet these requirements, a necessary and relevant stage in the development of the construction industry is its digitalization, which requires the transformation of business processes and business models traditionally based on CAD, GIS and BIMtechnologies. There is a problem of correct integration of these information technologies in a single construction project using digital platforms and twins.

There are many definitions of the term "digital twin". Here is one of them, in our opinion the most successful, applicable for a construction project. A digital twin is a virtual copy of a physical object that completely defines its real prototype, starting from a geometric representation, ending with the environment and modeling behavior in real production and operation conditions [1].

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An analysis conducted in 2021 by IDC shows that by 2024, 50% of companies included in the list of 2000 largest public companies in the world according to Forbes magazine (Forbes Global 2000) will use digital twins and digital twin ecosystems [2]. According to Gartner statistics, in 2021, half of large industrial companies have already used digital twins in their activities and stated a 10% increase in efficiency (Fig. 1) [3].

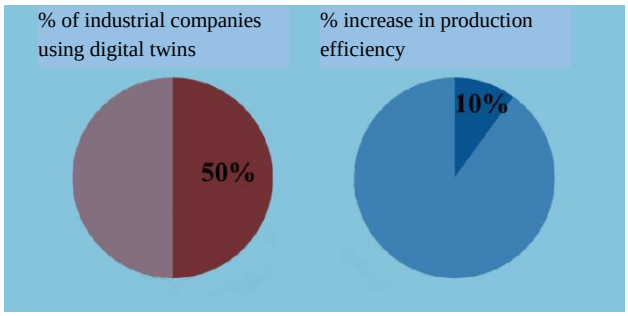

Fig. 1. Benefits of using digital twins by large industrial companies according to Gartner

IDC predicts that in 2022, 40% of Industrial Internet platform companies will integrate platforms and digital simulation technologies to create digital twins, and 70% of enterprises will use digital twins to conduct simulations and assess possible scenarios, which will reduce the risk of equipment failure by up to 30% [4].

Fig. 2 shows the growth forecast for the global digital twin market in 2025 based on Maximize Market Research, PRNewswire, Grand View Research, Market Research Future, Global Market Insights, MarketsAndMarkets, MarketWatch, Juniper Research. According to the analysis of the presented estimates, the forecast of the market size of digital twins varies from $13.8 billion in 2025 to $35.8 billion. Estimates of the average annual growth rates of the markets are estimated by expert agencies as high, but at the same time vary from 28% to 42.5% in year.

In general, experts form a positive forecast for the development of the digital twins market, over the next 5 years the market will grow by almost ⅓ per year, the demand for specialized software and information services for its maintenance and support will increase.

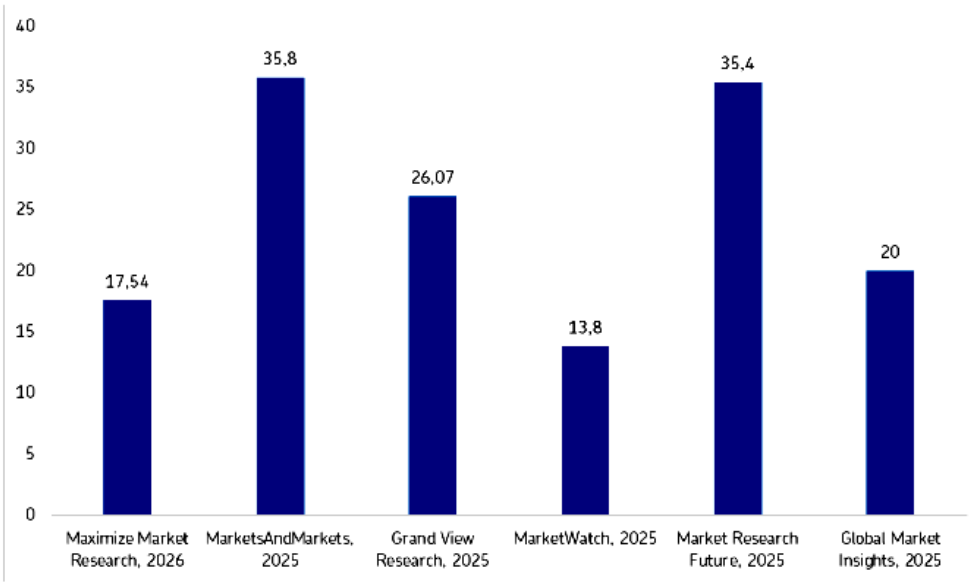

Fig. 2. Forecastofgrowthinthevolumeoftheglobalmarketofdigitaltwinsuntil 2025, billion US dollars [4]

The development and application of digital twins is an advanced driver technology that contributes to the creation of globally competitive and in-demand new generation products in the shortest possible time[5].

Datasets in a construction project accumulates quickly and becomes difficult to store and process due to the large file sizes of CAD, GIS and BIM systems. Managing such datasets is a complex problem, since the usefulness of such data lies in ensuring that it is available and used as needed by all participants in a construction project.

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The scientific works [6-31] confirm that the application of Big Data technology solves the problem of analysis and processing of large-scale and complex datasets, but the task of information integration from different automated systems to create a construction project digital twin still needs solving.

The purpose of this study is to develop an information system model for creating construction project digital twin, which will become an integrator of information technologies based on Big Data and BIM technologies, which are already the standards for the digitalization of the construction industry.

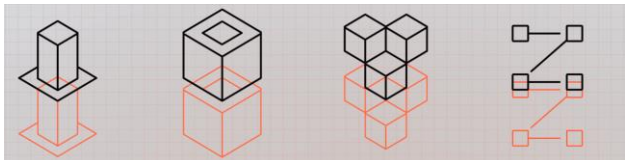
II. Research

The development of the information system model requires scientific and applied tools for the formation of digital twins.Global companies-vendors of high-tech computer engineering systems in the development of specialized solutions for digital counterparts rely, as a rule, on existing computer-aided design and modeling technologies, PLM/PDM solutions, Big Data processing technologies integrated into a single system.

Different vendors can use emerging complementary technologies to "enhance" digital counterparts: AR/VR technologies, industrial Internet platform solutions, additive manufacturing capabilities and Blockchain.

The concept of creating a digital twin in [10] emphasizes the importance of applying and improving industrial Internet technologies, collecting and processing Big Data.

Fig.3 shows the types of digital twins required to implement for construction project.



Digital twin of a component | Digital twin of an object | Digital twin of a system/complex object | Digital twin of a process

Fig.3.Types of digital twins required for construction project

Big Data in the construction industry is rapidly accumulating and becoming hard to store due to the large size of 3D modeling CAD files and 4D modeling BIM technology. Managing such Big Data is a complex and important task, since the usefulness of such data lies in ensuring that it is available and used as needed by all participants in a construction project.

Big Data also enables the development of sustainable structures using test models before actual construction [11].Fig. 4 shows ten propertiesof Big Data that are essential for creating a digital twin.

Fig. 5 presents the author's concept of creating a digital twin of the construction project during the life cycle. A digital twin is a complex model of an object, system and process that allows achieving strategically defined goals.

Thus, to implement the concept presented in Fig. 5, digital twins must be created for a separate component (wall), object (building), system (location area), complex object/set of objects (industrial object/ residential quarter) and process (supply of materials).

1. Value	•The construction project benefits greatly from Big Data
2. Volume	• Sets of Big Data development construction models
3. Velocity	•The increasing the speed of working with Big Data sources expand can stream construction
4. Validity	• The accuracy and validity is crucial for ensuring the usefulness of Big Data
5. Vulnerability	• Big Data enables development of reliable construction models
6. Volatility	• Construction models can change in accordance with Big Data sources
7. Vizualization	• Data vizualization is becoming complex with the increase Big Data
8. Variety	• The variety of Big Data sources increase opportunities for projects
9. Veracity	• The reliability of of Big Data sources is judged by its veracity
10. Variability	• Big Data can vary greatly depending on sources to extract datasets

Fig. 4. Tenproperties of Big Data required for digital twinfor construction project

The digital platform should be considered as a system for managing activities in the field of digital design, mathematical modeling and computer engineering, which is designed to solve the following problems:

- formation of a multi-level matrix of target indicators (characteristics) and resource constraints (temporary, financial, intellectual, technological/production);
- development of mathematical models with a high level of adequacy to real materials, structures, etc.;

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- performing virtual tests;
- development of virtual test sites, performance of virtual tests on them;
- development of smart digital twins;
- automation of engineering calculations;
- collection, processing, cataloging of models and calculation options;
- monitoring, processing and visualization of the results of engineering calculations, the evolution of various indicators / characteristics of objects and processes, as well as technological / production constraints at all stages of the life cycle.

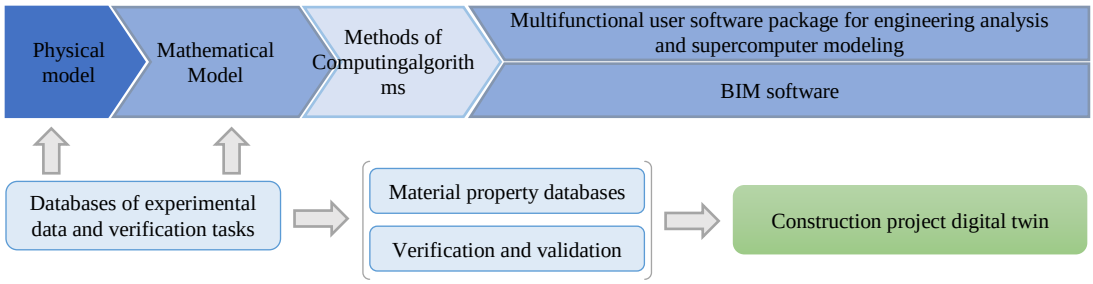

Fig. 5. The chain of creating a construction project digital twin during the life cycle

Digital tool platforms for a construction project have to be able to process huge amounts of data, create and quickly modify complex digital models.

Fig.6 presents a set of digital tools needed to optimize construction production and related business processes.

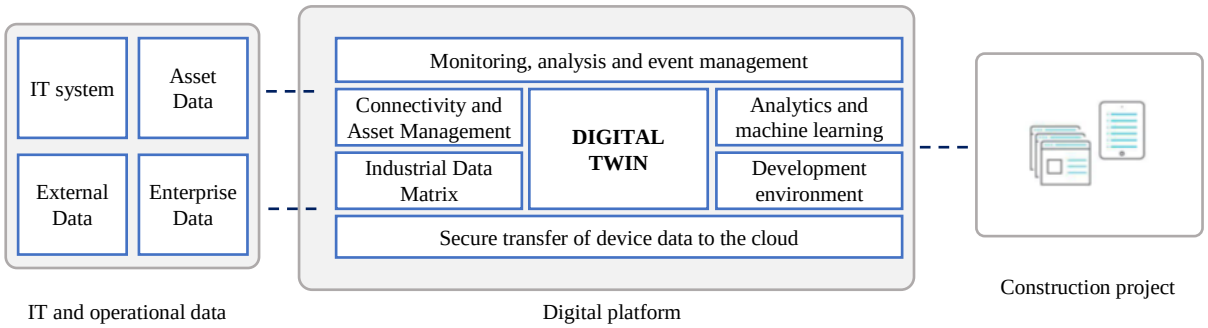

Fig. 6. Digital tools required for construction project

Thus, three key components are needed to create a full-fledged digital twin of a construction project,which are presented on Fig. 7.These components are:

1. *BIM-models:* information about the device and principles of operation of the object, its components, as well as data obtained during its operation.

2. *Big DataAnalytics:* a complete model of an object, including a base models, statistical data, as well as models obtained using machine learning and artificial intelligence to assess and predict the technological state of an object.

3. *Knowledge Base:* additional sources of information, expert opinions, guidelines, data on similar projects.

The presented tools should have a platform form and provide data integration, which allows systematizing and building the process of forming digital twins into a single information technology.

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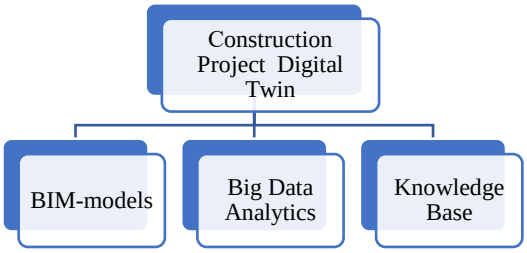

Fig. 7. Three key components to create a full-fledged digital twin of a construction project

Thus, based on rules of information support in design systems and information modeling in construction, it is necessary to adapt Big Data model for storing spatial and attribute data to solve the problem of maintaining a digital twin of a construction project. The Fig. 8 shows a conceptual model of Big Data for construction project digital twin in the form of three main domains.

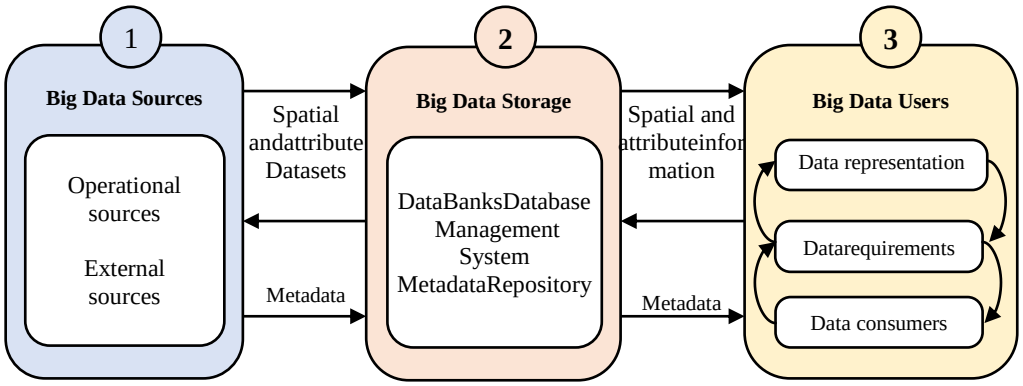

Fig. 8. A conceptual model of Big Data domains for construction projectdigital twin

Domain 1 is Big Data Sourcesthat contain operational and external sources. Domain 2 is a Big Data Storagethat containsData Banks (DB), Database Management System (DBMS) andMetadataRepository,in which operational and external sources supply spatial and attributedatasetsand metadata. Domain 3 is Big Data Users, information consumers who generate required queries to the Big Data Storage through information presentation tools.

To create an information systemfor creating digital twins of construction project management, it is necessary to have a "feedback" with the data storage, which allows you to notify the user about the appearance of the required information in the warehouse and automatically convert the presentation of this information into a convenient one for the user's data. BIM technology is already the standard for the digitalization of the construction industry.It is necessary to adapt the construction BIM model in [13] for information transfer about the digital twin to a conceptual model of Big Data domains for construction project.

Throughout the life cycle, a construction project uses many data sources from different automated information processing systems. The task of the BIM-model is to consolidate data from various sources of information to create a single information space available to all participants of the construction project. A BIM-model of Big Data exchange and information transfer for construction project digital twin presents on Fig. 9.

The databank at the stages of planning, designing and preparing the territory for development should generate information both for operational design decisions and for monitoring existing communications and real estate objects that are in operation. Therefore, means of data transfer and transformationshould be able to receive and transform information, but also provide or automatically download the necessary data from the repository for processing by the operating system in the required data format.

Data stores at the design and production stage of construction project are charactering by a multidimensional representation of information.

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This structure helps to compare the actual with the design data and to carry out the verification of the project. In contrast to the multidimensional information model of general construction tasks, the model requires multi-layering to store cadastral information, and its main element is a cadastral object.

There are some advantages that an information system will have for creating a digital twin based on the developed BIM-model:

- Use an open architecture that is easy to integrate and extend with metadata and data from various information systems: Cadastres, Analytics, GIS, CAD, BIM systems.
- Perceive and recognize information through standard procedures for extracting, transforming and loading data into storage;
- Ensure long-term storage of information and the history of its accumulation throughout the entire life cycle;
- Update and validate source operating system metadata and storage metadata mapping schemas;
- Automatically synchronize storage data with operating system data;
- Convert information in accordance with the metadata of the client;
- Protect information from unauthorized access by other project participants.

The result of applying such a model is aggregated data on a construction object, which will be an information slice for all layers of a multidimensional data model related to the object at a certain point in time of the life cycle.

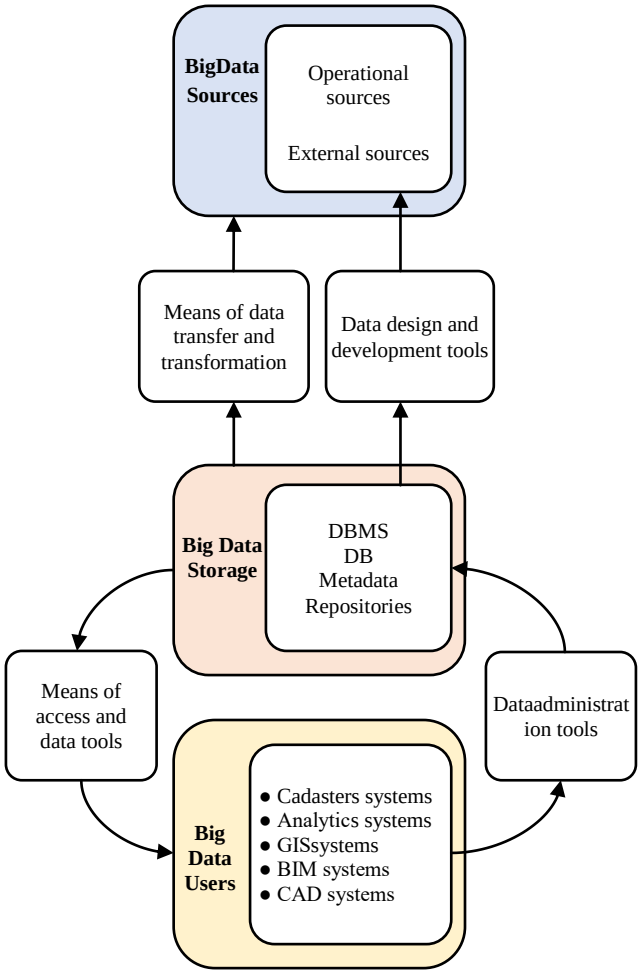

Fig. 9. A BIM-model of Big Dataexchange and information transfer for construction project digital twin

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III. RESULTS

The authors developed the information system model for creating digital twins based on the considered digital tools, designed for the development and maintenance of construction project (Fig. 10).

The use of the information system for creating digital twins will allow monitoring of all changes, evolution and modification of all calculation models, sub models, components and calculation options, as well as providing a clear link between the calculation option and the results of its calculation. This approach will allow to control, compare and visualize the results of chains of calculations performed during mathematical modeling and optimization of a construction project. The digital platform will serve to integrate the intellectual, software and computing infrastructure of all participants in the construction process: contractors, customers, developers, designers, engineers and manufacturers. Thus, the digital platform will ensure cooperation within the framework of project consortiums.

The information system for creating digital twins of construction project managementin Fig.10 differs from similar models of industrial facilities considered in articles [12]–[16] and takes into account the specifics of modeling construction objects with reference to the location area [17]–[22]and takes into account the requirements of digitalization of the construction industry in scientificworks [23]–[31].

The application of Big Data in BIM solves the problems of data analysis and processing of large-scale and complex data sets in BIM. At the same time, taking into account the needs of BIM for technical support in the planning of a large urban area for development, Big Data provides a number of parameters that are adjusted in relation to BIM models of existing and projected objects.The structure of information system for creating digital twin of territory urban planning project in the design company is presented in Fig. 11.

This is a BIM-based approach in which object-oriented elements from BIM form the core data elements fromBig Data Storageto which all other data refer, such as schedule, cost, assets, modeling and performance. It is based on software for developing models from BIM applications. Big Data is stored in systems outside of the core project workflow from BIM, but data keys tie it all together throughout the life cycle of a construction project.

An implementation example of information system for creating digital twin of territory planning project using a BIM-oriented software product is presented in Fig. 12.Information modeling and the creation of a digital twin of existing and project engineering communications (as part of a construction project) in the area allocated for development allows you to obtain a complete set of information data at the stage of urban planning. An open digital platform helps management make rational decisions about the prospects for the development of an urbanized area at the exploitation stage.

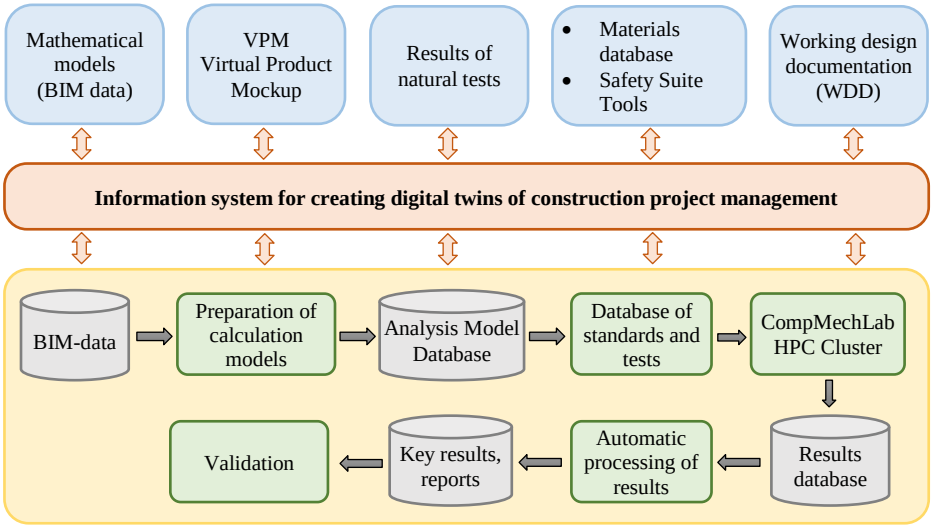

Fig. 10. The information system for creating digital twins of construction project management

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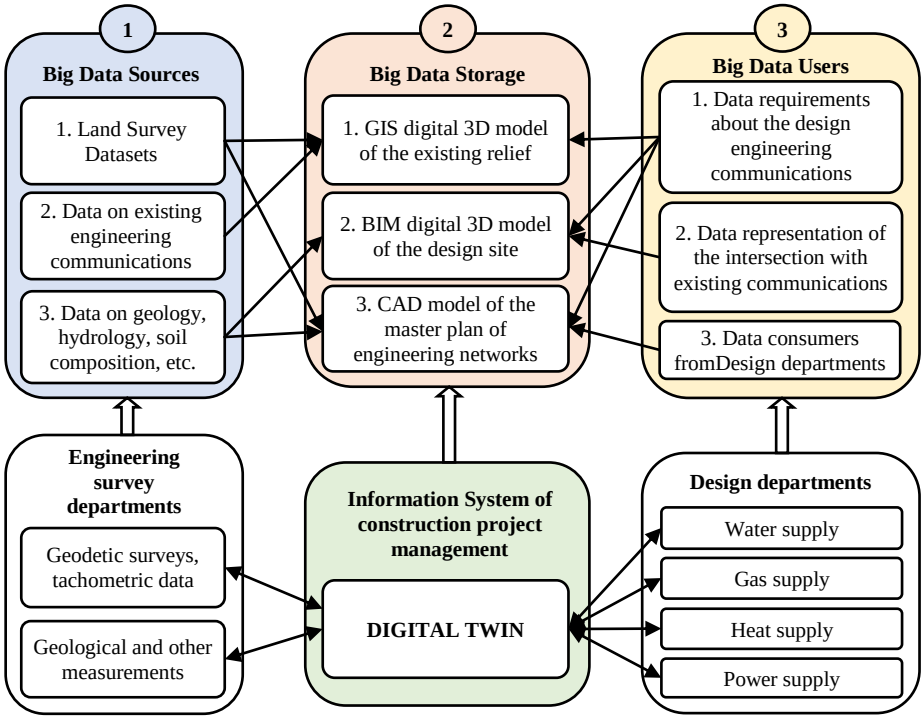

Fig. 11.The structure of information system for creating digital twinof territory urban planning project in the design company

Fig. 12. An implementation example of information system for creating digital twin of territory planning project using BIM-software

IV. CONCLUSIONS

The study proposes the information system model for creating digital twins, which provides opportunities both for processing a huge amount of data and for creating and quickly changing complex digital models in construction projects. The scientific novelty of this study is the emerging approach of forming digital smart tools, which has a platform form and provides data integration.

This position will make it possible to systematize and develop a unified information technology for the process of integrating digital twins of individual components, objects, systems and processes at all stages of the life cycle of a construction project.

The proposed model for the development and maintenance of a digital twin of a construction project should be implemented through the strategy of model-based system engineering based on BIM technology.

The practical implementation of the developed Smart Information System model is supposed to be carried out using a BIM-oriented software product that will allow:

- automate engineering calculations,
- structure and verify a set of models of varying degrees of detail,
- simplify work with the integrated shared data environment,
- check simulation results for collisions and improve the ability to present and compare the results of various engineering solutions.

Thus, the main difference between the presented BIM-model of Big Data exchange from traditional storage is determined by the purpose of accumulating information in a construction project to create a digital twin. The developed BIM-model allows organizing access to information in the database of all participants in the construction project, not for analysis, but for consolidating information from different automated systems. The developed conceptual model of Big Data is the information support of the construction project and provides for the creation of a single digital platform for an integrated information space using existing databases of various automated systems.

Further research can be the creation a digital platform for integrated modeling and creating a digital twin of urban development based on BIM technology.

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