Innovations as a Factor for the Sustainable Functioning of a Construction Company

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Abstract. Competitive threats from international and domestic construction companies compel construction industry participants to intensify innovative processes with a view to improving the profitability of construction operations, expanding their offerings and upgrading the quality of their products.

The introduction of assorted innovations is thus a way of enhancing the efficiency of construction operations.

In terms of development levels, innovations may be classified into global, national, regional and industrywide.

A construction company can introduce innovations by:
- Consuming or using materials, machinery or equipment;
- Making construction products in the form of units, buildings or structures;
- Applying products to control corporate organizational structures and construction operations.

Focused on technological innovations, this paper identifies those in the heaviest demand, used most frequently in construction operations, exploring the impacts of construction operation innovations on the sustainable functioning of a construction company. The authors propose a research and engineering hypothesis to the effect that the expert assessment method is instrumental in identifying innovations with positive impacts on construction operations, while ensuring the sustainable functioning of a construction company, subject to the correct selection of experts and assessment criteria.

1. Introduction

The Innovative Development Strategy for the Construction Industry was adopted by the Government of the Russian Federation on 4 March 2014, with a view to developing innovation policies. This Strategy is intended to boost the following three indicators by 2030: the share of construction companies involved in innovative operations; Russia’s share of the international high-tech goods market; and domestic market share held by innovative products [1]. It is worth noting that the Moscow Nanotechnology Center was set up under the auspices of the Moscow State University of Civil Engineering as an institution for training highly-skilled personnel using available and newly-established technology and material research laboratories and test benches. All this testifies to the authors’ relevant choice of the topic for this paper.

Innovative technologies are tools and methods designed for consistent introduction of innovations. In the construction industry, innovative technologies are classified by their focus (objectives), type of construction operations, groups of material resources, and other indicators. “Innovative activities of a
company are linked to the assessment of its innovative potential capacity, an indicator of the level of the company’s preparedness and ability to produce competitive innovative construction products”. [2].

In his paper [3], the author rightly notes that “lack of a unified program for introduction of innovative solutions in the construction industry results in the achievements of global science and technology being used in our country only occasionally. For the overall situation to change fundamentally, an integrated program for introducing innovative technological and organizational solutions in the construction industry needs to be launched”.

Construction operations as the basis of sustainability of a company viewed in terms of estimators are interrelated with innovations in the form of introduction of advanced machines, equipment and materials in the process of construction and assembly works. In his paper [4], the author rightly notes that factors constraining the activities of construction companies include shortage of skilled labor, underutilization of a company’s production capacity, and the worn-out state of construction machines. He also notes that “low labor productivity is the result of heavy physical deterioration and technological obsolescence of construction companies’ fixed production assets as well as inefficient labor management techniques”.

2. Discussion
After conducting an appropriate analysis, the authors have put forward the following hypothesis: the sustainable functioning of construction companies in the dynamic and competitive construction market can be achieved through the integrated introduction of construction innovations.

Sustainability is understood to mean the ability of a dynamic production system (a construction company) to function efficiently in an ever-changing probabilistic competitive environment, despite its production load uncertainties.

The sustainable functioning of a construction company requires cyclic innovations in construction operations through the use of new technologies and materials, with enhanced labor savings and the proper organization and modernization of construction product manufacturing activities [5]. An innovation cycle includes the following elements: research – production – consumption.

A major aspect of the production modernization process is the practical application of innovative scientific advances.

Innovation in the construction industry is becoming increasingly important, with impacts on the efficiency of construction operations and the sustainability of construction companies.

However, there are numerous factors (Figure 1) hindering the successful implementation of innovations: legislative hurdles; weak motivation among developers and designers; inadequate financial support by the state; poor interaction among the parties involved in construction operations; lack of up-to-date business frameworks for introducing innovations; high input intensity of innovations; and a lack of highly-skilled personnel [6].

![Figure 1. Factors impacting the successful introduction of innovations in construction operations.](image-url)
Despite so many obstacles curbing the introduction of innovative products in the construction industry, the State is fully aware of the need for Russia – and hence all construction companies – to pursue the path of innovative development [7].

Innovative activities are often viewed as a prerequisite for the formation of a competitive strategic outlook for the development of businesses. Market competition calls for upgrading the quality of construction operations and shortening their duration, while concurrently lowering construction output costs. At the same time, the deployment of innovations in the construction investment sector is noted for higher investment risks than other industries. Many researchers regard innovations as a key factor for the development of businesses, enhancing the efficiency of construction operations.

3. Theory
In some cases, construction companies must be buffered against destabilizing factors before innovative technologies can be introduced, in order to ensure the successful introduction of innovations in production activities. This process is subject to the following conditions:

- Maintaining and building up the potential output of the construction company (in physical and financial terms), thus underpinning the production capacity required for its sustainable functioning and long-term development;
- Maintaining the financial stability of the construction company, with its assets consisting of invested capital (equity and loans), with the latter being affordable only for profitable businesses.

When vulnerable to destabilizing factors, construction companies cannot operate in risky environments, often failing to comply with construction market conditions and going bankrupt. The construction business outstrips all other sectors in terms of the number of bankruptcies.

A key obstacle to the application of new technologies and materials in practice is the lack of a unified evaluation system that allows planning-stage assessments of all advantages and the downsides of their introduction, right at the start of investment projects.

Another major barrier to the application of new technologies in construction projects is the absence or underdevelopment of the necessary regulatory and engineering standards.

These factors prevent many entrepreneurs from implementing innovations in their operations.

The interrelations between innovation and construction company sustainability are now analyzed in greater detail.

The authors of this paper view sustainability as a factor for a construction company to attain its objectives, measured by the innovation strategy of its choice. The sustainability of its production system is measured by innovative organizational and technological indicators, in an uncertain environment.

Uncertainties related to production activities in the construction industry refer to the operating conditions of a construction company; the behavior of other participants in the construction process; and unpredictable situations that blur straightforward choices among decision-making options. When the probability of the occurrence of an event is unknown, situations may develop in unforeseeable ways, defined as uncertainty.

Uncertainty in strategic terms has an impact on sustainability of construction companies due to the unpredictable nature of innovation results. For this reason, it is of paramount importance that one seeks lower uncertainty in innovative components of development that could be achieved through monitoring and evaluation of innovations [7].

The level of applied technologies is determined by characteristics of advancement of available machines, equipment and materials and the cost effectiveness indicators of technological innovation activities.

The advancement of available machines, equipment and materials is currently evaluated by:

- Comparing the fleet of the company’s available machines and equipment with that required for delivery of its production targets (for example, pursuant to the construction master plan) [8];
- Analyzing the age structure of machines and equipment by dividing into age groups (less than 5 years, 5-10 years, 10-15 years, over 15 years) and determining the proportion of each group in the overall cost of machines and equipment.

The advancement level of available machines and technologies is measured by the following indicators:

- The advancement ratio of machines, equipment and materials:

\[ K_{adv} = \frac{C_{adv}}{C} \times 100\% , \] (1)

where \( C_{adv} \) is the cost of advanced machines, equipment and materials in thousand rubles;
\( C \) is the overall cost of machines, equipment and materials in thousand rubles;

- The proportion of construction products produced using advanced technologies introduced in the current year, in the total scope of construction and installation works:

\[ K_{advt} = \frac{Q_{ciw, advt}}{Q_{ciw}} , \] (2)

where \( Q_{ciw, advt} \) is the scope of construction products produced using advanced technologies in thousand rubles.

The ratio of the proportion of the products produced under the technology introduced in the current year reflects the degree of renewal and upgrading of engineering processes.

Assessment of capacity for innovation, despite a sufficient focus thereon, continues to be a vital problem due to lack of efficient evaluation techniques for innovative operations of construction companies. The issues of the choice of innovative capacity evaluation indicators, their quantity and evaluation methods still remain to be solved [9].

A company’s capacity for innovation is traditionally deemed to include the indicators of personnel, research and development, production and technological, organizational and managerial, and financial and economic capacity.

Analysis of partial estimators of investment capacity has revealed the following.

The impact of innovations on labor productivity in various countries is assessed by the World Economy Statistics. Data are compared in terms of duration of a construction project for the so-called “universal warehouse”. In Russia it takes 279 days, or 72% higher than the world’s average. Singapore occupies the top position in this rating with 26 days required for construction.

This comparison reveals the capacity for development of operations that can be ensured, as the authors believe, by introduction of innovative technologies at all levels of management and implementation of construction and installation works.

The low labor productivity in Russia is due to a large number of production factors [10-13]. Let us review some of them:

- Technological obsolescence of construction machines and equipment;
- Lack of preparedness for innovation risks in the application of new construction materials, techniques and methods;
- Obsolete management methods for construction investment processes;
- Insufficiently skilled labor force.

In view of the above it can be argued that the choice of the key indicators of a construction company’s sustainability is substantiated in terms of accounting for and reflecting the innovation component of construction operations. Dynamics of the sustainability estimators accumulate the attained levels of innovation:

1. Production and engineering. Via the indicators of average duration of construction projects and works, capital intensity, return on investment, the number of construction machines aged older than the standard depreciation term, productivity per worker, as well as the coefficient of renewal of production assets;
2. Organizational and managerial. Via the personnel turnover rate, the personnel stability rate (ratio of employees employed for over 3 years to the overall number of employees) and the ratio of trained employees to the overall number of employees.

Additional technological indicators of innovative nature can include:
- Ratio of the scope of in-house construction and installation works of innovative nature to the overall scope of performed construction and installation works, %;
- Proportion of expenses on technological innovations in the overall costs, %.

Innovative technologies can be exemplified by the new types of large panel construction operations, cast-in-place construction operations, combination of factory-precast structures with monolithic construction operations, precast panel technology, prefabricated low-rise residential houses, light gauge steel framing, permanent framework of various materials, etc.

**Large panel construction operations** mean construction of buildings and structures using special reinforced concrete slabs. This method is advantageous in large-scale projects in microdistricts and mass housing [14].

It should be noted that the technology of classic triple-layer walling panels and hollow floors has been sufficiently studied and introduced in mass construction operations. Russia has been the leader of this technology in mass housing. It has been the largest construction investment project using innovative technologies and materials on the global scale since 1945. This project has been successfully implemented and ensured improved living standards for the bulk of the country’s population. The great number of innovative solutions comprised by this construction method account for its advantages over other construction techniques maintained till now.

The idea of **cast-in-place construction operations** is to cast a monolithic frame first, including the foundation, columns, girders, and floors, and then to erect walls and other architectural forms. The frame is cast in formwork, which can be detachable or permanent. Detachable formwork is dismounted after the concrete sets and mounted on another site, where the next component of the building is cast. **Permanent formwork** is cast with concrete and remains in the structure as its component. It has good water-, sound- and heat-proof properties. This is the most frequently used type of formwork in individual housing projects.

Monolithic houses are predominantly built using heavy-weight concretes. A new development is light-weight concretes. They are characterized by improved efficiency and safety. In addition, houses built with light-weight concretes are much cheaper.

The strong points of the cast-in-place construction technology include:
- Rapid erection of structures;
- Limited shrinkage (due to evenly distributed loads);
- Strength and seismic resistance;
- Minimum joints, etc.

Moreover, a monolithic house is three times cheaper than a house built using the traditional brick or block technologies (cost savings in materials and labor).

The weak points of the said technology are:
- The need for forced ventilation caused by disrupted air exchange;
- High humidity;
- Reduced fire resistance of the building due to the use of permanent styrofoam formwork and sawdust concrete;
- Difficulties of concrete pumping to the upper floors of multistory buildings.

Decision-making on the choice of technologies should take into account all their advantages and disadvantages, the market situation, the company’s operational and technological capacity, the types of operations performed, the competitive environment and other factors. Innovations, if properly applied, reduce the costs and duration of construction and extend the building’s operating life [11-13].

The most widely used innovative building structures and materials include: reinforced concrete walling panels with various heat-saving layers; nano concrete; gas concrete; micro cement; magnesium oxide boards; fiber cement; green fiber; glass fiber and basalt fiber reinforcement, etc. [14,15].

Some current developments introduced in construction operations are borrowed from some other industries of no less importance for the state. Thus, composite materials have been developed by engineers of the leading aviation and defense enterprises. Their research was focused on reducing the
weight and improving the strength of materials. In 1970s, a material named kevlar was developed in the USA as a para aramid fiber that is 5 times stronger and 5 times less dense than steel.

What is also required is monitoring the sustainability of construction companies through control over admissible dynamics of variability of the key indicators of construction operations and introduced innovations.

The essence of this innovative approach lies in the adoption of managerial solutions based on the assessment of expediency of introduction of specific innovations.

Innovation introduction stages are as follows:
- Formation of the innovative idea;
- Assessment of efficiency of introduction of this technology or technologies in construction operations;
- Development of technical documentation;
- Development and testing of a working sample;
- Introduction and commercialization or complete rejection of the innovations.

The choice of assessment criteria should be based on particular features of the factors that have an impact on the organizational efficiency of the construction project. Efficiency (efficiencia in Latin) is the relationship between the result and the resources used (ISO 9000:2015). This particular characteristic allows an objective evaluation of the expediency of application of individual innovations in construction operations [16,17].

4. Methods and techniques
The research methods at the stage of assessing technologies introduced in construction operations for improving technical, economic and time indicators are based on heuristic (expert surveys, testing, etc.) and statistical approaches. Statistical methods are used if sufficient research data are available. The expert assessment method is a variety of surveys that involves competent individuals in the evaluation of various phenomena, in this case innovations. The said method produces a collective opinion as the most accurate and reliable tool of impartial assessment of the materials and technologies under review [18-21]. However, it should be noted that the application of this method is subject to a number of prerequisites:

1) Involvement of experts, who possess specialized knowledge in a certain field and professional experience of dealing with innovations;
2) Correct selection of evaluation criteria. These criteria should be clear for all parties involved in the research and mutually exclusive with other criteria in their content.

Thus, as the authors believe, expert assessment is the most acceptable method of evaluating innovative proposals in certain cases. This method allows a sufficiently objective evaluation of the expediency of application of various technologies and materials and mitigating the risks of inefficient technologies by promoting the introduction of new developments and improving the construction company’s production capacity and resistance to various factors.

The number of experts required for the assessment exercise using this method can be determined by applying the following commonly known formula ensuring representative statistics (3).

\[ E = \frac{h^2 r_a r_o}{\Delta^2} \]

where \( E \) is the minimum required number of experts; \( h \) is the confidence coefficient; \( r_a \) is the share of sample elements possessing the feature under consideration; \( r_o \) is the share of sample elements without the feature under consideration; \( \Delta \) is a sampling error.

The share of sample elements possessing the feature under consideration is determined by the following formula (6):

\[ r_a = \frac{m}{n} \]

where
Let us review an example of calculating the minimum number of experts. We assume that the overall sample scope (the number of research items) is 5, while the scope of the sample under consideration is 1. In this case, we have the following value of the share of sample elements possessing this feature: $r_a = \frac{1}{5} = 0.2$.

If we assume the confidence coefficient to be equal to 90%, we get:

$$m = \frac{h^2 r_a \tau_n}{\Delta^2} = \frac{0.90^2 \cdot 0.2 \cdot 0.8}{0.10^2} \approx 12$$

(5)

Therefore, research with a known sampling error of equal to or less than 10% requires the involvement of twelve experts possessing necessary knowledge on the research subject. Experts involved in the assessments are those registered in the National Register of Builders. Experts are divided into groups of six persons for research on two blocks of innovative proposals.

Accomplished expert assessments are weighted on the basis of their competence and qualification as follows:

$$\sum_{i=1}^{m} w_i x_i$$

(6)

where $m$ is the number of experts,

- $w_i$ is the weight of the $i^{th}$ expert depending on qualification ($0 \leq w_i \leq 1$),
- $x_i$ is the assessment produced by the $i^{th}$ expert.

The weight of each $i^{th}$ expert is determined depending on the expert’s competence and qualification with account of the expert’s experience, educational background and replies to test questions. In this context, $w_i$ equal to 0.5 means a moderate level of expert knowledge in this area of research. If $w_i$ is more than 0.5, a positive conclusion on the expert’s professional level can be made, while $w_i$ less than 0.5 testifies to poor expert knowledge.

As an example, we get a final score of 2 points if we assess an innovation being introduced in construction operations by points from 1 to 5. Accordingly, we can conclude on the efficiency or inefficiency of this innovation depending on the measurement scale we adopt. It should be noted that the experts participating in the survey should have professional experience in the introduction or application of the innovation they are evaluating.

### 5. Conclusions

In so doing, we lay focus on the right direction in evaluation research on innovations actively used and introduced in construction operations, through the application of the expert assessment method. Subject to proper selection of experts and evaluation criteria, this method makes it possible to identify innovations that produce a positive impact on construction operations with resulting attainment of the desired level of sustainable functioning of construction companies in general and improvement in the overall technical and economic indicators of construction investment projects.

It should be pointed out in conclusion that a balanced system of sustainability assessment indicators and the indicators of innovation activity of construction companies can be established at the methodology level as a result of their relative unity and interrelations. Long-term sustainable functioning of construction companies is unattainable without innovations.

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