Digital Transformation of the Construction Design Based on the Building Information Modeling and Internet of Things

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Abstract

This study is devoted to the problem of digital transformation in the construction industry. An original scheme of systematic approach to digital modeling of the design of a construction enterprise is proposed. The integration of Building Information Modeling (BIM) and Internet of Things (IoT) for digital modeling in design activity is analyzed in detail. The concept of introducing lifecycle management system construction objects using BIM implementation in directions renovation projects is proposed. The necessity of evolution of information technology IoT from smart things to smart planet is presented.The basic structure of the BIM platform is described, which consists of four components. There are Cloud Computing, Big Data analytics, Internet of Things and Blockchain information technologies. The result of the study is a model of a digital project company for management of the life cycle of a construction object.

Keywords 1

Construction design, digital transformation, Building Information Modeling, BIM, Internet of Things, IoT, Big Data Analytics, Blockchain

1. Introduction

In the process of digital transformation of the economic structure, approaches and tools are being developed that offer a solution to digital control problems by creating a system of algorithms for information flows and organizational relationships between project participants and the real estate market in an integrated information environment [1, 2].

Digitalization and the spread of digital technologies for organizing and managing production occur intensively in all industries and countries. Initially, these processes were evolutionary and discrete, automating individual processes and production cycles [3]. Now the development of strategies for the digital transformation of business processes has become a priority task for most large organizations, regardless of the industry, production specifics or legislative specifics. Moreover, the introduction of information technologies for production management in many countries is implemented at the level of state programs for the digital transformation of the economy. For example, these are such programs as the American Advanced Manufacturing Technology, the German Industry, the strategic concept for the development of production in China, the English program Innovate UK, the Australian National Digital Economy [4-6].

In the investment and construction complex with the formation of new conditions and digital opportunities not only at the level of large corporations, but also at the industry level, there is also an urgent need to rethink the goals of information modeling and develop approaches with a focus on

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long-term information models of a capital construction object, its organization and management of its life cycle.

The authors of the works [7, 8] describe using of BIM technologies to solve the problems of information modeling of construction objects like as most widely used today, which have spread all over the world since the early 2000s. At the same time, until now, most users are adopting BIM mainly for working with graphic 3D models. In practice, the potential and capabilities of BIM technologies that provide information exchange functions for BIM models and other benefits for construction organizations and the state as a whole are rarely used.

The articles [9-11] give a detailed review of requirements on the field of information modeling in construction, regulations, standards and codes of practice are developed separately, in relation to different levels of maturity and BIM integration. In management with the use of information modeling technologies, a BIM platform is being developed for the purposes of managing the life cycle of construction objects, which should interact with other information systems to ensure urban planning activities.

According to these rules, the model of the construction object was formed as a set of archives of poorly structured information is the so-called information containers. This reflects the existing structure of these capital construction objects, contained mainly in reference books and catalogs of buildings, their individual parts and structures [12, 13]. This approach to modeling contains significant risks associated with the fact that the information container operates on the basis of internal closed proprietary data formats. It is proprietary software that works with proprietary formats. As a result, information modeling of the construction and operation of buildings and structures on this basis increases the import dependence of capital construction.

Structuring construction information remains a difficult problem. Until now, there has not been a unified approach to the principles of building a classifier of construction information. The professional community, industry organizations and associations express many comments regarding the existing versions [14]. The most significant shortcomings are associated with the absence of basic library elements for accounting for the life cycle of elements in classifiers and reference books, an incomplete resource composition of processes and prices, which does not allow automatically calculating the cost of construction resources and conducting an examination of the cost of construction.

Another group of risks of the information container model is the problem of open data transmission both between different information systems of the project participants and between successive stages of its life cycle. The problems are related to the specifically large and variable number of participants in the construction project and its specifically long overall life cycle. All this brings a special requirement to the information model of a capital construction object - the need for adequate reflection of data in the process of multiple transformations and for a long time [15].

Accordingly, the state, setting the task of developing information modeling in construction and the strategic goal of developing a unified federal system for managing capital construction facilities based on information modeling technologies, should receive its conceptual solution in an open format that does not depend on a specific developer. At the same time, the created concept of an industry digital platform should provide the ability to add and transform data of different formats throughout the strategically justified life cycle of a construction site.

The purpose of creating an integrated structure is to consolidate the accumulated experience and professional competencies to optimize and increase the efficiency of the implementation of BIM technologies in construction [16].

The analysis of the situation in the work [17] reports as a whole suggests that an urgent request has been formed in the professional environment and there is an urgent need for a unified systematic approach to industry information modeling technologies and in the development of an appropriate comprehensive concept and standards. The development of technical and regulatory documentation in the field of information modeling of capital construction objects has so far been carried out haphazardly and separately.

A unified concept of data standardization has not been formed. Unified directions and stages of solving practical problems of informatization of the construction industry have not been.

There are no specialized integrated solutions. Further digital transformation of the construction industry requires:

1. formulate a single strategic building information modeling target;
2. determine the structure and logic of industry standards for information modeling within the framework of national and other standards;
3. develop directions for organizing a unified system of information modeling of buildings and structures;
4. substantiate practical approaches and the procedure for creating this system.

2. Main research

The authors present systematic approach to digital modeling of the design of a construction enterprise. Fig.1 shows system engineering of digital modeling in design activity.

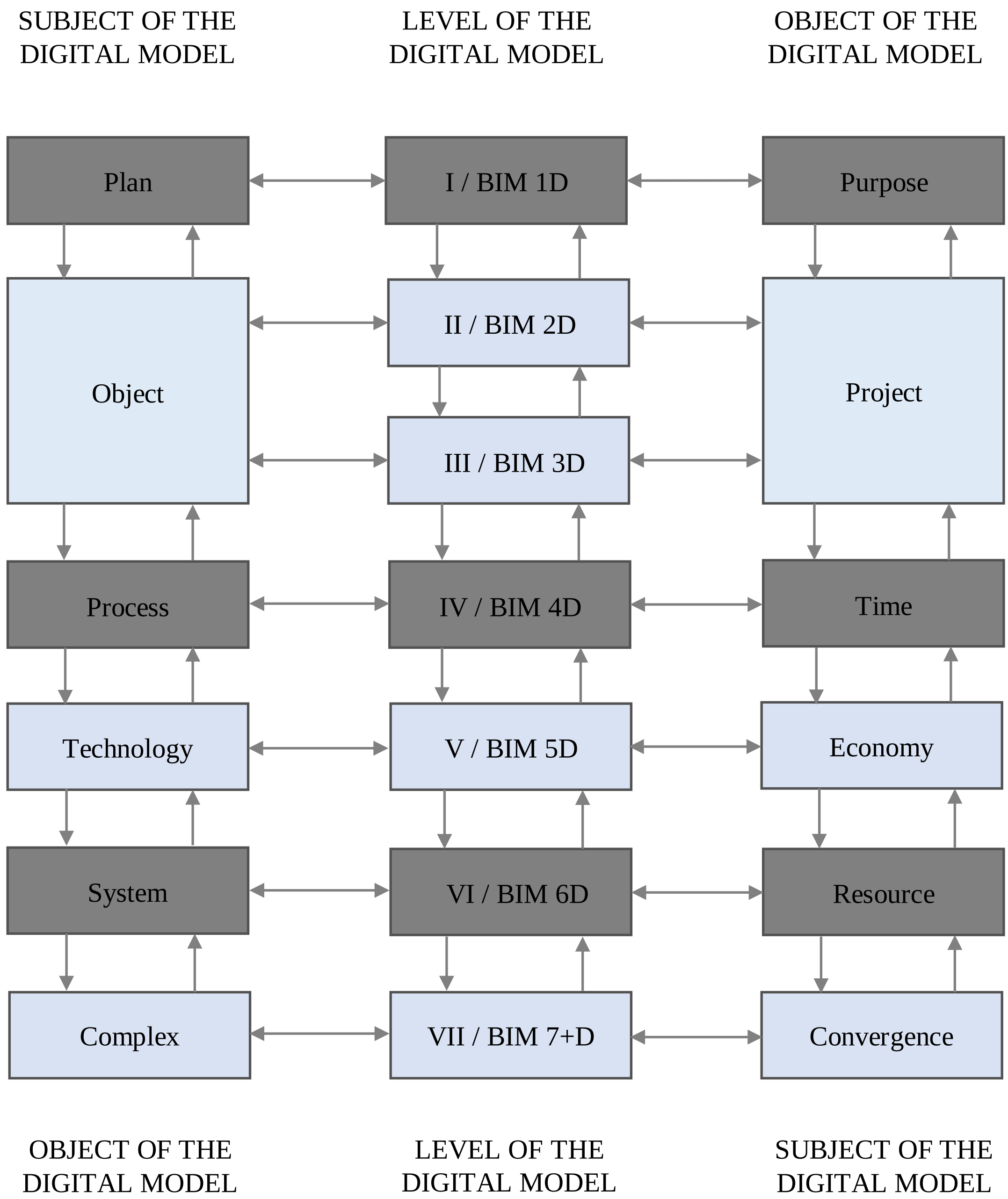


Figure 1: System engineering of digital modeling in design activity

On the presented logical-semantic scheme in the paradigm of cybernetics of problem-oriented modeling, the main subject-object (object-subject) horizontal connections of the constituent elements are abstractly distinguished, each pair of which is determined by the correspondence of its own level of digital modeling.

At the first (I) level of digital modeling of subject-object relationships (the top line of the names of the verticals of subjects and objects in Fig. 1), they are formalized, often in a simple arbitrary or established format, with a description that establishes a direct correspondence between a set of plans and a set of goals. The inverse object-subject connection presupposes the influence of the correction of goals on the plans for their implementation, and the conditionally symmetric subject-object connection (the bottom line of the names of the verticals of objects and subjects in Fig. 1) changes the scheme of priority of correspondence to the opposite - a set of goals is associated with a set of plans.

For the conceptual simplicity of the general logic of the scheme, the presented system technology of digital modeling of creative activity establishes a conditionally direct correspondence of the levels of digital modeling to the levels of BIM dimension. So, the first (I) level of digital modeling corresponds to the first (1D) level of BIM dimension. Similarly, in the logic of the system engineering scheme of digital modeling of creative activity, seven levels are distinguished, corresponding to six levels of aggregation of entities in terms of subject-object (object-subject) relationships: “plan-goal”, “object-project”, “process-time”, “technology-economy”, “system-resource”, “complex-convergence”.

At the second (II) and third (III) levels, the project formalizes two and three-dimensional models of some object of creative activity, respectively. A reverse object-subject relationship assumes the influence of a set of design conditions and constraints on the object itself, and a conventionally symmetric subject-object relationship changes the matching priority scheme to the opposite, when an object is created based on a design priority established for any reason (for example, using a typical project). It should be noted that the essence of the relationship “object-project” of the second (II) and third (III) levels of digital modeling is not limited to two and three-dimensional visualization of the object, but is the basis for the automation and optimization of variant design, design and intelligent parameterization of the project.

The second (II) and third (III) digital modeling levels are defined by the second (2D) and third (3D) BIM dimension levels, respectively.

At the fourth (IV) level, the processes that make up creative activity are formalized by the time necessary for them. Inverse object-subject communication assumes the influence of temporary conditions and restrictions on the processes under consideration, and conditionally symmetric subject-object communication changes the scheme of priority of correspondence to the opposite, when a set of processes is formed based on conditions and time constraints (for example, fixed terms of commissioning of critical for infrastructure object). The essence of the “process“ in the scheme is aggregated by their exhaustive formulation of a specific task set (production, organizational, management processes, etc.).

The fourth (IV) level of digital modeling corresponds to the fourth (4D) level of BIM dimension.

At the fifth (V) level, technologies used in creative activity are formalized by an assessment of the cost of their application. Reverse object-subject communication assumes the direct influence of economic conditions and restrictions on the technologies used, and conditionally symmetric subject-object communication changes the scheme of the priority of correspondence to the opposite, when technological schemes are formed based on financial conditions and restrictions (for example, the availability of one or another technological equipment).

The fifth (V) level of digital modeling is defined as the fifth (5D) level of BIM dimension.

At the sixth (VI) level, the considered objects, processes and technologies that make up construction systems are formalized by the aggregation of all types of resource support for creative activity, presented at the previous levels of digital modeling by economics and time. The inverse object-subject connection assumes the influence of resource conditions and restrictions on the systems under consideration, and the conditionally symmetric subject-object connection changes the scheme of the priority of correspondence to the opposite, when the construction system itself is formed based on the conditions and resource constraints (for example, construction in conditions of interruptions in the supply of construction materials or lack of qualified personnel). The essence of the “system“ in the scheme corresponds to the definition of a “building system“ as a finite set of functional components (elements, objects, construction complex) and the relationship between them, allocated in accordance with a specific goal within a certain time interval [1]. The essence of "resources" is aggregated by their exhaustive formulation of a specific task set (material, technical, labor, organizational, etc.).

The sixth (VI) level of digital modeling corresponds to the sixth (6D) level of BIM dimension.

At the seventh (VII) level, building systems that make up creative activity are combined into complexes that additionally include qualitatively different systems (for example, social or biosphere [9]) and constitute an object of digital modeling of a new class in terms of convergence. The inverse object-subject connection presupposes the influence of qualitatively different in relation to building systems on the complexes in which they are considered, and the conditionally symmetric subject-object connection changes the scheme of the priority of correspondence to the opposite, when qualitatively different in relation to building systems significantly affect the complexes of building systems regardless of their positioning in relation to the complex under consideration (for example, the influence of the geopolitical situation on the course of dependent construction projects).

It should be especially noted that the analysis and solution of most of the tasks of the new, mentioned above, stage of creative activity (stage 4 in Fig. 1) is formalized in terms of convergence precisely at this level of digital modeling.

The seventh (VII) level of digital modeling is defined by an extended seventh (7 + D) level of BIM dimension, which implies further abstraction of any next level of digital modeling of the qualitative convergence of components of systems of various properties (8D, 9D, ..., ND), objectively limited, however, the actual state of the scientific, technical and social progress of society, on the one hand, the objectivity of necessity and elementary common sense, on the other.

Any scaling of the I-VI levels of digital modeling and the corresponding BIM dimension levels is currently objectively exhausted by the framework of the six presented levels of entity aggregation in terms of subject-object (object-subject) relationships: "plan-goal", "object-project", "process-time", "technology-economy", "system-resource", "complex-convergence".

All levels of digital models of the presented system engineering of creative activity are connected by object, by object and by the logic of digital model itself arbitrarily.

Any designated level of digital modeling of creative activity is open for organizing connections with digital modeling systems external to the complex under consideration (for example, weather forecasting).

The described approach to the construction of subject-object and object-subject direct and feedback links at the model level makes it possible to correctly understand the essence and revise the emphasis in many completely practical areas of innovative development and construction industry regulation.

3. Integration BIM and IoT

The most promising, reliable and meeting all the requirements way to achieve these goals is the use of BIM technologies. The concept of BIM technology is in the stage of deep development and is distinguished by the use of information technology in the construction industry. The fields of application, methods and specificity of the concept are rethought by different experts and scientists from different points of view with different fields of research. BIM technologies are interpreted in different ways: as integrated building models, virtual building models and models of individual buildings. That is why, at present, the definition of BIM technology does not have a uniform interpretation at the international level.

The concept is based on the relevant information data of the construction project as the basis of the model, establishes a 3D information model of the construction project and simulates the real information that the building receives through digital information modeling [18].

BIM technology has many features such as visual analysis, collision checking and construction schedule simulation. With the established BIM model, solar radiation, ventilation and lighting of buildings can be modeled to determine the most appropriate location and spacing of buildings, and to formulate reasonable structural design schemes and scientific approaches that effectively reduce the energy consumption of a building [19].

The concept of introducing lifecycle management system construction objects using BIM implementation in directions renovation projects presents in the Table 1.

Table 1

The concept of introducing lifecycle management system construction objects using BIM implementation in directions renovation projects

Directions	Description
First	Formation of the legal framework of implementation of life cycle management of buildings and structures with the use of information modeling
Second	Implementation of the construction information classifier and ensuring its interconnection with existing international and national classifiers
Third	Formation of methodological, regulatory and technical foundations for managing the life cycle of buildings and structures using information modeling
Fourth	Introduction of modern technologies and platform solutions that support business processes, state functions and public services within the lifecycle management of buildings and structures with the use of information modeling
Fifth	Formation of legal, technological and organizational foundations for the exchange of data and ensuring their reliability and relevance in information resources that make up the digital ecosystem for managing the life cycle of buildings and structures using information modeling
Sixth	Development and implementation of professional training programs for specialists in the field of information modeling in construction
Seventh	Development and implementation of performance indicators of the life cycle management system for buildings and structures using information modeling
Eighth	Development and implementation of performance indicators for renovation projects of territories (residential areas), including complexes of buildings and structures using information modeling
Ninth	Strategic planning of the resource base for current and major repairs in order to extend the life cycle of buildings within the predicted time frame using information modeling
Tenth	Development and implementation of indicators of investment attractiveness and efficiency of renovation projects of territories (residential areas) using information modeling for the state and for business in the long term

Fourth direction of the concept for the implementation of a lifecycle management system for capital construction objects using information modeling technology, taking into account the proposed additions, which we considered earlier, provides for the introduction of the latest technologies that support business processes, government functions and public services within the framework of building and structure lifecycle management using information modeling. Within the framework of this direction, it is advisable to integrate BIM and IoT as an actively developing area of Internet infrastructure development in the world, providing enhanced connectivity of devices, systems and services and their interaction with each other.

Integrating BIM with real-time data from IoT devices is a powerful paradigm for applications that improve construction and operational efficiency. Numerous applications enable real-time data streams from the rapidly expanding set of IoTs for high-fidelity BIMs. However, research on the integration of BIM and IoT is still at an early stage, it is necessary to understand the current situation of the integration of BIM and IoT devices [21].

In essence, construction is project management. With digitalization, it turns into control based on data obtained automatically at the point of their origin from IoT devices and sensors, connected machines, platforms and equipment, which allow creating information and mathematical models and algorithms, and realizing more and more autonomous production and business processes having the property of adaptability. That is, the basis for digitalization of construction is informational and mathematical modeling of end-to-end processes, which allows to optimize work in terms of cost, timing, business sustainability and minimization of negative environmental impact, and any other specified characteristics, based on high quality data (in terms of parameters – relevance, accuracy and completeness). So, for almost 30 years of IoT development, according to a number of experts, 4 evolutionary stages have passed [21]. Let's present them in the Table 2.

Table 2

Evolution of the Internet of Things

Stage	Stage characteristics	Example
Stage I – Smart Things	Identification of each object is carried out separately. One fact remains unchanged - a person is needed to connect all objects. It was at this stage of development that the idea of effective interaction between all objects appeared.	Indoor humidity data over a period of time; information about insufficient amount of washing powder in the machine.
Stage II – Smart Building	A system of connected devices and objects that have the ability to communicate. The ability to delegate a significant part of your daily routine to the Internet of Things.	Everything in the house, from the refrigerator to the curtains, is connected to each other, the level of illumination and temperature is regulated thanks to sensors and smart watches. The devices are able to make independent diagnostics, as well as inform about the need for repair work.
Stage III – Smart City	Collective image. It shows a situation where every house will become smart. In other words, the prototype can be implemented if IoT technologies become available to everyone. The collection of individual nodes will create an infrastructure in which all objects will communicate with each other. Provides for the collection and processing of all information related to the inhabitants of the settlement, as well as individual districts, quarters and houses.	All residential areas are under the control of a general analysis of the data that comes from things. Thanks to this feature, electricity consumption is regulated; various breakdowns are recorded and eliminated as quickly as possible. A smart city is an ecosystem in which everything from urban transport to the regulation of commodity and retail relations is shaped by the collection of data. Ultimately, the standard of living rises.
Stage IV – Smart Planet	Sensory planet. Acts according to the example of the third level, but already on the territory of the entire planet. When humans can create an ecosystem of smart things, it's time to shift their focus to Earth. With the help of a system of sensors, humanity will be able to control absolutely all natural processes. It will be possible to avoid the consequences of natural disasters; a base will be formed to track the health of the planet and the possibility of improving it; people will be able to	All cities and countries, all populated and uninhabited areas of the planet are under the control of a general data analysis that comes from things. Thanks to this opportunity, the consumption of natural resources is regulated, the negative consequences of dangerous natural phenomena are recorded and eliminated as quickly as possible, and possible disasters are prevented.

effectively track, control and use resources.

Practical applications of IoT in the construction industry range from smart thing to smart home. The implementation of IoT in construction is complicated, among other things, by the need to take into account the impact on the environment, close ties with housing and communal services, energy and consumer electronics. Based on this, it is possible to determine the current areas of application of the IoT in this area.

A serious advantage of the integration of BIM and IoT is that the Internet of Things is being introduced not only during the operation of the building, but also directly in the design and the stage of construction work.

The integration of BIM and IoT in smart building spans different areas, uses an integration approach in the implementation process that includes a range of cutting-edge technologies, and faces a range of opportunities and challenges. After analyzing this information, it is possible to determine the level of awareness of the population with the possibilities of Smart Construction, to understand which modern technologies used and developed in the world are advisable to invest funds, thereby providing themselves with real competitive advantages. The analysis will focus on those devices of the IoT world, the implementation of which will most significantly strengthen the company's position in the market. And the integration of BIM and IoT, in turn, will provide a synergistic effect.

Fig. 2 presents the key aspects of BIM and IoT integration in smart construction. In our opinion, first of all, it seems necessary to analyze the preferences of potential consumers. Consequently, in the process of new construction, as well as in the framework of the reconstruction of residential areas, builders and developers are invited to use the following scheme to determine the promising directions of the company's development.

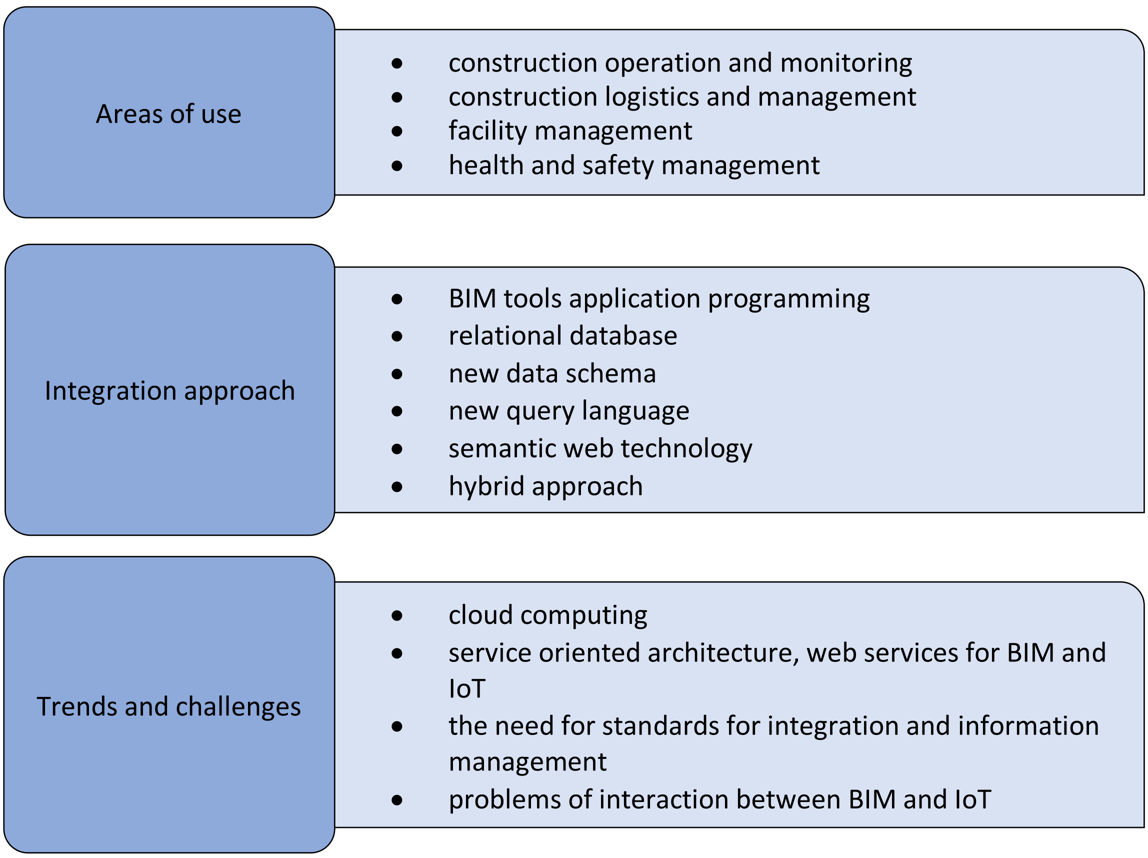


Figure 2: BIM and IoT integration in smart construction

4. Results

Information characterizing a capital construction object appears, replenishes and transforms during all stages of its life cycle – design, construction, operation and liquidation of the object. In fact, this is an information flow, therefore, the structural information model of organizing and managing the life cycle of a construction object can be represented as a set of interrelated information flows of project subsystems. The functionality of digital transformation of organization and construction management is determined, on the one hand, by the growing capabilities and tools of information and communication technologies, and on the other, by the specifics of information flows in construction [18].

Consolidation of many algorithms, tools and approaches of IT technologies leads to the formation of completely new conditions and opportunities for organizing and managing processes in the industry, determines the essence and strategy of changes in the corresponding information flows and forms their new infrastructure.

Let's single out the information and communication technologies that are closest to the industry-specific tasks of information modeling. Fig. 3 presents basic structure of the BIM platform.

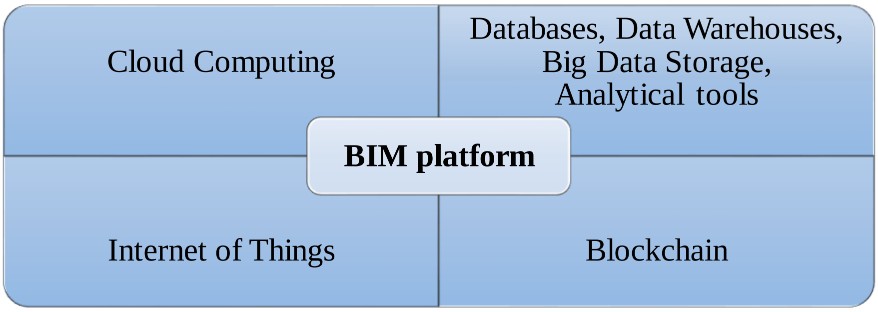


Figure 3: Basic structure of the BIM platform

Firstly, these are cloud computing technologies, which make it possible for numerous project participants to work with project information from different devices with minimal effort to manage their interaction. Cloud services, such as Iaas, PaaS, SaaS, and the like, are currently based on technologies for sharing resources in business processes. Secondly, these are Big Data technologies that use horizontal scaling software tools to analyze and synthesize very significant amounts of diverse data from different sources. It is important that the tasks of organizing and managing the life cycle of a construction project are characterized by varied and unstructured source information. Standard methods and tools for working with data do not allow solving management tasks of this level, and tools and methods of big data in relation to project lifecycle management correspond to the specifics of information flows of a capital construction object. Big Data software products and methods make it possible to work with different, independent and often unstructured arrays of direct and indirect information related to the project, as well as to analyze significant amounts of data from different project subsystems, the information of which is growing, stored and updated with different frequency and speed. To date, leading developers have created many software solutions for big data processing. There are programs from Microsoft, Oracle, IBM, Hewlett-Packard, EMC, Apache Software Foundation (HADOOP), etc. [19, 20].

Another digital concept is the Industrial Internet of Things (IIoT) [21]. The essence of the concept is the unification of engineering developments for equipping with sensors and online connection of structures and devices. Their integration provides instrumental monitoring, organization and management of production processes in real time, remotely and automatically. The digital IIoT concept of the industrial Internet of Things is already forming the infrastructural basis of information flows for the organization and management of the project life cycle.

In the context of the openness and security of the format for managing the life cycle of a construction object, it is also advisable to consider the applied prospects of digital Blockchain technology [22, 23]. This technology is rapidly expanding the scope of various applications. The Blockchain functionality is designed in such a way that:

- information exists in a distributed network built and maintained by network users;
- data are copied in multiples, which ensures maximum stability and security of data storage;
- all information has an open history, which allows to control the authenticity and origin of the data.

Taking into account the specifics of the information flows of the project life cycle in construction, the implementation of these functions is necessary and extremely in demand in the information management model.

Fig. 4 shows a model of the proposed system architecture based on integration of BIM, IoT, Big Data Storage, Cloud Computing and Blockchain.

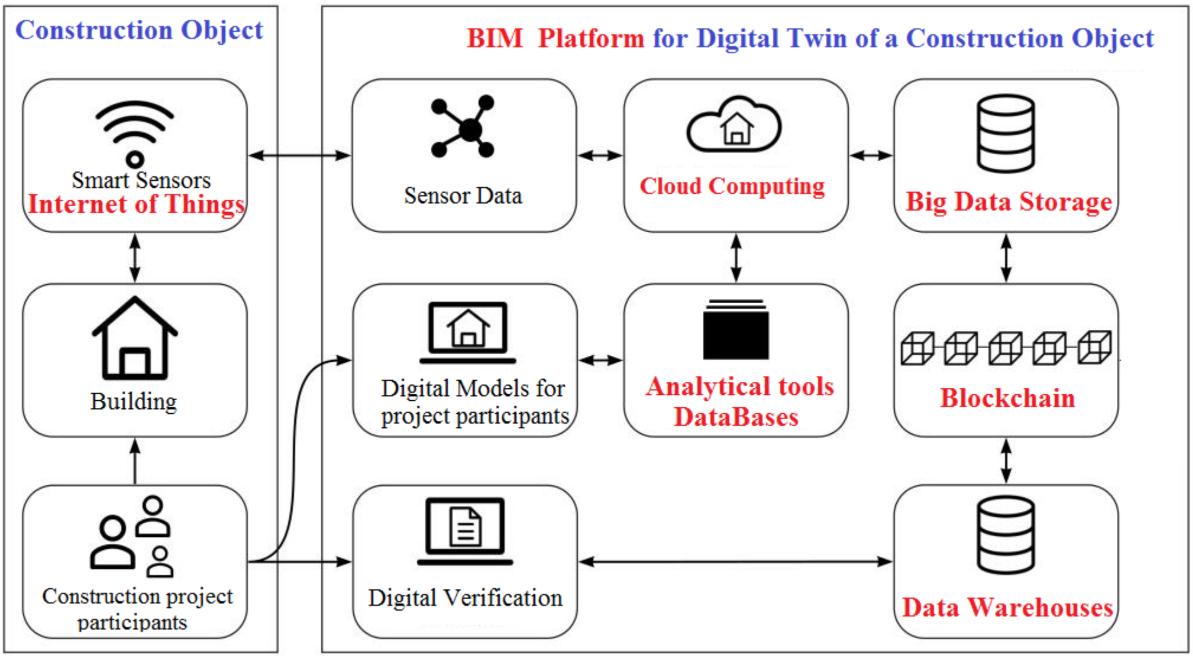


Figure 4: The proposed system architecture based on integration of BIM, IoT, Big Data Storage, Cloud Computing and Blockchain

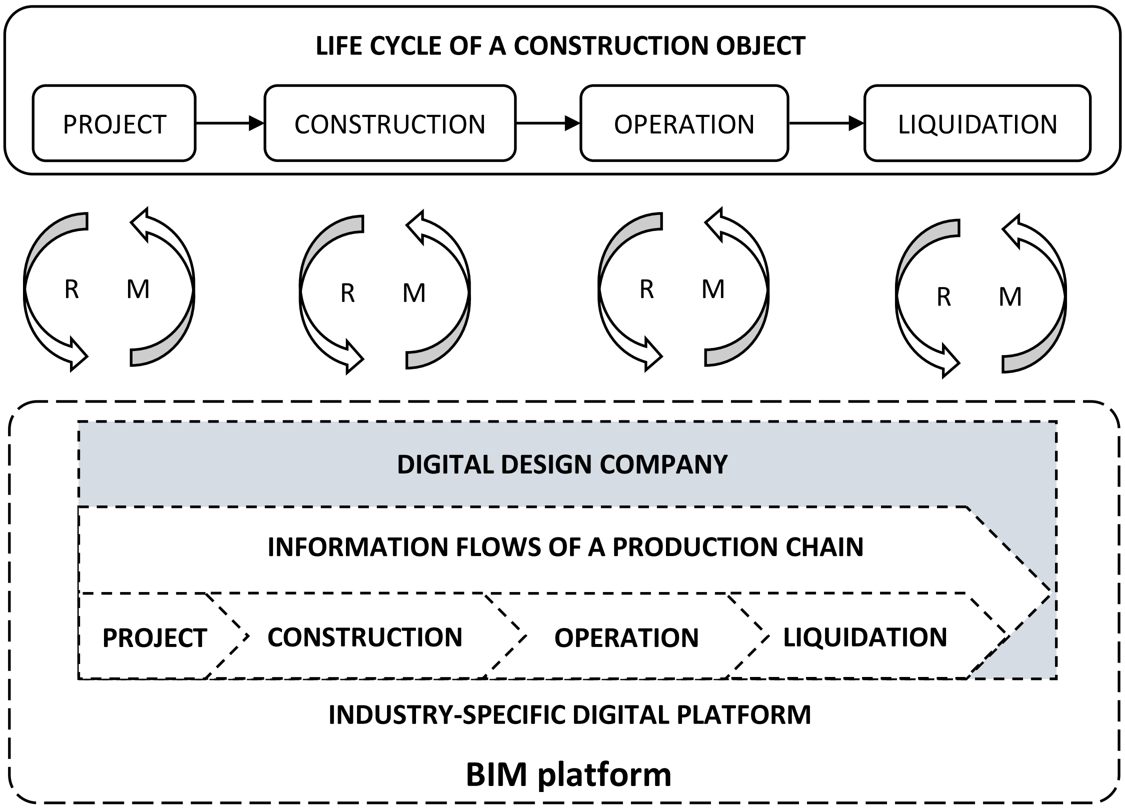
Digital technologies in any industry lead to the economic feasibility of the transition from the number of automated business processes to their qualitatively new information and communication organization and a change in the production organization system. In recent years, on the basis of network communication tools, complex digital production concepts have been formed, which allow organizing the interactions of production participants on new principles.

The defining concept of sectoral digitalization in general and the construction industry in particular, is the sectoral digital platform [24]. The platform consolidates all information and communication software tools necessary for solving industry problems, provides specialists and other participants with access to information and professional services for analytics, planning, organization, management, etc. Without a platform, it is impossible to track the full life cycle of a project and correctly reflect it with information flows. The backbone property of a digital platform is its functionality or an ordered set of algorithms for interactions between project participants and production in a single information space. The available interaction functions of the project participants and the corresponding algorithms determine the advantages, disadvantages, effectiveness and level of maturity of the digital platform. Platforms are classified depending on the functionality available. The industrial digital platform for capital construction must have comprehensive functionality that allows it to solve information tasks (access and work with data on the project and the real estate market), infrastructure tasks (access to digital resources), technological tasks (access to specialized tools and technologies) and corporate tasks (optimization of control processes).

To manage the life cycle of a capital construction object, a management model with a flexible organizational structure is proposed that meets the peculiarities of transformations of successive stages and the composition of participants in the life cycle of a capital construction object is a virtual design enterprise. Fig. 5 shows a model of a project company for managing the life cycle of a construction object.

During the life cycle of an object, a lot of resources are integrated under the project: financial, production, material, intellectual, information, communication, etc. Mobilization of the necessary resources for the needs of the sequential stages of the project can be based on the industry digital BIM platform within the infrastructure and functional services of the virtual project enterprise. The industry digital platform and its tools allow you to quickly organize the attraction of resources and constantly monitor the project. The platform makes it possible to use the resource in the required amount in the required period of time and reduce losses from downtime or resource search. A virtual project enterprise as a management model, along with organizational flexibility, reduces the use of its own resources to the necessary and sufficient minimum. In practice, an own asset in most cases is more expensive than the attracted resource, since it must be maintained in operational condition, even when it is not being serviced. In a virtual engineering enterprise, only those resources are used as its own assets that are required over a long period of the project life cycle. This becomes another factor in increasing the efficiency of the project and its life cycle.

The virtual engineering enterprise operates in real and digital format throughout the entire life cycle of the facility. The information flows of the successive stages of the life cycle are built conceptually as a production chain on a single industry digital platform. All organizational and resource changes are recorded in the digital twin of the project in real time using cloud technologies, big data, the Internet of things and communication technologies for transferring large amounts of information.



R – resource (request ↔ resource mobilization)
M – management (rationale ↔ controlling action)

Figure 5: A model of a digital project company for management of the life cycle of a construction object

5. Conclusions

This study suggests the integration of four information technologies for the digital transformation of the construction industry in terms of their applications, benefits and limitations. BIM and Blockchain integration can improve the safety and efficiency of a construction project, asset management and supply chain. But dynamic project digital data is missing from these technologies. The integration of IoT and BIM provides dynamic digital data throughout the life cycle of a construction project, but these different formats of such data require uniform analytical tools for processing, storing and transferring Big Data. The only combination of IoT and Blockchain is impossible without BIM, because the project data must be presented in digital form. The integration of all these four technologies allows accessing digital information about a construction project and organize its use in the most efficient and safe way.

Thus, we can conclude that information modeling technologies are an extremely promising topic. The topic of "relevance of BIM technologies" is raised at all kinds of forums and exhibitions. Due to the high interest of the state in the implementation of BIM technologies in the construction industry, construction organizations that are making the transition to the use of information modeling technologies can seriously count on state preferences. Today, some of the tasks set by the state for construction organizations seem to be impossible, however, as the experience of many countries shows, the solution of these tasks are just a matter of time.

The urgent need to rethink the goals of BIM technologies in the direction of long-term economic models and life cycle management of capital construction objects was realized. From these positions, the production concept is promising – a virtual design enterprise on a single industry BIM platform, combining digital tools that correspond to the specifics of information flows of the full life cycle of a project in construction.

The virtual design enterprise as a management model optimizes and reduces the costs of the existing management systems. With further development and implementation, this management model on the industry BIM platform can form the information technology basis for a new work organization and interaction between project participants' employees and companies. At the same time, a virtual project enterprise is proposed as a production concept and an organizational basis for the transition to full cycle BIM, to the management of the full project life cycle and the reengineering of the corresponding information flows.

Finally, the authors believe that integrated BIM, Cloud Computing, Internet of Things, Big data and Blockchain information technologies create an innovative framework supporting digital transformation in the construction industry.

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