Construction 4.0: immaterial assets types in the development of design estimates for effective digitalization of building projects

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Abstract. The world building sector is experiencing the global transformation stage. In this process, traditional methods of building and engineering are being refused. Innovative ways to manage investment projects are chosen. They refer to the intangible assets of the enterprise. In the Russian Federation, building digitalization is in its first phase. Nevertheless, the need for the integration of digital technologies is recognized by many branch subjects and is approved on the state level. Many national projects and development strategies also endorse the course. The following problems caused massive engineering digitalization: the lack of needed information or its distortion that helps to decide on building investment realization, the growth of pressure due to reduced time, and price of projects’ realization. The trend of digitalization of the construction industry determines the need to develop the scientific and methodological basis of the management theory of the introduction of advanced technologies. The article represents characteristics and the main aspects of the Construction 4.0 concept in three directions: intellectual factory, modeling engineering, digitalization, and visualization. It also describes and highlights the main provisions in the implementation of such intangible assets as digital document management and the Internet of Things. It is proved that implementation of control and audit procedures based on intangible assets are parts of the information model of the project and digital platforms. This way, effective systematic investment initiatives’ realization can be provided on every building project control level.

Industrial revolutions lead to radical changes in basic technologies. They determine new stages in the development of all spheres of the economy. At the beginning of 2015, the Fourth Industrial Revolution (also known as Industry 4.0) took place. The main focus of the revolution is the transition to digitalization, automation of the production environment. Potentially, it can create a need for a change in the management paradigm. Industry 4.0 modifies technological and innovative business processes by including digital components. Each industry makes a gradual transition from a labor-intensive to a knowledge-intensive industry. To create value, companies are increasingly relying on intangible assets including knowledge, corporate culture, human creativity, and innovation. The building industry is not an exception. Having struggled with competitors and wide innovation usage, the industry should possess the appropriate knowledge, intellectual capital, and technologies. Remarkable is that these kinds of resources are intangible.
The development of intangible resources of the construction company will not only increase the efficiency of internal processes of production and operational activities. It will have a positive effect at the national level in an economic way as the building industry is the basis of the Russian economy. Research analysis has shown that units of construction companies manage and develop intangible resources. That is because the construction industry is described as low productivity with weak technological progress. Computerization, digitization, and automation are being poorly used. However, the industry has to integrate advanced technology to ensure competitiveness and adapt to the era of the knowledge economy.

Many studies of such scientists as G. G. Garanina, N. V. Dolgusheva, N. Yu. Yaskova, K. E. Shannon are aimed at the point-by-point implementation of certain technologies in the realization of investment and construction projects. But it is the lack of a complex approach in the technical development of building organization that stops technological breakthrough. The construction industry must ensure the implementation of innovative developments for the entire product existing cycle. The cycle includes concepts for the development, planning and organization of construction, maintenance, and removal.

Industry 4.0 focuses on digitizing the product value chain and increasing productivity through the use of various technologies and automated production. With the beginning of the Industry 4.0 stage, the innovative development of the building sector became much more accessible and real. However, despite the advantages of the Industry 4.0 stage, the building sector still can not be called a hi-tech sector. Thereby, the purpose of the research is to study the main problems of the construction projects which can hinder the development of the company's intangible resources – new technologies. The second purpose is determining the principles of the digital concept strategy to implement Industry 4.0 technologies into building projects.

Industry 4.0 is a developing and changing environment. The main place there is taken by revolutionary technologies. This term refers to the fourth industrial revolution that includes growing tendencies in technology, such as an autonomous robot, big data analytics, cloud computing technologies, internet of things (IoT), additive manufacturing (3D printing), systems integration, cybersecurity, augmented reality, automation, modeling and artificial intelligence (AI). The leading world’s industrial and manufacturing companies are deeply transforming all the processes according to the Industry 4.0 concept. Companies digitize the main functions inside their systems of the value chain and supply chain. Moreover, they expand their product portfolio using digital functional opportunities and the introduction of innovative services.

At the fourth industrial revolution époque, more and more enterprises give preference to the development of intangible resources, understanding them as an important asset of increasing efficiency of the enterprises and achieving competitive advantages (fig. 1).
Building companies are not an exception. The change of traditional organization methods is predetermined by the complexity and scale of construction projects, the ever-growing demand for sustainable construction. But the building sector of intangible resources development still lags far behind other industries if we watch on process automation and their digitizing level.

There are well-known problems in the construction industry, many of which have remained constant for decades (Figure 2). The impact of these problems is exacerbated as the complexity of the project increases throughout the construction lifecycle.

Faced with the challenges described above, construction companies must recognize the importance of adequately coordinating resources using Industry 4.0 technology. - manpower, materials, financing, machinery, equipment to achieve the project objectives, with minimum time and minimum cost to achieve high-quality finished products.

Traditionally, the construction industry has tended to focus on incremental improvements to individual elements, linking this to the uniqueness of the project and the lack of scalability of innovative technology. In fact, the construction industry has enormous potential for digitalization, innovative technologies and modern construction methods. In general, the main directions of digitalization of construction can be represented as a scheme (Fig. 3).
Figure 2. Problem areas of the construction industry.

Overspending of funds and deadlines specified in the contract

Poorly planned calculation of the necessary costs or underestimated cost indicators, when conducting contract bidding, lead to exceeding the planned costs and timelines for construction projects

Continuous interaction and dependence on suppliers and contractors

55-70% of project work depends on the fulfillment of obligations by external entities. Each company involved seeks to complete its activities as quickly as possible, which can reduce the quality of work and lead to conflict

Lack of or ineffective knowledge management

In construction companies, internal information exchange processes are not automated, which does not allow effective access to information from current and previous projects

Shortage of skilled workers

The industry has a low-skilled workforce, high job rotation, a growing average age of employees, and a high turnover rate

Ineffective financial management

The industry has overdue payments from public or private funds that affect the company's payments to employees and subcontractors. This generates problems in the construction schedule, there is distrust on the part of third parties

Changes in design and construction solutions

Changes in design decisions can occur for a variety of reasons, primarily the predominance of economic criteria over the technical quality of the project during the bidding process.

Lack of strategic planning of fixed assets

Failure to use software tools in the construction process that cause delays in the delivery of materials, equipment, people and other resources

Figure 3. Fundamentals of the formation of digitalization directions in construction.
With the advent of Industry 4.0, the built environment sector was able to move towards more efficient manufacturing based on efficient business models and value chains. Construction 4.0 is a strategic, tactical, and operational paradigm that provides the concepts, principles, and components of the 4.0 industry. Construction 4.0 includes the entire process of construction, from obtaining land for housing to designing and preparing investments. The next stages are the construction of the facility, operation, and maintenance of the building.

The key importance of the paradigm in the construction industry can be traced in three directions: intellectual production, design modeling, digitization, and visualization (fig. 4).

Figure 4. Implementation of Construction 4.0 principles in the construction industry.

The first direction concerns the creation of a smart enterprise, which consists of automation of all processes, digital product lifecycle (PLM). The second direction modeling and value chain includes modeling tools, building information modeling (BIM), augmented reality (AR), virtual reality (VR) and mixed reality (MR). Finally, the third area of digitization and visualization entails cloud computing, mobile computing and social media, which are used to effectively manage construction, including in the operational phase. These volumetric value chains are the key to successful management activities in the construction industry that will drive organizational growth.

As the transition to digital technology progresses, the implementation of the above will become much more complex. They can be managed if building life-cycle models are purposefully integrated into existing systems.

To implement the Construction 4.0 effectively, managers must determine which information technologies will create this concept for the business, for each investment and construction project. The life cycle of a building object consists of four enlarged phases, each of which is interconnected. It is, therefore, appropriate to consider adaptive intangible assets under Construction 4.0. These assets can be applied at each phase and will lead to efficiency gains.
For the successful implementation of the Construction 4.0 concept by the life cycle of changes and the postulated principles of change management, it is necessary to take into account the peculiarities of organizing communication between the participants in the investment and construction project, project changes, as well as the information environment for the project implementation. The solution to this problem within the life cycle of an investment and construction project requires effective management not only operational and objective information and the consistency of the relevant information flow at all stages of the project, but also the use of advanced technologies. As part of the interaction of the participants in an investment and construction project, an important aspect is the use of digital document management and the Internet of things.

One of the fundamental intangibles is the technology of digital workflow, automation and mobility. The purpose of digital workflow is to digitize processes, namely the transition from paper documents to online documents, that is, the exchange of information in real-time to ensure transparency and collaboration, timely progress and risk assessment, quality control, which will ultimately lead to quality and reliable results. As noted earlier, when introducing any technology, it is advisable to determine its value to the company, that is, to determine the problems that the technology solves.

One of the reasons for low productivity is a lack of digitization of key processes and outputs, such as project drawings, orders for materials, equipment use logs, daily progress reports. Informational exchange is often delayed and becomes not relevant for all subjects of the construction project because of a lack of digitization. Wrong documentary management also can lead to disagreement between owners and contractors on issues such as construction progress and work management. In order to minimize this problem, directions for the development of digital document management technologies, automation, and mobility are determined.

For the practical implementation of technologies, it is necessary to develop software that will be fully adapted for each construction project. As you use the software, project managers, specialists and operators will be able to monitor all construction processes in real-time, manage data, and determine the direction of work and generate reports.

To provide control and analytics, it is advisable to use such an intangible asset as the Internet of Things. From the point of view of the construction industry, the Internet of Things is a relatively new and unknown concept. In the last decade, the projects of smart buildings and smart cities include the use of this type of intangible resources. The Internet of Things can be used at all stages of the building life cycle in such processes as sensing, information modeling, ensuring safety on the construction site, quality management of construction and installation works, etc. Thus, the Internet of Things is used in the construction industry to optimize construction processes, which will ultimately lead to money savings and reduce construction time. To ensure the operation of the principles of the Internet of Things, it is necessary to connect all devices, machines, and their digitization in a single software. The use of
the Internet of Things on construction sites provides several advantages for all subjects of an investment and construction project (Figure 5).

![Benefits of using the Internet of Things on a construction site](image)

**Figure 5.** Benefits of using the Internet of Things on a construction site.

Let's take a closer look at the use of the Internet of Things in the field of controlling machines and mechanisms on the construction site when performing construction and installation work. Construction sites are characterized by an abundance of construction equipment and construction and installation work performed simultaneously, which generates huge amounts of data, most of which is not recorded or analyzed. The use of the Internet of Things technology on the construction site will allow you to control the productivity and reliability of personnel, fixed and working capital (Table 1).

**Table 1.** Possibility of using the Internet of Things in quality control of productivity at a construction site.

| Areas of use                                      | Characteristic                                                                                   |
|--------------------------------------------------|---------------------------------------------------------------------------------------------------|
| Monitoring work and assessment of the degree of need for equipment repairs | Installed sensors track equipment uptime and detect maintenance needs                           |
| Inventory and order management                   | The system predicts and warns about the minimum level of reserves of resources that are necessary for the implementation of the project |
| Quality assessment and control                   | Installed vibration sensors are used to check the strength and reliability of the structure during the construction phase, which allows for the early detection of inconsistencies. |
| Security                                         | Installed sensors for employees are used to send alerts and monitor employees, their status and work. |
The use of the Internet of Things will allow organizing control over construction equipment, equipment, materials, personnel. Which will ensure the collection, registration, analytics of information and will allow you to manage labor safety. The essence of information modeling is to ensure the correctness and efficiency of information management processes at all stages of the life cycle of an investment and construction project. The content of information management processes using IoT technologies includes the creation, transformation, storage, distribution, confirmation, and disposal of information by stakeholders. Achieving the goal of ensuring the correctness and efficiency of information management processes leads to the fact that the information management process becomes an integral part of the overall management process of an investment and construction project.

At the level of a construction enterprise, the motivation for the transition to the use of Construction 4.0 technology and, in particular, digital workflow and the Internet of Things will help to meet the existing innovative technological needs of the modern construction market and meet business goals, solving existing problems at each stage of the life cycle of an investment and construction project. This will allow obtaining the corresponding benefits and economic effects from the elimination of problem areas and will allow the enterprise to implement innovative development goals. The main criteria for the effectiveness of digital transformation of construction at the micro level include:

1. Growth in quality: compliance with standards, increased innovation, digital production.
2. Increased efficiency: reducing construction time and cost, increasing competitiveness, increasing profitability.
3. Reducing risks: increasing the accuracy of calculations, increasing controllability at the construction site, reducing transaction costs, increasing the objectivity of control measures.

Control and audit procedures are carried out based on a unified digital environment, a project information model, and digital platforms. In the direction of obtaining possible benefits, this will ensure the effective systematic implementation of investment initiatives at all levels of the construction project management hierarchy.

Construction is a globally significant industry that involves millions of people. This industry makes a great contribution to the GDP of selected countries and the world’s economy in general. But this industry is still conservative in its approach to any innovations. Unlike other economic sectors, the building industry does not take full advantage of the opportunities of the new technological paradigm, technologies of which can increase the efficiency and productivity of the construction sector. Opportunities given by Construction 4.0 concept can truly revolutionize the construction industry and make it a leader in intangible assets and technological innovation.

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