Creation of the information system based on the integrated evaluation of a construction object at various life cycle stages

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Abstract. This work contains analysis of the problems regarding the development and maintaining of executive documents on the construction, reconstruction and overhaul process. The study considers the following matters: goal-setting for elaborating process of an object operational model; improvement of the construction organization efficiency in order to reduce labor and time costs on executive documentation preparation and processing, as well as to minimize the number of mistakes contained in it.

1. Introduction
At present, one of the urgent problems of construction operation is empirical data translation into information for the further processing and using at operational phases, repair, reconstruction and dismantling of buildings and structures. The main sources of information about an object upon its construction completion are working and executive documentation which are being drafted at the erection stage when various construction and installation works have been completed [1]. Executive documentation contains text and graphic data reflecting the compliance with project requirements, actual parameters, as well as position of structural parts [2].

In reality, development of executive documentation is carried out in a traditional way which is time-and-labor consuming and doesn’t guarantee the documentation consistency and reliability of the data contained therein [3]. The main reasons for the low level of quality are the need for analyzing and processing a big amount of data obtained from various sources, as well as the lack of unified regulatory requirements for information regarding the documents confirming the quality of materials, products and equipment used in construction [4]. For now, the contents and the maintaining of executive documentation during different objects construction, reconstruction and overhaul, as well as the requirements placed on inspection certificates for constructions, engineering networks, are determined by the decree of the Federal Service for Environmental, Technological and Nuclear Supervision (Guidelines) and some others. They do not give a full description of the construction sequence and do not take into account the possibility of the complex automation systems implementation.

The impact of the existing production conditions results in problems in the formation of an information base about an object, expressed in improperly executed documents, presence of mistakes, absence of comprehensive documentation set needed for subsequent analysis [5]. The above-mentioned in turn causes considerable difficulties in identifying deviations from the project and violations of regulatory documentation requirements by a foreman, difficulties in operation. It also
excludes the possibility of objective assessment of structural residual properties within post-warranty period. The importance of detection and timely elimination of inconsistencies in the executive documentation is also justified by the fact that it’s impossible to create it for a finished object a posteriori due to the certain types of performed works concealment and the enormous amount of work subject to office study.

At present, a considerable part of attention is paid to the construction organization. However, the matter of smart modeling in the aspect of an integrated executive base creation is considered insufficiently [6, 7, 8].

The aim of this study is to elaborate an approach to an information model formation under construction to consolidate the best practices within the regulatory framework, as well as to implement the measures for the large-scale use of information modeling technology in construction industry.

2. Materials and methods

System analysis of construction operations has been used by the authors as the main approach to the study. Work has been carried out in order to develop a practical approach to construction organization with the use of modern information technology.

The main focus of the problem solution is an application of information systems, including BIM (Building Information Modeling) technology, as their logical development in the construction field [9]. The prerequisite for the study is also regulatory and methodical documentation development on the use of information technology in constructing, as well as various technological specifications for their use in the construction organization at various life cycle stages (Figure 1). Globally, the concept of buildings information modeling has already been taking a sustainable position in construction industry. It is characterized by a fundamentally different approach to an object constructing, fitting, operating, repairing as well as its managing, including their economic component [10, 11]. Its implementation impacts on the speed of analysis and organizational and technical decision-making.

![Figure 1. Life cycle of a construction object](image-url)
In order to improve the quality of construction products, it is necessary to solve the problems hindering the efficiency increase in construction organization. That shall be done by means of the cyberphysical systems (CPS) application [12, 13]. The distinctive feature of CPS is in its structure which consists of multiple objects, artificial subsystems and controllers allowing to consider them as a whole. The CPS scope may be applied to almost all activities including multiple systems of various purposes. CPS may improve human analytical capabilities, thus, there is a need for advanced interactive systems [14]. The existing problems solution based on cyberphysical management techniques is crucial for large-scale automated distribution systems and construction industry in general.

Executive documentation is ascertained to be elaborated in order to ensure the correct operation of buildings and structures, as it depicts technical condition and gives a clear idea of responsible manufacturers on all types of completed works, structures and engineering systems.

In general terms, executive documentation is divided into executive production and executive documentation (Figure 2). Executive production documentation (primary documents) refers to a set of documents collected during the construction process. It captures the process of construction and installation work and displays technical condition of the object. The set of primary documents is determined by building codes and the project under construction (acceptance acts for essential structures, acts of inaccessible works and executive surveys, as well as records containing the results of laboratory control, logs with test results and several documents confirming the quality of the construction products used) [15].

Executive documentation (executive drawings) refers to a set of drafts with information on the compliance of the project to the actual work done; or on the amendments made therein by the people responsible for the production upon agreement with the design institute [16].

The first step for intensification must be comprehensive integration of information systems into the process of primary executive documentation development which should begin with the creation of an
information base for the documents depicting the quality of the materials, products, structures and equipment supplied to the construction site.

The obtained information model is to have the qualities intended for operational purposes as a result of amendments and increased detailing, given the consolidation of information on actual work performed and its volume, as well as used materials, products and structures, architectural content.

The interaction with the information model at the construction phase results in a parameterized digital model of a building or structure based on executive documentation, elements of which are prepared by the employees of production and technical department and construction control.

In practice, the project information model, filled in at a building or structure life cycle stages (Figure 3), represents an «as-built» model with modules of construction and installation schedules, purchases, supplies, photo and video materials, test results, drawings, technological solutions, summary statements and specifications.

In order to formalize and simplify the search for documents used as appendixes to acts of inaccessible works and acceptance acts for essential structures, the approved Russian Classification of Product by Economic Activities is proposed. In order to identify the acts of inaccessible works as an element of the information model, the following parameters are to be entered: the number and date of the act, the date of the actual work done, the name of the foreman (contractor).

The elements of the information model must be strictly classified in accordance with the types and categories of the objects; the constructs must have actual geometric dimensions, spacial altitudes, quality characteristics, executive documentation and attribute information. In order to process the executive documentation properly and avoid any conflicts, information on the documents confirming the quality of materials, products, structures, characteristics declared by manufacturers and suppliers are to be fully entered (including business names, the number and volume of each batch, delivery dates and shipping addresses). The number and types of the indicators may vary depending on the types of structures used at the sites.

Figure 3. Block diagram of information modeling application at various stages of a construction object life cycle

The evaluation of the data quality is formulated as a generalized concept of its usefulness which is formalized within a certain set of criteria. There are six criteria established for corporate data of management information systems, i.e. demand, accuracy, consistency, timeliness, availability and interpretability [17]. A set of key performance indicators is defined for each criterion, and practices to
improve them are elaborated. Information systems are to be connected throughout the entire object construction process and must be based on the principle of information technology and construction operation interpenetration [18, 19]. Such kind of tasks are challenging and result in the need for transferring individual blocks of tasks and actions into CPS, and consequently, putting a human out of the control loop. CPS ensures a strong correlation and coordination among computing and physical resources [20]. Computers monitor and manage physical processes using a feedback loop in which whatever happens in physical systems affects computing and vice versa [21].

The integration described above makes it possible to achieve the greatest efficiency in production processes management in terms of reflecting the actual data on project elements by means of combining individual components into larger systems. The creation of full-fledged CPS systems eventually will lead to fundamental changes in interaction with the physical component.

Primary executive documentation development and verification based on the information system makes the processing and translation of the data received from the construction site more efficient. Information for decision-making is consolidated, structured and available for analysis.

The information model of a building or structure may be passed on to the operating organization along with the documentation approved by the regulatory acts. In this regard, all the data obtained during construction may be stored until the end stage of the construction object life cycle.

3. Results

The results of the proposed approach (Figure 4) to assess the effectiveness of automation in the primary executive documentation development (information model of an object with quality certificates/construction object passport/compliance certificates, test reports for the subsequent elaboration of appendixes to acceptance acts for structures), as well as the foregoing, allow us to claim that the presence of basic data in the information base along with the data about certificates for materials, products, structures and equipment have undeniable advantages, as follows:

– the possibility to elaborate flow charts, regulations and site work execution programmes in a more detailed way;
– the reduction of inconsistencies in the accompanying documents on the products actually used;
– the detection of deviations in mounted structures and service lines from their design positions necessary for technical decisions;

Figure 4. Information model
- the formation and extraction of data on the amount of work carried out with separation the operators from constructs;
- the possibility to prevent the materials duplication or shortage by means of minimizing the human factor impact;
- the possibility to provide the customer with an up-to-date information model, taking into account the accumulated and newly created executive documentation;
- improvement of executive documentation overall quality and completeness;
- reduction of the time for executive documentation verification and for the assessment of the compliance with estimate documentation;
- there is no need to expand the archive space;
- the possibility of using the information model as baseline data for a building and structure reconstruction and overhaul;
- the possibility to create an operational information model by integrating the existing operational data and documentation.

4. Discussion

One of the priorities for construction customers and general contractors is to ensure the high quality of construction and installation work. For that purpose, the quality control services are established. Due to the lack of an appropriate regulatory framework, organizations are forced to develop their own standards and regulations for building supervision, as well as to describe the basic principles of its realization. Construction objects are unique, therefore, each of them requires the development of individual documents, and as a consequence, individual regulations for each object must be drawn up.

Considering that the quality control service is a participant of construction production and it is mostly interested in the reliability of the data presented in executive and other documentation, thus, it is proposed that the responsibility for the formation of the information database ought to be assigned to this service.

Working in a single information field, coupled with the separation of data processing processes, contributes to a more detailed understanding of the entire production process; a reduction in the time frame for coordinating organizational and technological solutions; as well as improvement of building supervision, including the information database formation which serves as a basis for accompanying documents.

This approach will allow us to analyze the construction organizations activities, as well as to make a comprehensive evaluation of all the processes within the work at the construction sites.

5. Conclusion

The ability to parallelize information flows in cyberphysical systems, the asynchrony of decisions regarding changes and inclusion of intelligent network for processing a large amount of information are all key features of the proposed approach to the production organization.

As the practical testing shows, the proposed approach allows us not only to obtain full information about the works for identification in a timely manner, but it also increases their efficiency, since the office study and systematization of the data on physically performed works serve as the basis of planning and the only source of information about a construction object throughout its life cycle. The application of the proposed approach in practice leads to: reduction in the risks of downtime and extra costs within construction and installation works; operational quality control during construction and actual amounts of work at the intermediate stages of construction process; reduction of expenditures by means of engineering information processing optimization; creation of an information model with comprehensive data in order to develop an operational information model.

Collection and thorough evaluation of the data from various sources shall become the standard for real-time decision-making. The greatest effect from the integration shall be achieved by combining individual components into large systems connected throughout the entire production process. The
information system created on the basis of the integrated evaluation results, is designed to support decision-making at various stages of a building or structure life cycle, besides, it serves as a fundamental solution for typical problems of information metabolism.

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