Factors of Innovative Development of Investment and Construction Complex in the Processes of Industry - 4.0

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Abstract: The study goal which consists in the need to analyze the factors of innovative development of investment and construction complex in the processes of Industry -4 is defined; the result on formation of digitalization models for investment and construction company based on the experience of spreading Industry-4 trends in Russia and foreign countries is achieved. The factors that contribute to sustainable development of the investment and construction complex as a socio-economic system are identified. It is concluded that the economic growth basis of the investment and construction complex are the processes of Industry-4, which absolutely ensure its sustainability through implementation of processes of investment and construction complex digitalization, ecology, innovation and location.

1 INTRODUCTION

The investment and construction complex (hereinafter – the ICC) forms the basis for economy and society development, creating the necessary material objects for development of industry and other economic activities, determining the population's quality of life. The ICC's significant role in the economy is confirmed by a number of statistical indicators: scope of work performed in 2020 by type of activity “construction” amounted to 9.5 trillion rubles, the average annual number of people employed in construction – 6.4 million people or 9% of the total number of people employed in the country's economy. 439 thousand enterprises and organizations are involved in the construction field, which is 11.5% of their total number in the Russian Federation.

At the beginning of 2021, the business confidence index, which characterizes the business climate in construction, had a negative value (-15), indicating a low business climate state in this type of economic activity. The improvement of the business climate in construction will be facilitated by enhancing innovation in the investment and construction complex.

The goal of this study is to analyze the factors of ICC innovative development in the processes

Industry-4.0.

Within this analysis, an attempt is carried out to confirm the hypothesis that the basis for progressive economic growth of participants in the investment and construction complex and its sustainability is the increase their competitiveness in increasing the share of the occupied construction market through the introduction of Industry-4 processes.

2 MATERIALS AND METHODS

A significant number of scientific papers by researchers and practitioners in this field are devoted

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to the problems of development of the investment-construction complex and innovations in construction. The works presents general issues of sustainable development of the investment and construction complex as a complex economic and social system and individual issues of analyzing the possibilities of digitalization in the investment and construction complex based on Industry-4.0.

The following articles prove the multidimensional nature of the studied problem, the credibility and correctness of the authors' attempts to prove the inevitability of innovative development in construction.

Ivanova and Zagidullina (2016) analyze the main activation directions of innovation activity in the investment and construction field, highlighting the topical areas of innovation activity, which include: modularity in manufacture and design, manufacture robotization, increasing the manufacture flexibility, development of modern monitoring systems, shows a growing tendency to increase the innovative factors role in the development of ICC and region's economy.

Khrustalev and Artamonova (2016) consider the main aspects of ICC enterprises' development and management, as well as the formation of an innovative approach in the activities of enterprises of investment and construction complex.

Separate issues are devoted to the concept of Industry-4.0. Götz, Jankowska (2020) in the concept of Industry - 4.0 describe specific Industry-4.0 tools that are possible for ICC construction companies to apply, such as an intelligent manufacturing network in which physical manufacturing operations are integrated with digital technology, machine learning and big data, forming a holistic digital ecosystem.

Vertakova and Plotnikov (2019) note that sustainable development is a priority in the modern world and one of its effective tools is the development of a green economy. Scientists propose priorities and directions for green economy development in order to achieve the main goal – sustainable development in Russia.

The social and economic benefits of green technologies in the construction field are known and given in articles by domestic and foreign scientists Bachurinskaya, Vasileva, Yudenko, and Nikolikhina (2020), Acemoglu, Aghion, Bursztyn, and Hemous (2012), Zhineng Tong (2020).

Gizem Erdoğan (2019) in article presents a study aimed at the assumption of significant influence of location factors of industrial enterprises, including the ICC objects on the development of territories within Industry 4.0, the hypothesis is put forward that the existing manufacturing sites will be moved from urban centers in the process of Industry 4.0, and urban settlements will be changed by transforming the land selection criteria, taking into account new requirements.

The analysis of scientific works allowed to conclude that scientists and practitioners share one view about the fact that the ICC innovative development is an important element in solving socio-economic problems, is closely connected with the problems of sustainable development and green economy and has a significant impact on competitiveness and economic growth of the country as a whole, as well as on the prospects of innovative development of ICC as a functioning mechanism and industry development.

The article's research method is based on a qualitative analysis of the observable innovative development factors of the investment and construction complex, realities and facts of their interaction. Collecting data on the investment and construction complex development is a complex process, the implementation of which is helped by usual terminology (investment and construction complex as a socio-economic system, redevelopment); tendency, trends and integrated concepts (for example, Industry - 4 and trends in its development in construction); abstractions in the form of simplified models (for example, digitalization models in construction).

The authors of this study consider Industry-4 as an innovative factor in construction, without denying that the path to Industry-4.0 will be an evolutionary process. Existing basic technologies and experience should be adapted to the specific requirements for the investment and construction complex, and innovative solutions for new territories and new markets in this type of economic activity should be studied.

2.1 Tendency in the Impact of Industry - 4 Processes on the Sustainability of the Investment and Construction Complex as a Socio-economic System

How do the processes of Industry-4 in construction affect the stability of the investment and construction complex as a socio-economic system? According to the authors, the development of Industry - 4 processes should be aimed at increasing productivity (as a result of functional connection between man and machine), the utilization efficiency of fixed assets (the ability of system to make autonomous decisions) and efficiency as a whole (integration of manufacture and IT systems). And we consider it important to refer to the

concept of entropy as a qualitative measure of disorder. The proposed digitalization model in the investment and construction complex, as the socio-economic system, will contribute to the system ordering and self-organization, i.e., the growth of its stability. Entropy characterizes the event and process tendencies, and if the probability of implementing such models increases, then activities within such models begin to occur more often and entropy decreases.

ICC as the socio-economic system refers to dissipative systems that have both stable and unstable states. The sequence of these states is determined by the control parameters by which the external world determines its relationship with the system. By controlling through ICC external influence and choosing certain control parameters, we can manage the development tendency of ICC as a system, in our case, the development tendency of the investment and construction complex. Such control parameters include models of digitalization of investment and construction complex organizations within Industry-4.

The evolutionary process of Industry-4 uses all the resources of increasing entropy. One can speak of evolution towards entropy as a progressive evolution (Prangishvili, 2015). The evolutionary growth of entropy of ICC organizations in the Industry-4 processes means an increase in the probability of emergence of more and more progressive development directions of such organizations and an increase in the prevalence of digitalization models (Table 1), and the high prevalence means the adaptability of such models in construction. And in this case, the investment and construction complex stability as the socio-economic system increases.

3 RESULTS AND DISCUSSION

The success of various approaches to stimulating the innovative ICC development largely depends on the study of factors that affect this process. The concept “factor” is disclosed in literature as the cause, the driving force of a process, a phenomenon, determining its nature or its individual features, an essential circumstance in any process. The study of these driving forces and significant circumstances is the key to making effective and innovative decisions for the ICC development and the growth of its sustainability.

Innovation activity in ICC has its own specifics, which is manifested in the fact that at each stage of the investment and construction project innovation may have different objectives, volumes and sources. This fact distinguishes them from most industrial innovations and requires a systematic approach to the organization of innovation throughout the life cycle of the investment and construction project.

The global tendency in the field of innovative development of the construction industry includes scientific research aimed at reducing energy consumption and withdrawal of natural resources for the production of building materials, reducing the construction period of buildings and other objects, providing recycling of construction waste, efficient use of investment and construction activities.

Let's highlight the most relevant and significant factors of ICC innovative development. These factors include:

- technological modernization of building materials manufacture, construction and installation work performance;
- ICC greening;
- introduction of innovative approaches to the ICC management and the financing of investment and construction projects;
- providing the investment and construction complex with highly qualified personnel;
- ICC digitalization and introduction of Industry-4.0 technologies.

Technological modernization of manufacture processes in construction as a factor of innovative development provides for the introduction of new technologies and equipment at construction enterprises, the production of innovative building materials. Enterprises will be able to create a more technologically sophisticated final product that replaces imports on the domestic market or is able to compete on the foreign market. The need for technological modernization not only in relation to a separate field of activity, but also to the economy as a whole, is considered as a factor of innovative development and other researchers (Boyko I.V., 2018).

ICC greening is the most relevant trend that encourages innovative solutions, the use of innovative materials for building structures, the introduction of energy-saving technologies (energy-efficient house, energy-efficient city, etc.), the creation of “smart networks” and energy-information systems. Of particular importance in this direction is the widespread use of secondary material resources in ICC - waste production and consumption, which not only reduces CO2 emissions and saves natural resources, but also reduces the construction cost.

The defining factor of innovative development, in our view, is the introduction of innovative approaches

to the ICC management. It is about the introduction of multidimensional project management systems that use extensive information bases and digital twins of ICC objects, which will allow to make management decisions reasonably and within a short time, and that will contribute to the capacity building of ICC innovative development. ICC innovative development requires more complex management models for both the state and business, associated with investing in projects for the development of high technologies and human capital development projects with payback time that go far beyond the long-term limits established in the market.

Among the main factors of the ICC innovative development is the availability of highly qualified personnel. In the last decade, the availability of personnel has significantly decreased, according to the Ministry of Construction of the Russian Federation by almost 1.5 times. Innovative development involves the formation of innovative competencies and the effective use of potential of highly skilled workers. In this direction, it is necessary that the competencies formed in the process of education meet the objectives of innovative development of construction and installation materials industry, which can be achieved by strengthening the interaction between higher education institutions and construction companies. It is especially important to create an effective system for the formation of innovative competencies in the field of system engineering, organization and construction management.

A powerful factor of innovative development is the use of modern digital technologies, primarily Building Information Modeling (BIM) technologies, which allow to automate labour intensive processes, simplify the project adjustment, to make decisions based on cost estimates not only for construction but also for the facility operation. Such technologies are aimed at creating a unified scientific, technical and technological, regulatory and information environment for intelligent management of the life cycle of construction projects.

3.1 Industry-4.0 Processes in the Investment and Construction Complex

In the fourth industrial revolution, various economic activities of manufacture are undergoing a series of transformations: robots are working in factories, the internet of things is regulating the use of resources, and new technologies are changing the labor process. Unfortunately, construction has been very slow to transform in this direction, and many construction sites differ little from those of the early 20th century. But there is still some progress.

Construction is a type of economic activity, which is characterized by limitations associated with rising prices of construction materials, high rate of credit, high level of debt between participants in the investment and construction process, which forces builders to optimize their production, accelerate production processes. The answer to solving the objectives can be Industry-4.

The article's authors, having studied and summarized the progressive experience of Industry-4.0 in construction, proposed a list of models within Industry-4 (Table 1).

Table 1: Digitalization models of ICC organizations within Industry-4.

Model name	Content	Participants of the investment and construction market
Construction information classifier (CIC).	Translation of various construction documents into machine-readable format, i.e. document capture	Etalon Group, Platforma stroitelnykh servisov LLC, YUIT Sankt-Peterburg JSC, SiSOFT Development JSC
Ecological safety of buildings as a megatrend in construction, green construction	Reducing CO_2 emissions from their own activities and their own investment projects. Striving for carbon-neutral operation. Availability of licensed software product. Secondary use of water, purification of meltwater and rainwater, automatic control of signals through control room, lighting control in common areas and street lighting.	YIT House, MirLand Development, Millhouse company
Artificial intelligence and machine learning	Machine learning helps teams identify the most critical safety and quality risks on a construction site that require immediate attention.	Banks, financial organizations, energy companies, retail, telecommunications. Construction companies have a low start-up base.

Table 1: Digitalization models of ICC organizations within Industry-4.

Programmed (automatic) devices for operating machines and mechanisms	For example, sensors attached to working equipment will transmit real-time data about its use and possible problems to the supplier. So it will be possible to prevent breakdowns and repairs. Real-time data will also provide the ability to download automatic adds.	Construction companies have a low start-up base.
"Live" materials in construction	Examples include: self-healing biocement, self-replicating concrete substitute, and mycelium-based composites for construction and packaging	Experimental tests
3D printing in construction	Process of creating a three-dimensional model of buildings and structures	Single projects. Pilot construction Apis Cor Company (the city of Stupino, Moscow region). Spetsavia company (residential building).
Robots at construction site	Application in emergency rescue, renovation, construction and dismantling works in harsh environments. The first group consists of manipulators, robots for installation work performance. The second group consists of construction manipulators and robots for concrete work. A large group of construction manipulators and robots are the means of finishing works robotization, etc. (Shagina, 2014)	Mostly – foreign experience. In Russia – Victoria GC

Construction information classifier (CSI). On December 1, 2020, the provisions of Article 57.6 of the Urban Planning Code of the Russian Federation entered into force, which defined the scope of the construction information products. This is an information resource formed as a result of a large scientific research. At the moment, all housing projects of YIT (the largest Finnish and one of the largest Northern European construction companies) use information modeling technologies, which allows to automate the processes of creating standard construction documentation and reduce labor costs for manual information processing. Without a doubt, the CIC implementation is a factor that determines the system's ability to maintain its current state under the effect of external influences.

Ecological safety of buildings and green construction.

At the Summit of Leaders on Climate Issues, the President of the Russian Federation noted that Russia intends to increase the volume of associated gas utilization; implement a large-scale program of environmental modernization and energy efficiency in all economy sectors; ensure the capture, storage and use of carbon dioxide from all sources.

Programmed (automatic) devices for operating machines and mechanisms. Professor and British engineer Paul Newman believed that increasing automation

is met with excitement and fear in equal measure. But the benefits of autonomy for humanity are enormous. At Volvo Construction Equipment, a survey of 205 workers at the construction site yielded the following results – nearly half of all construction workers fear that the reliability and safety of their jobsites could be compromised by the artificial intelligence introduction and machines and equipment automation.

Artificial intelligence and machine learning. The technologies exist and are used by innovative companies to mark visual data and analyze it for potential threats, as well as to reduce all possible risks.

According to McKinsey Global Energy & Materials Practice research, artificial intelligence techniques are used very little in the construction industry. And in heavy industry, many companies have spent years creating and storing big data, but still have not revealed its full value. In fact, the authors' research shows that more than 75% have tried some form of artificial intelligence, but less than 15 % have implemented a meaningful scalable impact (Agarwal, Buckley, Samek, Somers, Hoey, Niel, and Wells, 2021).

What are the limiting factors that make it difficult to use artificial intelligence in construction? These factors include:

– that, if violated, can lead to substantial fines, and the US Federal Trade Commission (FTC) has issued a notice that it may hold organizations accountable for spreading bias or inequality through artificial intelligence;

- shortage of process specialists, in part due to the retirement of full-time employees and a lack of young candidates for employment;
- lack of funds for R&D.

"Live" materials in construction. The choice of building materials for construction purposes is based on profitability and quality in the implementation of investment and construction projects. "Materials for life" is a sustainable system that includes materials and structures that constantly monitor, regulate and repair themselves without external interference. Davies, Kanellopoulos, Pilegis, and Trupti (2015) note in their study that their team is developing a multi-scale system that uses a number of interdisciplinary technologies to promote and enable self-healing in cement materials. The individual healing methods under consideration are designed to eliminate damage at various scopes of duration and time and are encapsulated heal over agents, bacterial heal over, crack close up using shape memory polymer tendons.

In Russia, one of the main building materials is concrete, which is affected by humidity, and therefore scientists Yudenko, Chepachenko, Polovnikova and Nikolikhina (2019) concluded that it is necessary to adapt concrete to a wet environment. In such an environment, self-produced concrete can be used to fill cracks in roads, walls, and sidewalks.

3D printing in construction. If from January 1, 2022 the use of BIM technologies is mandatory for all objects of state order from January 1, 2022, then the use of 3D printing in the Russian market is a promising direction of digitalization, but has a limited application field. This technology is mainly applied for low-rise house building, the creation of small architectural forms, children's playgrounds and sport venues. The advantage of 3D printing is not only reduced expenses and time required for project construction, but also reduced dependence on humans. So far, most printers are adapted to the manufacture of small parts.

Robots at a construction site. At the end of 2020, an experiment began in Moscow to introduce the technology of digital duplication of workers' activities at the construction site. This is a joint project of the Department of Urban Planning Policy and the Department of Information Technology. As an experiment, a special suit and a software and hardware complex were developed that can significantly increase working efficiency.

Another promising field is robot masons. The robot of the Australian company Fastbrick Robotics is capable of laying out up to 225 bricks per hour without human intervention, that is, 4 times faster than an ordinary builder. And the updated model of the device is able to lay out up to 1000 bricks per hour. Swiss engineers, together with architects, materials scientists and robotics specialists, are developing a mobile robot builder to carry out construction work directly on the site. The device can build objects with various tools with an accuracy of up to 5 mm, reach high walls and work in semi-autonomous mode. The architect remotely manages the system, adjusting the construction plan.

3.2 Redevelopment Role in the Industry-4.0 Processes

When forming the Industry-4.0 concept within ICC management, it is necessary to pay special attention to the location selection of investment and construction complex enterprises. This statement is confirmed by the research carried out by Gizem Erdoğan (2019). The study suggests that existing production sites will be moved from urban centers in the Industry 4.0 process, and urban settlements will be changed by transforming the criteria for land selection to meet new requirements. At the same time, special attention should be paid to the redevelopment processes of urban areas with the choice of sites for the transfer of industrial enterprises from central part of city's territories.

The issues immediacy of urban areas redevelopment in the ICC management processes is due to such reasons as the physical and moral obsolescence of the urban real estate fund (residential and industrial buildings), changes in the structure of urban land use due to structural changes in the urban economy (reduction in the share of industrial manufacture and increase in the share of service industry, including trade), low efficiency of the use of urban areas, relatively low density of development in areas of cities built up with houses of the first industrial series, the so-called houses of the Khrushchev and Brezhnev era. For example, in St. Petersburg, according to estimates of the Urbanika Institute, the building density in areas built up in the 1950s-1960s was about 6000-10000 sq. m per hectare, while in the central areas it is more than 20 000 sq. m of buildings per hectare.

The general tendency of changes in the structure of urban land use, for example, in St. Petersburg is a gradual reduction of industrial land. Thus, according to the Committee on Land Resources and Land Management of St. Petersburg, as of 2011, industrial land accounted for 19 thousand hectares or 13.6% of the city's territory. In 2016, their share was already 13% or 13.3 thousand hectares. At the same time, it

should be kept in mind that the practice of urban planning develops faster than changes are made to the documentation on territorial zoning. Former industrial areas are increasingly becoming the object of redevelopment with their transformation into public and business or, even more often, residential development. In general, this process should affect about 6 thousand hectares belonging to the so-called "gray zone" of St. Petersburg.

The implementation of redevelopment projects of industrial territories has been carried out up to the present time, mainly on the basis of the acquisition (or equity participation) of industrial land by investors interested in using it for the development of commercial or residential facilities without direct government participation in the implementation of such projects. And in cases where the case touched on territories with a single owner, such decisions are quite possible. But where the territory has a complex structure of use and ownership (many small plots of land with different functional uses, many owners and holders of other rights to land, buildings, premises, etc.), the decision to redevelop is taken at big expenses, and often hangs in mid-air.

Bachurinskaya I A, Vasileva N V, Maksimov S N, and Yudenko M N (2020) proposed a unified methodological foundation for the formation and implementation of territorial development programs from the perspective of their integrated development in a major city. As a methodological basis for the formation of a system of criteria and performance indicators, it is proposed to use the concept of the best and most efficient use of land, which is well-known in the field of economics and real estate valuation, which will allow, when choosing a location for ICC enterprises within Industry-0, to comply with the principles of energy efficiency and environmental standards, as well as ensure the social, urban planning and economic efficiency of using the territories.

4 CONCLUSIONS

The article considers the main factors of ICC innovative development in the Industry-4.0 processes. The following characteristics of the most significant factors are given: technological modernization of building materials manufacture, construction and installation work performance; ICC greening; introduction of innovative approaches to the management of ICC and financing of investment and construction projects; provision of ICC with highly qualified personnel; ICC digitalization and the introduction of industry 4.0 technologies.

The development features of Industry-4.0 technologies are revealed, such as the growth of labor productivity (as a result of functional connection of man and machine), the efficiency of use of fixed assets (system ability to make decisions independently) and efficiency in general (integration of production and IT systems) in application to the formation of models of ICC organization digitalization within Industry-4.0.

It is noted that the proposed digitalization models in the investment and construction complex, as the socio-economic system, will contribute to the system ordering and self-organization, i.e., the growth of its stability. From the point of ICC management view, the necessity of implementing multidimensional project management systems that use extensive information bases and digital twins of ICC objects is justified, which will allow to make management decisions reasonably and within a short time, and that will contribute to the capacity building of ICC innovative development.

Attention is drawn to the fact that when forming the concept of Industry-4.0 within ICC management, it is necessary to pay special attention to the choice of location for enterprises of investment and construction complex and as a methodological basis for this choice of location concept of the most effective use is proposed. Thus, within the framework of the conducted research, the hypothesis that the Industry -4.0 processes are the stability and development basis of the investment and construction complex is confirmed.

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