Assessment of Effectiveness of Organizational and Technological Solutions in Retrofitting of Urban Areas

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Abstract. The stage of construction is one of the main compulsory periods of the life cycle in the formation of construction end-products — capital construction projects of various functional purposes. It is at this particular stage that actual reliability and safety indicators of capital construction projects (specified at the design stage) are formed determining to a large extent the parameters of operational, functional and economic efficiency. The compulsory assessment of conformity of buildings and structures, as well as design (including survey), construction, installation, setting up and recycling (demolition) processes associated with buildings and structures is conducted in Russia in the form of state construction supervision. An assessment results in a document certifying conformity of the actual indicators with the requirements of design, normative (industrial) and legislative documents. Conformity is assessed in accordance with procedural rules depending on the functional purpose of the capital construction project. There are two conformity assessment forms that appear to be similar (at first glance): "construction inspection" and "state construction supervision". Similarity of these terms lies in the fact that they both characterize an approach used to assess the conformity of activities of participants in the construction operations (customers, developers, contractors) on formation of construction end-products – capital construction projects. These terms differ in so far as the construction inspection implies control by the customer of operations of contractors (with possible involvement of authorized persons not associated with state construction supervision authorities). State construction supervision authorities undertake supervisory (including inspection) activities in order to identify and crack down on violations of the requirements of technological regulations or other normative legal acts and design documents, committed by the key players in the construction investment activities (customer, developer, contractors), with the involvement of state authorities.

1. Introduction

The main **objective** of formation and application of construction products (capital construction projects of various functional purposes) is fulfilment of requirements of the effective normative documents in accordance with a hierarchically arranged sequence known as the life cycle of a construction project.

2. Materials and methods

Figure 1 presents the **main task** of such cycles, the structural sequence (diagram) of the main life cycle stages of capital construction projects:

-*Compulsory* stages (or processes highlighted by a continuous line on the diagram);

-*Possible* stages (or processes highlighted by a dashed line on the diagram).

Figure 1 highlights the **main stages** (processes) of the life cycle (compulsory and possible) that are assessed in terms of conformity with the quality and functional efficiency indicators (including compulsory indicators) in the form of *state construction supervision.*

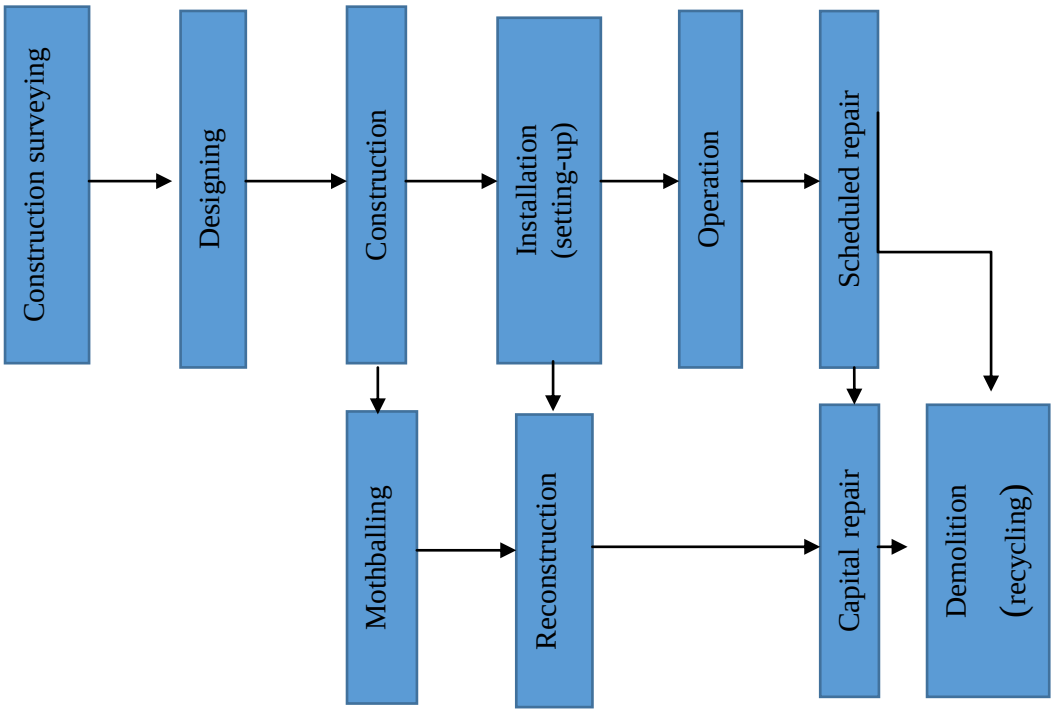

Figure 1. Sequence of life cycle stages (processes) of a capital construction project

"A compulsory assessment of conformity of buildings and structures, as well as design (including survey), construction, installation, setting up and recycling (demolition) processes associated with buildings and structures ... is conducted only in the cases provided for by urban planning laws"(Article 39).

Pursuant to the normative document, a conformity assessment in the form of state construction supervision is conducted in the cases of:

-*New* capital construction projects;

-*Reconstruction* of capital construction projects including reconstruction of cultural and historical heritage sites.

New construction projects include projects implemented on sites that are prepared and free for development, or sites that have been developed previously, but are now scheduled for alteration of the set-up or structure of construction projects (or elements of anthropogenic environment). This particular type of projects is the **subject** of this study [1]. New construction is the most widely used approach to the formation of capital construction projects. This format makes it possible to apply a variety of advanced innovative construction methods and technologies in the implementation of architectural and constructive solutions for construction projects of various functional purposes and responsibility levels.

Reconstruction of a construction project means complete or partial elimination of physical wear out of an individual element or of the whole project without construction of new areas or volumes, but

with construction, if necessary, of new and/or expanding existing auxiliary facilities. Reconstruction includes: replacement of outdated and worn out equipment; enhancing mechanization and automation of production and technological processes. Reconstruction of capital construction projects results in better technical and economic indicators of the output achieved in a shorter period of time and at less costs (investment) as compared with new construction. Reconstruction of civil buildings may include replacement of structural members (bearing and enclosing) characterized by unacceptable physical wear, replanning of premises, and alteration of their original functional purpose [2].

An assessment of conformity of design solutions (technical documentation) with the provisions of effective normative documents in the course of state expert review of capital construction projects (new construction and reconstruction) makes it possible to identify:

-Availability and composition of approval documentation for survey, design and construction works;

-Composition, completeness and quality of structural solutions;

-Importance of implementation of the adopted structural solutions in the specific environment of the construction site;

-Ability of the local construction facilities (industrial, transport, infrastructure) to organize construction operations;

-Efficiency of construction process organization, planning and management methods.

State construction supervision (of new and reconstructed capital construction projects) is focused on verification of:

-*Conformity of the works and construction materials used in construction, reconstruction or capital repair of capital construction projects, as well as the results of such works with the requirements of technical regulations, other normative acts and design documentation, including the requirements with respect to power efficiency and availability of power metering devices;*

-*Availability of construction permits*;

-*Compliance with the requirements of Parts 2, 3 and 3-1 of Article 52 of the Town Planning Code of the Russian Federation*.

Inspections of investors in construction operations and corresponding capital construction projects (of any responsibility level) in the form of state construction supervision are conducted on and off schedule in accordance with the following basic principles:

-A priori acknowledgement of responsibility, competence and integrity of the entities involved in construction investment activities;

-Strict and exclusive adherence to the inspection procedure established by corresponding legislative and normative acts;

-Ensuring openness, continuity, and operational efficiency of inspections;

-Practical feasibility of the requirements to the entities involved in construction investment activities being inspected;

-Financing of inspection exclusively at the expense of the state budget.

The state construction supervision procedure is established by corresponding Regulations of the Government of the Russian Federation [3].

The main task of the state construction supervision is detection of violations in the course of construction operations of the provisions of normative town planning documents (including technological regulations and design documentation) committed by the entities involved in construction operations at corresponding life cycle stages of capital construction projects.

The following tasks and functions of the state construction supervision can be distinguished:

-*Control of territorial state construction supervision authorities in the specified scope of activities;*

-*Control and supervision of conformity of works and materials used in the course of construction or reconstruction of capital construction projects as well as results of such works with the requirements of technical regulations, design documentation, compulsory standards, construction norms and rules, industrial safety requirements, and other normative legal acts in the field of construction;*

-Environmental control, and sanitary, epidemiologic and fire supervision as part of the state construction supervision;
-Control and supervision of compliance with the established procedure of construction and reconstruction of capital construction projects;
-Organization of methodological support to the state construction supervision;
-State control (supervision) of activities of self-regulating organizations in the field of engineering surveys, architectural and construction designing, construction, reconstruction and capital repair of capital construction projects, including:

- *Compliance with the requirements to construction, reconstruction and capital repair of capital construction projects by persons engaged in the construction process subject to availability a competence certificate for performance of corresponding types of works affecting the safety of such projects;*
- *Activities of self-regulating organizations in the field of engineering surveys, architectural and construction designing, construction, reconstruction and capital repair of capital construction projects;*
- *Compliance of self-regulating organizations in the field of engineering surveys, architectural and construction designing, construction, reconstruction and capital repair of capital construction projects with the requirements to self-regulating organizations and their operations established by the Town Planning Code of the Russian Federation, federal laws and normative legal acts in this field;*
- *Compliance with the requirements to availability of a competence certificate for performance of corresponding types of works, as well as compliance with the minimum requirements to the issuing of competence certificates for performance of corresponding types of works by persons engaged in engineering surveying, architectural and construction designing, and construction, reconstruction and capital repair of capital construction projects;*

-Maintenance of the state register of self-regulating organizations engaged in engineering surveying, architectural and construction designing, and construction, reconstruction and capital repair of capital construction projects;
-Normative, methodological and software support to the maintenance of the state register of self-regulating organizations;
-Organization of the state control (supervision) of activities of self-regulating organizations engaged in engineering surveying, architectural and construction designing, and construction, reconstruction and capital repair of capital construction projects.

The state construction supervision of construction of new and reconstruction of existing construction projects (in cases where design solutions provide for activities that determine the actual values of characteristics of structural, technological and environmental reliability and safety, with the exception of nuclear power facilities) is undertaken by: "… *a federal executive government body authorized to conduct federal state construction supervision and by executive government bodies of the subjects of the Russian Federation authorized to undertake regional state construction supervision"*:

-Federal Service of Environmental, Technological and Nuclear Supervision (Rostekhnadzor);
-Ministry of Defense of the Russian Federation;
-Federal Security Service of the Russian Federation;
-Federal Protective Service of the Russian Federation;
-Other federal executive government bodies entrusted with the state construction supervision functions:

- Federal state fire supervision;
- Federal state sanitary and epidemiological supervision;
- State control (supervision) of conformity of a capital construction project with the requirements with respect to its power efficiency and availability of power metering devices.

The Federal Service of Environmental, Technological and Nuclear Supervision (Rostekhnadzor) is the main federal body (authorized to conduct federal state construction supervision) that determines

the required format and content of scientific and methodological support to the state construction supervision in the Russian Federation and possesses appropriate structural and managerial resources for this purpose [4].

As an example of an executive government body of a subject of the Russian Federation that undertakes the state construction supervision of construction of new and reconstruction of existing construction projects in its territory we can take the authorized executive government body of the federal-level city of Moscow.

Territorial bodies of the subjects of the Russian Federation authorized to perform federal state construction supervision functions in various formats include territorial departments (the main department and territorial divisions), territorial supervision services, state supervisory inspectorates (inspectorate divisions for territorial and urban planning entities) (State Construction Supervision and Inspection Service, or Gosstroynadzor).

The main tasks entrusted to territorial bodies of the subjects of the Russian Federation are inspections of operations of the entities involved in construction investment activities (customers, developers, contractors) in their respective territory.

Inspection programs are developed by officials of the respective structural subdivisions (territorial bodies of the subjects of the Russian Federation) subject always to structural and other particulars of the capital construction project and construction works thereunder, reconstruction of conditions, urban planning and other factors to be taken into account in accordance with the requirements of technical regulations (norms and rules) and design documentation.

An inspection findings report drawn up by officials of the respective structural subdivisions is used as the basis for issuing a prescriptive order to the entity involved in construction investment activities with respect to the revealed violations and the procedure, terms and conditions of their elimination. As a general matter, a prescriptive order on elimination of violations includes: description of the revealed violation; a formalized reference to the technical regulations (norms, set of rules) or other normative, technological or legal acts; the section (chapter, volume, book) of design documentation which requirements have been violated as revealed by the inspection. The order also determines (prescribes) the deadline for elimination of violations with due account for engineering solutions and particulars of the organizational and technological sequence [5].

The technological sequence of construction processes employed in the implementation of a capital construction project requires accounting for and management of these processes, inspection (control) of the quality and scope of production tasks being performed, and drawing up corresponding as-built documentation. No deviations from the design documentation are allowed.

Possible amendments (to be introduced in the design documentation on the basis of the findings of an inspection undertaken by a state construction supervisory structural subdivision) require an approval with the involvement of representatives of the entity that has developed the design (engineering, technological) documentation for the construction project under review. Representatives of the entity that has developed the design documentation exercise the designer supervision in accordance with the established procedure (irrespective of any amendments required in the design documentation).

Clearance for practical operations of a completed capital construction project is granted after receipt of a statement that authorizes operations of the project on the basis of a corresponding (final) verification (by officials of state construction supervisory structural subdivisionы) of conformity of the actual functional quality indicators to their design values or, to the extent stipulated by federal laws, the provisions of specialized industrial standards [6].

The revealed violations committed in the implementation of the project and a description of the procedure and results of their elimination are reported to the interested parties (entities involved in construction investment activities), who will subsequently operate the capital construction project.

The information received by results of conformity inspections in the course of state construction supervisory activities is formalized, normalized and submitted for consolidation and inclusion in the information systems (federal and/or regional) of the state construction supervision. This approach

ensures a higher efficiency of operations of state construction supervision subdivisions (primarily, by eliminating the negative consequences of an overlap between the functions of regional and federal executive government bodies) [7]. It seems appropriate, for practical implementation of the project under review, to organize in each subject of the Russian Federation an information and communication system for interaction between regional executive government bodies and territorial subdivisions of federal authorities. Such system is focused on ensuring the function of sharing information on the purposes, objects and timing of activities (within the conformity verification program) with subsequent coordination of actions on joint decision-making: expediency of the inspection; scope, timing and duration of the inspection; composition and skills of a joint inspection team[8].

The purposes, subject and functions of the state construction supervision established by effective normative and legislative acts determine the need for its implementation at various life cycle stages of capital construction projects [9].

It can be assumed that specifics of a particular life cycle stage determine the composition of activities (within the established state construction supervision procedure) that make it possible to ensure the reliability and functional efficiency indicators of construction products set out in the detailed design[10].

This circumstance can be reviewed in the context of analysis of available and possible methods of state construction supervision: analytical (expert) and empirical [11].

The mathematical model is designed for assessing the state (quality and established design parameters) of the construction operations system (preparatory, main, final construction stages). The model is based on the concept of probability of the construction operations system (associated with a particular construction project) being (at any arbitrary point of time) in any of the accepted states (Figure 2) [12].

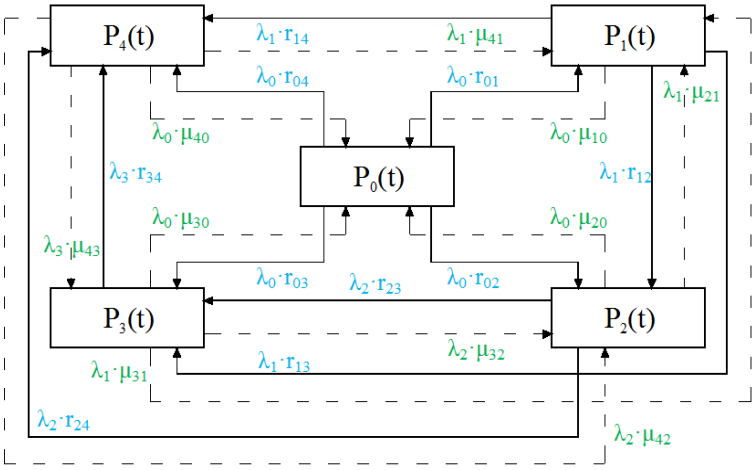

Figure 2. A graph of accepted states of the construction operations system.

3.Result

Possible states of the system (model) are identified as:

-The expected (designed) conditions of the functioning of a construction operations system (the standard quality of implementation of a construction project) [13] – state $P_0(t)$;

-Minor deviations (from the designed conditions) in the conditions of functioning of a construction operations system (an acceptable quality of implementation of a construction project) [14] – state $P_1(t)$;

-Noticeable deviations (from the designed conditions) in the conditions of functioning of a construction operations system likely to result in a certain deterioration in the quality of construction

products, but acceptable in terms of safe operations (a satisfactory quality of implementation of a construction project) – state[15] $P_2(t)$;
-Regular (systematic) deviations (from the designed conditions) in the conditions of functioning of a construction operations system likely to result in deterioration in the quality of construction products that is acceptable in terms of safe operations with considerable limitations (an unsatisfactory quality of implementation of a construction project) – state $P_3(t)$;
-Regular (systematic) deviations (from the designed conditions) in the conditions of functioning of a construction operations system resulting in irreparable deterioration in the quality of construction products that is unacceptable in terms of safe operations and requires mothballing or demolition (a critical quality of implementation of a construction project) – state $P_4(t)$.

Parameters λ, μ and r are quantity values that represent transition of the construction operations system between the determined states[16].

For example, parameter λ represents the possibility of installing a structural unit in the designed position with unacceptable deviations (deterioration in the quality of construction products), while parameter μ represents the possibility of rectification of unacceptable deviations in a structural unit revealed by control measurements [17].

The quality values of parameters λ, μ and r can be ascertained by various means, for example, statistical processing of frequency of occurrence of corresponding negative factors (unfavorable atmospheric factors, construction equipment malfunctioning, construction personnel errors, design errors, "malfunctioning" structural units — the number of factor groups under review can be arbitrary). The whole process of construction (mathematical model functioning) is described by a differential equation system [18].

Initial conditions are as follows:

$$P_0(t) = 1,\ P_1(t) = P_2(t) = P_3(t) = P_4(t) = 0 \quad (1)$$

Analysis (using the proposed mathematical model) results in distribution of probabilities between possible states [19].

For example, Figure 3 shows the results of distribution of probabilities of the state of a construction operations system (with certain initial values of parameters λ, μ and r and relationship (1) for the term of construction equal to 281 working days.

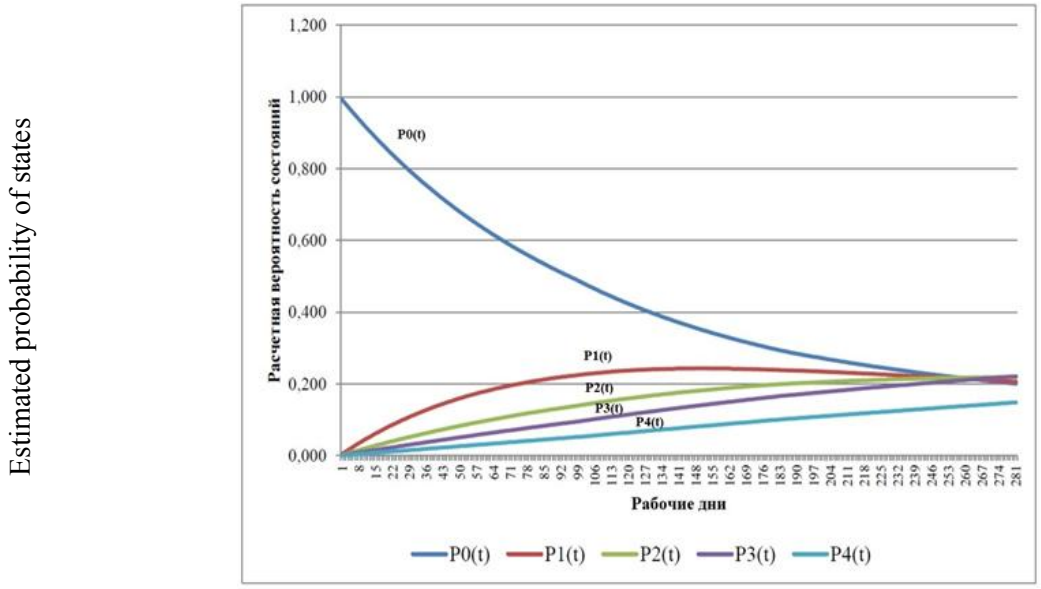

Figure 3. Distribution of probabilities between states of a construction operations system.

An estimated value of the probability of a state of a construction operations system can be linked to construction risk assessment by a relationship as follows:

$R=P_i(t)\cdot F$

where:

R – quantitative value of the risk of deterioration in the quality of construction products;

$P_i(t)$ – estimated value of the probability of a state of a construction operations system;

F – quantitative value of the function of the severity of consequences (risks).

4. Conclusion

A substantial number of activities by structural subdivisions of regional and federal executive government bodies (inspections, conformity assessment) is undertaken at the construction stage (of the life cycle of the capital construction project) [20].

State construction supervision procedures involve collection of up-to-date trustworthy information on actual parameters of organizational and technological reliability of a capital construction project being constructed, as well as on the impact of construction operations on the technical condition of the existing (neighboring) buildings and the environment. Solving this task allows for timely undertaking of necessary technical activities for ensuring, maintaining and improving the technical condition of the construction project under review and/or preventing inadmissible damage to the existing buildings and structures.

Analysis of the subject area has resulted in the formulation of a **hypothesis** that assumes that the adequate choice and application of up-to-date basic strategy development methods for a construction organization are instrumental in boosting the efficiency, quality and performance of construction end-products.

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