Innovation incentive mechanism in the construction industry

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Abstract. The construction industry carries out effective innovation activities and is characterized by dynamic creation and implementation of construction technologies. In current economic conditions, the most acute problem is intensification of innovation activities of enterprises and restoration of the investment potential of the construction industry. The author developed an organizational economic mechanism for implementing innovative technologies into the construction industry. The mechanism covers the full cycle of the innovation process, determines the list of its main participants, their functions, and is based on the principles of consistency and integrity. This integral approach makes it possible to plan the innovation process due to the shared information space which has to be created by the government. The article describes a method for assessing the economic efficiency of the innovation process in the construction industry, calculating the economic effect of an economic entity for a certain period and identifying the level of innovation activities of enterprises. Innovation activity indicators are used to evaluate achievements of development and implementation of advanced construction technologies.

Introduction
Currently, the most urgent problem is innovative development of the construction industry. Its efficient operation is required for development of other economic sectors.

In the context of modernization of the construction industry in the structure of the national economy, studies on the current state of the construction industry and prospects for innovative development of this economic sector is a crucial theoretical and practical task [1, 2]. Until recently, the main cause of the economic growth of the construction industry was investment. Currently, market advantages can be achieved through the use of innovations [3,4,5]. With the development of science and technology, the construction process is changing and improving [6]. In these conditions, there are difficulties in maintaining competitive advantages over a long period [7, 8, 9]. More and more attention is paid to creating favorable conditions for attracting additional investment [10], as well as to increasing the share of innovation technologies used in the construction industry [11,12].

Research purpose

The relevance of this article is due to the fact that current conditions for stimulating innovation and investment of construction companies are a key success factor contributing to market competitiveness and production efficiency.

The gap with the world leaders has increased due to the lack of adequate funding for fundamental, exploratory and applied scientific research which forms a theoretical basis for testing and introducing breakthrough developments in new directions [13,14]. The weak development of technology commercialization mechanisms does not contribute to a breakthrough in the most important areas of global innovation development and does not strengthen national positions in high-tech markets [15,16,17].

Thus, the Russian sector of science and high technologies generates ideas and elements of technological solutions that are turned into ready-made integrated solutions in the competing countries and imported back as equipment.

Solving large-scale economic tasks, the construction industry creates an order for optimal technical, technological and organizational solutions that have a multiplicative effect on the entire economy.
Organizational economic innovation incentive mechanism in the construction industry

The authors have developed an organizational and economic mechanism for implementation of innovative technologies in the construction industry - Figure 1.

The main efficiency criterion is a systematic approach that helps implement innovations in the construction industry as a permanent process and follow the principle of integrity when implementing all the stages of the innovation process.

Figure 1. Organizational economic innovation incentive mechanism in the construction industry.
At the first stage, the main task is carried out by the government authorities that create an effective system of interaction between domestic enterprises of the construction industry and research organizations involved in innovative development. To do this, it is necessary to create a shared information space that helps create an open information field to identify the need for innovative products and search for organizations that can develop them.

In the USA, there is an information field where contract centers determine the need for innovation products, form a research project team comprising researchers from various organizations in accordance with the specifics of the innovation development, determine the need for other required resources, and work closely with the government authorities as one of the participants and investors of the innovation process [18,19].

At the first stage, it is necessary to reduce administrative barriers. Involvement of small businesses in the innovative project is also crucial as their main task is to test innovations and determine their efficiency.

The mechanisms for attracting investment for implementation of innovative projects initiated by both research organizations and construction enterprises are venture financing, factoring and franchising.

At the second stage, the innovation idea, based on the economic needs and the innovation project implementation mechanism, is transformed. For this purpose, the research fund concentrates all the resources required for organizing innovative projects, forms an innovative project team, attract resources and controls development of the innovative product.

At the third stage, the innovation product is implemented into the production process of the construction enterprise. Small businesses are more mobile than large enterprises, so it is easier for them to implement innovations in the production process. The period for implementing innovation products as well as making changes in the production process will be shorter and the innovation process will be less painful. Small businesses having limited financial resources get access to the latest achievements of science and technology.

At the fourth stage, the return on investments is carried out as a result of the mass spread of innovative products in large and medium-sized enterprises of the construction industry. The figure shows a direct return on investment which includes the purchase of an innovative product from the owner – the research fund, and a return on investment to the research funds - government authorities. The indirect return on investment is carried out by increasing tax revenues as a result of an increase in the income of construction enterprises.
At this stage, it is important to identify the efficiency of innovative development, taking into account the effect of scale. Innovations in the construction industry occupy a special place in the general classification, since they create positive synergistic effects at the stages of the life cycle of the construction project and in many adjacent economic sectors. Therefore, it is necessary to develop appropriate measurement methods for various innovation activities performed at each stage of the life cycle of construction projects.

**Method for assessing the economic efficiency of the innovation process in the construction industry**

To assess the economic efficiency of the innovation process, the following indicators can be used:

1. The effect of production cost reduction (\(E_{p,c}\)) resulting from the use of innovation products:
   \[
   E_{p,c} = \frac{V_{n,o}}{V_{n,i}} \times (C_{n,o} - C_{n,i})
   \]  
   where, \(V_{n,i}\), \(V_{n,o}\) are the volumes of the production before and after implementation of the innovation process, RUB.;  
   \(C_{n,i}\), \(C_{n,o}\) are the initial cost of production and cost of production before and after implementation of the innovation process, RUB.

   It should be emphasized that this indicator takes into account savings per unit of product or service and the effect of scale. Using this indicator, it is possible to calculate the economic effect for a certain period during which the innovative product is planned to be used.

2. The effect of production cost saving can be calculated by evaluating the rate of reduction of material costs per ruble of output (\(S_{m,c}\)) if the innovation product is aimed at improving the efficiency of material resources:
   \[
   S_{m,c} = \frac{V_{n,i}}{V_{n,o}} \times (M_{c,o} - M_{c,i})
   \]  
   where \(M_{c,o}\), \(M_{c,i}\) are base materials costs of production per unit of product before and after implementation of the innovation process, RUB.

3. The profit increase (\(\Delta \Pi\)) after implementation of the innovation process is calculated by formula:
   \[
   \Delta P = (P_2 - C_2)PV_2 - (P_1 - C_1)PV_1
   \]
where \( P_1, P_2 \) are the prices of the unit of product before and after implementation of the innovation process, RUB;
\( C_1, C_2 \) are the production costs of the unit of product before and after implementation of the innovation process, RUB;
\( PV_1 \) and \( PV_2 \) are the volumes of production before and after implementation of the innovation process in natural measurement units.

4. If the innovative product is aimed at improving the process, it is advisable to apply the technical and economic effect (\( E_{t.e.} \)):
\[
E_{t.e.} = [(C_B + D \times K_B) - (C_R + E \times K_R)] \times N_R \tag{4}
\]
where \( N_R \) is the annual volume of products produced after implementation of the innovation process, units;
\( C_B, C_R \) are the costs of the unit of product produced before implementation of the innovation process, RUB;
\( K_B, K_R \) are capital investments per unit of product before and after implementation of the innovation process, RUB;
\( D \) is the discount rate which brings the capital investment to one year and is calculated in accordance with the method of discounting function application.

5. If the purpose of implementation of the innovation process is to achieve an economic effect, it is possible to use the following methods for assessing the efficiency of the innovation process:

- the first method:
\[
E_T = (\sum_{i=tn}^{tk} P_t \cdot dt - \sum_{i=tn}^{tk} C_t \cdot dt) \rightarrow \max \tag{5}
\]
- the second method:
\[
E_T = \frac{P_t - C_t}{k_p + r} \rightarrow \max \tag{6}
\]
- the third method:
\[
E_T = \frac{(P_t - C_t)(1+r)}{(k_p + r)(k_p^1 + r)} \rightarrow \max \tag{7}
\]
where \( E_T \) is the economic effect of the innovation project for its whole life cycle (from the first investment \( (tn) \) to project completion \( (tk) \);
\( P_t \) is the cost of the results of the innovation event in the \( i \)-th year of the calculation period;
\( C_t \) is the sum of expenses on all types of resources in the \( i \)-th year;
\( dt \) is the discounting rate;
\( k_p \) is the renovation coefficient for the service life calculated by formula
\[
k_p = \frac{r}{(1+r)^{t_l-1}}, \quad t_l \text{ is the life of long-term innovation products;}
\]
\( k_p^1 \) is the coefficient of renovation for the period of production determined by formula
\[
k_p^1 = \frac{r}{(1+r)^{t_n-1}}, \quad t_n \text{ is the period of innovation product production.}
\]
The conditions for applying the first method are possibility of cost assessment of the innovation project and its implementation costs; instability
of the main technical and economic indicators of production and maintenance activities.

The second method may be applied if it is possible to assess the results of an innovative project, stable technical and economic indicators by the years of the calculation period and financing of an innovative project (which is of one-time nature).

The conditions of application of the third method differ from the conditions of the second one. The financing of an innovative project and production after implementation of the innovation process can be carried out over a long period of time.

If it is impossible to carry out the quantitative assessment of the results in order to determine the economic effect of the innovation, the cost estimate according to the minimum cost criterion can be used:

the fourth method: \[ E_T = \sum_{d_{tn}}^{d_{tn}} 3C_t \cdot dt \rightarrow \min \] (8)

the fifth method: \[ E_T = \frac{32}{k_p + r} \rightarrow \min \] (9)

the sixth method: \[ E_T = \frac{3c_i(1+r)}{(k_p+r)(k_p^2+r)} \rightarrow \max \] (10)

where \( C_t \) is the cost of development and implementation of the innovation product for the entire calculation period, RUB.

The fourth method is applied if there are data on costs and their instability by years of the calculation period.

The fifth method is applied for cost stability by years of the calculation period and for production of innovation products over several years.

The sixth method is applied under the conditions of the fifth method, but taking into account the renovation coefficient for the production period.

Thus, the method makes it possible to assess the economic efficiency of the innovation process in the construction industry and calculate the economic effect of activities of the economic entity over a certain period.

**Conclusion**

The development of the construction industry and the national economy is characterized by an increase in the science-intensive production. These structural changes are due to the need for improving the quality of construction products, economic efficiency of investment and construction projects, and their competitiveness. Given the specificity of the development of the world economy, taking into account a new technological order, further development of the construction industry is impossible without close
relations with the scientific sphere [20,21].

The organizational economic mechanism developed by the author covers the full cycle of the innovation process, takes into account the principles of consistency and integrity, identifies functions and tasks of each participant.

The developed system of indicators characterizing the level of innovative activity of construction enterprises, their compliance with the requirements of transition to the sixth technological mode will justify its development strategies in the industry.

The potential for further development of the issue are possibility of improving the theoretical and methodological provisions and practical tools used by 1) the government bodies to stimulate innovative activities of enterprises of the construction industry, 2) and commercial enterprises to increase their efficiency.

References

[1] Antuchevičiene, J., Turskis, Z., Zavadskas, E. K. (2006). ‘Modelling renewal of construction objects applying methods of the game theory’, Technological and economic development of economy, 12(4), pp. 263-268. DOI: 10.1080/13928619.2006.9637752

[2] Andreas Hartmann. (2006) The context of innovation management in construction firms. Construction Management and Economics 24:6, pages 567-578.

[3] Chan, A. P. C., Scott, D. and Chan, A. P. L. (2004), "Factors affecting the success of a construction project", Journal of Construction Engineering and Management, 130(1), pp. 153-155. DOI: 10.1061/(ASCE)0733-9364(2004) 130:1153.

[4] Ellie T. Rigby, Andrew P. McCoy PH.D.Michael J. Garvin PH.D. (2012) Toward Aligning Academic and Industry Understanding of Innovation in the Construction Industry.International Journal of Construction Education and Research8:4, pages 243-259.

[5] Dulaimi, M.H., Ling, F.Y.Y., Ofori, G., et al (2002), Enhancing integration and innovation in construction, Building Research & Information, 30.4, pp237-247

[6] Hardie, M. and Newell, G. (2011). ‘Factors influencing technical innovation in construction SMEs: an Australian perspective’ Engineering, Construction and Architectural Management, 18(6), pp. 618-636. doi:doi:10.1108/09699981111180926
[7] Martina E. Murphy, Srinath Perera, George Heaney. (2015) Innovation management model: a tool for sustained implementation of product innovation into construction projects. Construction Management and Economics 33:3, pages 209-232.

[8] Lim, J. N. and Ofori, G. (2007). ‘Classification of innovation for strategic decision making in construction businesses’, Construction Management and Economics, 25(9), pp. 963-978. doi:10.1080/01446190701393026

[9] Karen Manley, Steve Mcfallan. (2006) Exploring the drivers of firm-level innovation in the construction industry. Construction Management and Economics 24:9, pages 911-920.

[10] Gary D. Holt, Jack S. Goulding. (2016) Positioning construction businesses on an ‘evolution–innovation’ continuum: conceptualization of the ‘equivocal zone’. International Journal of Construction Management 16:3, pages 220-233.

[11] Ozorhon, B. (2012). ‘Analysis of Construction Innovation Process at Project Level’, Journal of Management in Engineering, 29(4), pp. 455-463. DOI: 10.1061/(ASCE)ME.1943-5479.0000157

[12] Strategy for the innovative development of the construction industry of the Russian Federation for the period up to 2030.

[13] Eugenio Pellicer, Christian Luis Correa, Víctor Yepes, Luis Fernando Alarcón. (2012) Organizational Improvement Through Standardization of the Innovation Process in Construction Firms. Engineering Management Journal 24:2, pages 40-53.

[14] Khosrowshahi, F., Ghodous, P. and Sarshar, M. (2014). ‘Visualization of the Modeled Degradation of Building Flooring Systems in Building Maintenance’, Computer-Aided Civil and Infrastructure Engineering, 29(1), pp. 18-30. DOI:10.1111/mice.12029

[15] Bossink, B. A. (2007). ‘Leadership for sustainable innovation’, International Journal of Technology Management & Sustainable Development, 6(2), pp. 135-149. doi:10.1386/ijtm.6.2.135_1

[16] Rose, T., Manley, K. (2010). ‘Client recommendations for financial incentives on construction projects’, Engineering, Construction and Architectural Management, 17(3), pp. 252-267. DOI:10.1108/09699981011038051

[17] T. Michael Toole, Matthew Hallowell, Paul Chinowsky. (2013) A tool for enhancing innovation in construction organizations. Engineering Project Organization Journal 3:1, pages 32-50.

[18] Assessing Innovation and Project Performance, Construction Management and Economics, 23.6, pp 565-577.
[19] Jay Na Lim, George Ofori. (2007) Classification of innovation for strategic decision making in construction businesses. Construction Management and Economics 25:9, pages 963-978.

[20] Brown, A. D. and Phua, F. T. T. (2011). ‘Subjectively construed identities and discourse: towards a research agenda for construction management’, Construction Management and Economics, 29, pp. 83–95. DOI: 10.1080/01446193.2010.531028

[21] Baiden, B. K., Price, A. D. F., Dainty, A. R. J. (2006). ‘The extent of team integration within construction projects’, International Journal of Project Management, 24(1), pp. 13-23. DOI: 10.1016/j.ijproman.2005.05.001.