Universal model of building inspection in construction of technically complex and unique facilities

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Abstract. The article presents the outcomes of the research into improvements of building inspection in construction of technically complex and unique facilities. The authors have defined specific features of building inspection for technically complex and unique facilities and highlighted factors affecting the building inspection of such facilities. They have also ranked factors affecting the building inspection and their differentiation by criticality, further distribution by groups and substantiation of features causing such distribution. All of these issues have been addressed to ensure high quality of construction using construction materials provided in the construction project, complete the project within the cost estimate limits and within the initially defined timeliness. The research resulted in a mathematical model that help combining factors from various groups. An algorithm has been developed comprising guidelines to improve building inspections of technically complex facilities using the proposed model.

Keywords: improvement, building inspection, high-rise construction, technically complex facilities

1 Introduction

Scientific and technological progress intensifies production of sophisticated items including technically complex facilities in construction.

A reasonable transition of global economy from the fifth technological mode to the sixth one taking place in the 2020-s represents new requirements to production quality [1].

It is objectively known that growing complexity in construction related with the development of design and process solutions, using new materials, etc., requires adequate methods of building inspections, which predetermined the relevance of this research.

Therefore, the objective of the described research is to find ways to improve building inspections in construction of technically complex facilities by building a respective universal model.

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1.1 Reference framework

The reference framework of this research includes famous scientific papers dedicated to building inspection improvement in general and in construction of complex facilities, by such authors as Baulin A.V., Perunov A.S. [2], Brodsky V.I. [3], Desyatkov A.S. [4], Kazakov D. A., Tkachenko A. N., Vasilenko A. N., Spivak I.E. [5], Lapidus A.A. [6-9], Motylev R.V., Karpushkin A.S. [10], Orlova E.A., Fomin N.I. [11], Popov, Yu.L. [12], Sabinina S.V., Sinenko S.A., Ognev N.V. [13], Topchy D.V., Tokarsky A.Ya. [14] and others. The reference framework also includes regulatory documents in building inspection for construction of complex facilities such as: Town-Planning Code of the Russian Federation (Article 53 Building Inspection), STANDARD OF THE NATIONAL UNION OF BUILDERS STO NOSTROY 2.20.150-2014. Inspection System for Construction and reconstruction of Power Supply Network Facilities. General Requirements, Decree of the Government of the Russian Federation dated June 21, 2010 No. 468 On Procedure of Building Inspection in Construction, Reconstruction and Overhaul of Capital Construction Projects, Letter of the Ministry of Construction of Russia dated October 15, 2020 No. 41307-IF/09 as to the delimitation of functions and allocating expenses for building inspection and design supervision, Corporative Standard of SRTO Rosatomstroy Building Inspection. Procedure, STO SRO-S 60542960 00038–2019 Standard of the Union's Member Energostroy, Corporative Standard BUILDING INSPECTION. GENERAL REQUIREMENTS, STO 62724300.102-2019, and others.

2 Materials and methods

Technically complex facilities subject to building inspection in this research are extremely hazardous and technically complex facilities (Fig. 1) and unique facilities (Fig. 2) defined by Article 48.1 of the Town-Planning Code of the Russian Federation.

Taking into account a great variety of extremely hazardous and technically complex facilities defined by Article 48.1 of the Town-Planning Code of the Russian Federation (Fig. 1, Fig.2), in accordance with a unified nature of managing complex system, this research was aimed at forming a universal model for improving building inspection in the construction of technically complex facilities.

When defining the approach to a universal model improving the building inspection in construction of technically complex facilities, this research takes the principles of quality improvement by E. Deming [15] where:

- on one hand, attention is paid to improvement of each process (Principle 5), including quality processes;
- on the other hand, it is required to put an end to the dependency on mass inspection [15] (Principle 3).

In this manner, it is necessary to find a compromise approach to quality control (building inspection).

Based on interpretation of Principle 6 of E. Deming proposed in [16] we suggest that quality improvement must be done at all stage of the life cycle, e. g., quality loops described by E. Deming and U. Shewhart, so called PCDA cycles (Plan-Do-Check-Act) (Fig. 3). The control process is planned in each link of the quality loop upon the results of planning and when implementing processes for the purpose of their improvement.

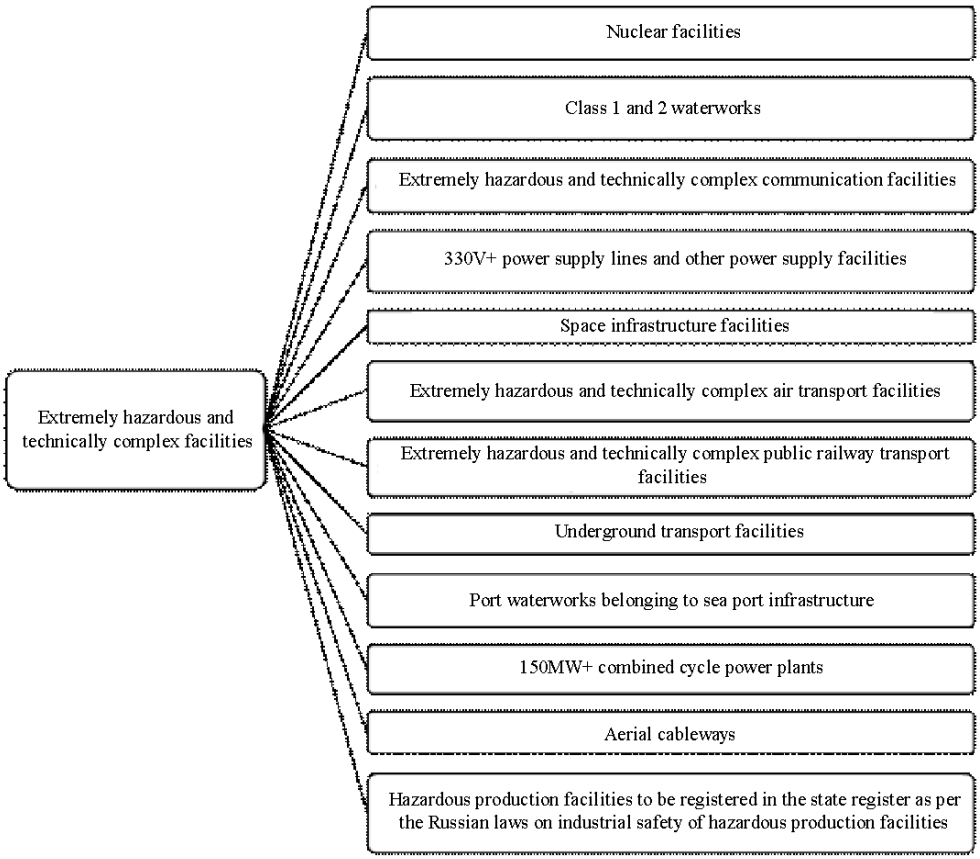

Fig. 1. Extremely hazardous and technically complex facilities defined by Article 48.1 of the Town-Planning Code of the Russian Federation.

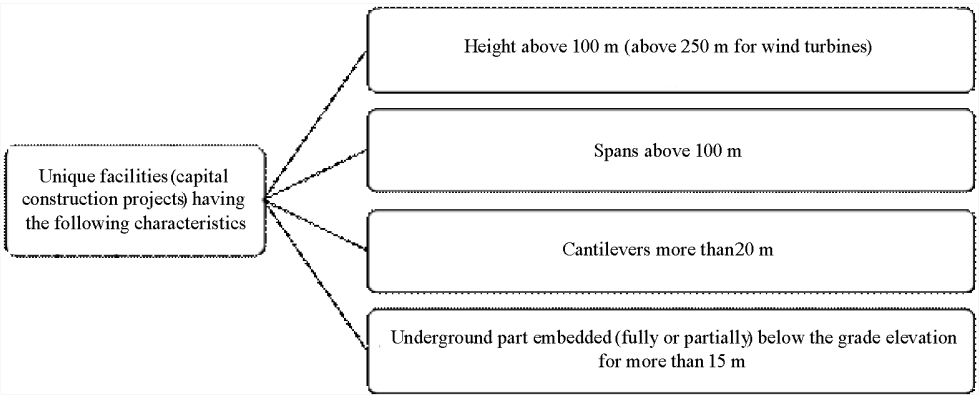

Fig. 2. Unique facilities defined by Article 48.1 of the Town-Planning Code of the Russian Federation.

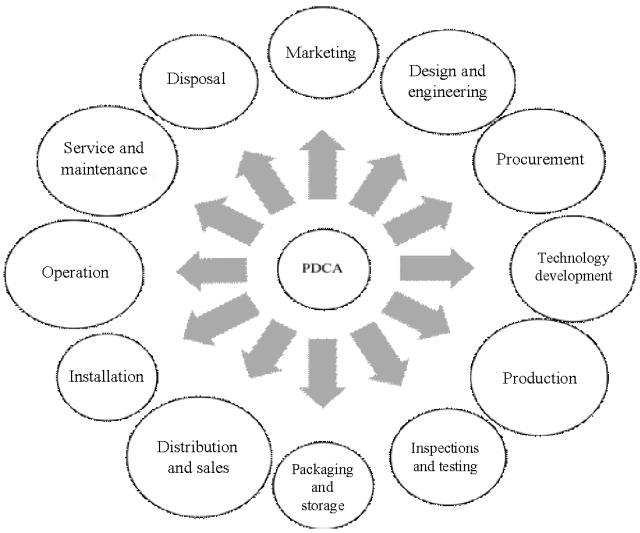

Fig. 3. Implementing PDCA cycle in all links of the quality loop.

Taking into account Principle 3 of E. Deming and the quality philosophy, according to which expenses are reduced and deliverables are improved as the quality grows:

$$\textbf{Quality}\uparrow = \textbf{(Deliverables}\uparrow\textbf{) / (Total expenses}\downarrow\textbf{)}, \quad (1)$$

when forming a universal model for building inspection improvement in construction of technically complex facilities, we suggest it reasonable to selectively improve building inspection of such facilities (Fig. 1, 2) in those links of the quality loop (Fig. 3) that show complexity and appreciation of processes as compared to a previous level.

Equation (1) initially suggests that the value of deliverables must be invariably higher than expenses needed to achieve them:

$$\textbf{(Deliverables / Total expenses)} > 1, \quad (2)$$

The level of building inspection improvement in construction of technically complex facilities must be adequate to the growth of complexity of existing quality loop process (Fig. 3):

$$[(\Delta IL_i/IL_{0i})]/[(\Delta EL_i)/(EL_{0i})] \geq [(\Delta IC_i/IC_{0i})]/[(\Delta EC_i)/(EC_{0i})], \quad (3)$$

where ΔILi is the gain of the improvement outcome of i-the process of the quality loop in construction of technically complex facilities;

IL0i is the initial level of outcomes for the i-th process of the quality loop in construction of technically complex facilities;

ΔELi is the gain of expenses for improvement of i-the process of the quality loop in construction of technically complex facilities;

EL0i is the initial level of expenses for the i-th process of the quality loop in construction of technically complex facilities;

ΔICi is the gain of the control improvement outcome of i-the process of the quality loop in construction of technically complex facilities;

IC0i is the initial level of control outcomes for the i-th process of the quality loop in construction of technically complex facilities;

ΔECi is the gain of expenses for control improvement of i-the process of the quality loop in construction of technically complex facilities;

EC0i is the initial level of control expenses for the i-th process of the quality loop in construction of technically complex facilities.

In the general case, the following relations must be fulfilled when improving the building inspection in construction of technically complex facilities:

$$\sum[(\Delta IL_i/IL_{0i})]/[(\Delta EL_i)/(EL_{0i})] \geq \sum[(\Delta IC_i/IC_{0i})]/[(\Delta EC_i)/(EC_{0i})], \quad (4)$$

$$\sum[(\Delta IC_i/IC_{0i})] > \sum[(\Delta EC_i)/(EC_{0i})]. \quad (5)$$

The total growth for quality loop elements in the construction of technically complex facilities must be no less than the quality growth of building inspection improvement in the construction of technically complex facilities (4), and a relative gain of the improvement outcomes of control processes for all links of the quality loop in the construction of technically complex facilities must be higher than the gain of expenses for improvement of control processes for all links of the quality loop in the construction of technically complex facilities.

To use the proposed universal model for building inspection improvement in the construction of technically complex facilities, it is reasonable to use the developed algorithm represented in Fig. 4.

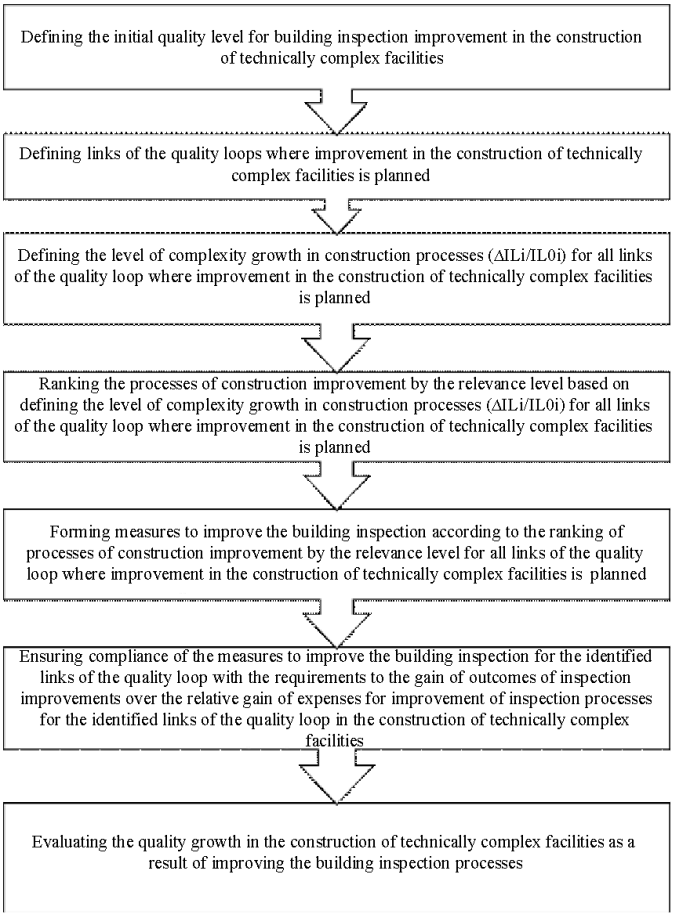

Fig. 4. Algorithm of using the proposed universal model for building inspection improvement in the construction of technically complex facilities.

3 Discussion and conclusion

The research showed that reasonable transition of global economy from the fifth technological mode to the sixth one taking place in the 2020-s represents new requirements to production quality. It is objectively known that growing complexity in construction related with the development of design and process solutions, using new materials, etc., requires adequate methods of building inspections.

Technically complex facilities subject to building inspection in this research are extremely hazardous and technically complex facilities and unique facilities defined by Article 48.1 of the Town-Planning Code of the Russian Federation.

Taking into account a great variety of extremely hazardous and technically complex facilities defined by Article 48.1 of the Town-Planning Code of the Russian Federation, in accordance with a unified nature of managing complex system, this research was aimed at forming a universal model for improving building inspection in the construction of technically complex facilities.

When defining the approach to a universal model improving the building inspection in construction of technically complex facilities, this research takes the principles of quality improvement by E. Deming where, on one hand, attention is paid to improvement of each process (Principle 5), including quality processes; on the other hand, it is required to put an end to the dependency on mass inspection (Principle 3). In this manner, it is necessary to find a compromise approach to quality control (building inspection).

The paper notes that according to Principle 5 of E. Deming, quality improvement must be done at all stage of the life cycle, e.g., quality loops described by E. Deming and U. Shewhart, so called PCDA cycle. According to Principle 3 of E. Deming, taking into account the quality philosophy, according to which expenses are reduced and deliverables are improved as the quality grows, when forming a universal model for building inspection improvement in construction of technically complex facilities, we suggested it reasonable to selectively improve building inspection of such facilities in those links of the quality loop that show complexity and appreciation of processes as compared to a previous level.

A universal model has been proposed to improve building inspection in construction of technically complex facilities, according to which the improvement level of building inspection must be adequate to the growth of complexity of respective processes of the quality loop in construction of technically complex facilities.

It has been shown that in the general case for improving the building inspection in construction of technically complex facilities:

- the total growth for quality loop elements in the construction of technically complex facilities must be no less than the quality growth of building inspection improvement in the construction of technically complex facilities,
- a relative gain of the improvement outcomes of control processes for all links of the quality loop in the construction of technically complex facilities must be higher than the gain of expenses for improvement of control processes for all links of the quality loop in the construction of technically complex facilities.

An algorithm of using the proposed universal model for building inspection improvement in the construction of technically complex facilities is presented, which requires further research in order to elaborate it in more details.

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