Formalisation of the methodology of the construction design documents taking into account the fuzzy logic

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Abstract: *This study investigates the methodology of formalisation of the process of development of design solutions for construction using artificial intelligence methods, taking into account fuzzy logic. The relevance of the subject matter is conditioned by the need to compile a description and methodology for solving problems for which cybernetic methods are not applicable or are limited. The purpose of this study is to make recommendations for managing the development of construction project documentation based on artificial intelligence systems. The main results obtained is: considered the definition of mathematical models for calculating methodological parameters and the hierarchical structure of the project document flow. A method of effective implementation of an organisational and technological solution using its information model and a system for developing management decisions based on the results of monitoring the construction process is proposed. The prospects for further research in the stated line are conditioned by the need for further development and practical implementation of accounting methods for construction design documents to systematise accounting processes in conditions of incomplete or limited information. The applied value of this study lies in the possibility of practical application of the results obtained to optimise the maintenance of construction design documents.*

Key Words: *artificial intelligence, information system, logical-linguistic model, formalisation of the control system, technological process*

1. INTRODUCTION

One of the important factors for the effective development of construction operation is the improvement of the methodology for the development of a construction project, taking into account both external and internal factors of the construction industry as an economic entity. This became possible as a result of the accelerated development of computer technologies and logical-linguistic methods based on fuzzy logic and the introduction of linguistic variables. The active use of information and computer technologies allows choosing economically sound methods based on reliably sound artificial intelligence methods [1], [2]. The main approach to ensuring information and system security of a complex system is the intellectualisation of such a system, i.e., equipment of the system with elements of intelligence, creating a special information and software environment that ensures the security of the system behaviour in its metasystem throughout its life cycle [3]. Admittedly, the "sharp, abrupt change in something" is conditioned by an event earlier than the "possible danger". In this case, the concept of "situation" (from the Latin *situatio*) is also applicable – a set of circumstances, a situation that is characterised both by the presence of "possible dangers" and their event – "a sharp, steep break". That is, there is a need for situational management to overcome the crisis situation, which can later be taken as the basis for anti-crisis management of the enterprise development for a rather long, according to experts, perspective [4].

The construction system consists of subsystems, for example, the life cycle of a building structure consists of several stages (design, construction, operation, reconstruction, and disposal). Each stage has its own peculiarity, is described by its own parameters, and therefore the method of finding the optimal solution has its own specifics inherent in each particular stage [5]. In addition, each method must ensure the continuous adaptation of a complex system to changing internal and external conditions, diagnose, monitor, analyse and synthesise individual components of the system and the operation of the system as a whole, taking into account the consequences of such operation. The intellectualisation of complex systems is a major process in modern information technology in various industries [6], [7], [8].

Signs of such a process are, for example, computerisation and informatisation in all spheres of human activity, and the construction industry is no exception. The application of the metasystem method in construction and architecture involves the design of rational agents by logical and linguistic methods based on the synthesis of evolutionary modelling, morphological maps, functional-physical and functional-cost analysis. The development of rational agents based on logical-linguistic methods is based on proportional logic, the methods of which are well developed. The use of the latest modern technologies in this process, which can provide high-quality integrated provision and processing of information, is based on the development of artificial intelligence systems. Such systems allow, based on the accepted rules and regulations, and the axioms and facts provided, to find out the situation, make an accurate diagnosis, as well as to develop an optimal solution and make recommendations for its implementation [9], [10], [11].

Discrete methods of analysis and, in particular, graph theory have proven themselves well as a tool for building a mathematical model, including in the construction industry. A full-fledged mathematical analysis of some technological processes can be carried out most fully using discrete methods. The mathematical models based on them allow taking into account external factors and find optimal solutions. So in the process of developing construction design documents, it is mandatory to plan network schedules. At the moment, there is no acceptable universal programme that allows the designer to quickly solve this problem. At the stage of development of a project for the construction entity, the task is inevitably set to visually display the sequence of all the work in the form of a graph. Thus, a network graph is an image of the construction sequence of an entity. In this case, events are represented by circles, and activities are represented by arcs (arrows). The circles are marked with arbitrary but different numbers (events), and above the arrow – the name and duration of the activity [12], [13], [14].

The design of construction projects is a complex, multi-stage process, which involves a large number of qualified specialists from different fields, with different types of construction design documents [15]. In addition to the development of technical solutions, their comprehensive assessment is carried out, estimates of various details are formulated, which serve as the basis for subsequent management decisions focused on the safety of construction and compliance with quality standards, efficiency, compliance with customer requirements [16], [17]. In this context, the formalisation of the methodology of project documentation, taking into account the fuzzy logic, is extremely important from the standpoint of compliance with the necessary quality standards of the construction operations performed. The purpose of this study is to make recommendations for managing the development of construction project documentation based on artificial intelligence systems.

2. MATERIALS AND METHODS

The main meta-projection of the model is the result of associative search and associative reasoning, based on the position that the solution to an unknown problem, in one way or another, is based on already solved problems that are somewhat similar to those that need to be solved. The new problem is considered already known, although it is slightly different from the known one. Based on the collected information, the system is described by information entered into the knowledge base containing axioms derived from regulatory, technical and legislative documentation. Individual procedures (operations) are classified into formalised and non-formalised. Given that system analysis allows for certain situations, unformalised decisions made by a person are more preferable. The project documentation for the construction of both production and non-production facilities is analysed from the standpoint of computerisation [18], [19], [20].

According to this document, the project documentation consists of n sections, each of which is uniquely described by a set of parameters Mi, where i=1, n. Let n=12 for concreteness. In total, it is necessary to analyse the parameters where the cardinality of the set representing the Cartesian product Mi is present. The structure of each set Mi is defined as the intersection of two subsets Ti and Gi, i.e., where Ti is the set of parameters defining the textual part of section i, and Gi is the set of parameters defining the graphical part of section i. Some of these sets may be empty, i.e., their cardinality is zero. According to the accepted position, the first section is described by parameters, where G1 is a set of parameters that characterise the graphical part of the first section and whose cardinality is zero, i.e. it is an empty set. The set of parameters that characterise the first section of the text part T_1 consists of m (let m = 20) subsets $T_1=\{t_{1,1}, t_{1,2},..., t_{1,20}\}$, where $t_{1,j}$ (j = 1, 20) where $t_{1,j}$ (j = 1, 20) is an element of the set T_1, which, in turn, is a set consisting of elementary linguistic statements. Thus, for example, t_1, 1 consists of three elements r_l (l = 1, 2, 3), that is, the details $t_{1,1} = \{r_1, r_2, r_3\}$, and specifically r_1 – the development programme of the subject, r_2 – the decisions of self-government bodies, r_3 – decisions of the developer.

Construction management should cover a set of processes for the construction of buildings and structures and should ensure high productivity of construction work, reduce construction time, reduce the cost of construction and installation work, reduce the volume of construction in progress, high-quality construction, eliminate losses in the work of construction organisations [21], [22]. The main task of management in construction is to establish and implement links between the performers of individual production processes of construction and installation works, turning them into purposeful activities to achieve the intended result – the commissioning of the construction entity. The method of implementation of this task is the system of intellectual analysis of construction management [23], [24].

Intelligent information systems are technical and software systems focused on solving a large class of problems that lack information about external or internal factors, that is, they are not formalised. In such systems, data is replaced by knowledge, and algorithms are replaced by artificial intelligence methods. Initially, structured databases are established, which provide an integrated representation of the management object. The training methodology can also be based on genetic algorithms used to solve problems by randomly selecting, combining, and changing desired parameters using mechanisms similar to natural selection in nature. When the neural network scans the images, certain layers and groups of nodes will start shooting at it, which will help it identify and highlight the categories of the main attributes of the target.

3. RESULTS

Associative reasoning most accurately reflects the real reality and allows transfering the methods used earlier to the current situation. This approach, taking into account the fuzzy logic, allows using meta-procedures that work with a set of knowledge from the problem area to which this problem situation belongs. The main meta-procedures in the model hypothesis, taking into account fuzzy logic, are the representation of knowledge, reasoning, search for relevant (related to this problem situation) information in the totality of existing knowledge, its replenishment and correction. These meta-procedures form the core of the intellectual capabilities of modern software systems focused on solving creative problems [25], [26]. Together with the meta-procedures of targeted associative search, they form the tools available to modern intelligent systems. These meta-procedures contribute to solving such problems of digitalisation in the construction industry as: problem formulation, knowledge representation, formalisation of reasoning, planning of relevant activities, training of intelligent systems.

The process of converting information into a form suitable for further use on a computer is the main one in the development of artificial intelligence systems. Here, the following steps come to the fore: collecting information, pre-processing, classifying data, correcting models, and others. In this case, an intelligent information system is an environment consisting of computers, computer networks, software products, databases, and includes: the control object, the environment, and a set of external factors. The intelligent information system is able to diagnose the state of the management system, assist in management, and ensure the selection of optimal solutions for management activities. For this purpose, a corresponding knowledge base on construction management technology is developed, based on the collection of knowledge of both internal and external factors of construction, which may be incomplete and not subject to strict formalisation. The procedure for developing an intelligent information system, as a rule, can be presented in symbolic form as follows:

$$N: \langle S; L; (A \Rightarrow B); Q \rangle \tag{1}$$

where: N – individual number of the factor; S – description of the class of the situation in which this factor can be used; L – condition for activating the factor; A B – the essence of the technological process; Q – operations and actions that must be performed after B.

A common way to represent a logical database model is to build ER (Entity-Relationship) diagrams. In this model, an entity is defined as a discrete object for which data elements are stored, and a relationship describes the link between two objects. This framework consists of three sets of computational tools. The first set is an executive system, that is, a set of tools that execute programmes designed from the standpoint of effective problem solving, and in some cases have a problem orientation. Adapting to the Executive system (task type): software-computing, logical; search tools. The second complex is the establishment of a knowledge base, which is used to integrate all the tools of the computer system involved in solving problems and adapting to the subject area, and consists of two levels: conceptual and informational. The third set of tools is an adaptation to the end user, a communication system (translators, a system for ensuring mutual understanding).

The practical implementation of this idea is in the field of the neural network, which takes the actual knowledge about the construction technology, forms the rules-the knowledge describing the solution method found by the neural network. Expert systems are self-taught based on experimental facts. This allows the creation of process control systems for construction management, and the objectives of the task cannot be expressed in terms of a precisely defined objective function. Figure 1 shows a diagram of the hierarchical structure of the electronic document flow of design and technical documentation used in construction works, taking into account the fuzzy logic.

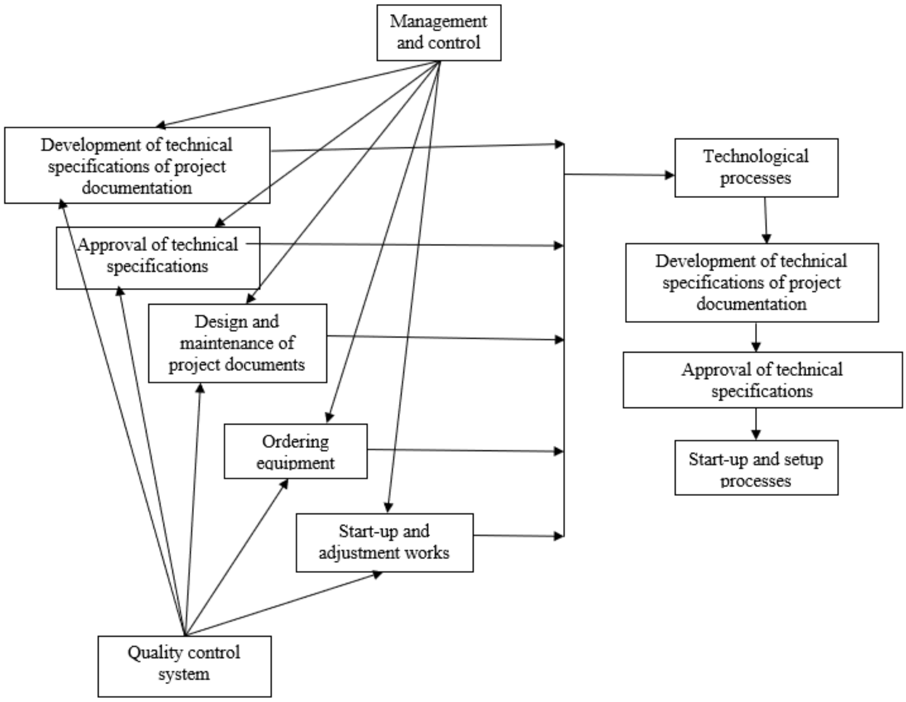

Fig. 1 – Hierarchical structure of electronic document flow of design and technical documents used in construction works, taking into account fuzzy logic

The conceptual model of building a hierarchical structure of the turnover of project documentation used in the planning of construction works involves taking into account many factors that have a direct impact on the technological process. In this context, to synthesise a system that improves the efficiency of the automation and telemechanic facilities, including the implementation of a sequence of monitoring, management and quality control of work performed based on the electronic document management system for project and technical documentation, it is necessary to distinguish technological chains by the stage of work execution from their beginning to the completion of the processes of construction of systems and their commissioning. This can be done by analysing the interaction of the subjects of the road management structure, the sequence of stages of work, approval of documents. At the same time, the level of formalisation of the stages of the technological cycle should be sufficient to monitor and control the quality of their implementation. To increase the completeness of control, individual stages of work, in turn, can be presented as detailed technological chains, the level of detail of information display in which corresponds to the completeness of quality control.

Thus, monitoring the processes of functioning of the elements of the meta-system involves taking into account many factors that affect the final efficiency of this process. The practical solution of such problems of the construction industry digitalisation as: formulation of problems of ensuring construction work; presentation of the necessary knowledge; formalisation of reasoning; planning of relevant activities. Training of intelligent systems should be clothed in information and logical system that can over time become a reliable basis for the consistent construction of the processes of formalisation of the methodology of construction design documentation, taking into account the principles of fuzzy logic.

Thus, the basis for the effective formalisation of the methodology of project documentation is the methods and principles of constructing mathematical models and hierarchical structures for describing the processes that take place in the operation of intelligent information systems that provide a high-quality solution to a large volume of construction problems. Automation of electronic document management processes, in relation to solving issues of the construction industry, ensures timely and uninterrupted construction of the structure of a neural network capable of receiving actual knowledge about the technological features of construction work, forming rules for obtaining knowledge describing the decision-making methodology found by the neural network. This will later help to create systems for managing the processes that occur during construction work, despite the fact that the goals of such a task cannot be expressed in terms of a single, strictly defined objective function.

4. DISCUSSIONS

The discussion of the results obtained in the course of this study, in comparison with the conclusions obtained by other researchers of the issues submitted for consideration, clearly demonstrates the wide variety of opinions of researchers on the problems of formalisation of the methodology of construction design documentation. In particular, A. N. Pytkin and E. V. Ponosova [4] in a joint study note that the use of situational theories in the development and adoption of management decisions involves taking into account the limiting or constraining factors that exist in the organisation itself. Within the framework of these theories, there are three main types of restrictions: – technological, determined by the type and flexibility of organisational means of production of goods and services; – human, reflecting the levels of competence of the organisation's personnel, factors of motivation for work, the degree of perception of employees of changes occurring in the organisation; – restrictions in the task statement, due to the actual nature of the work performed. The researchers also draw attention to the fact that the central point and object of situational management is the managerial situation. The term "situation" itself is often used in a wide variety of aspects and is sometimes inseparable from such concepts as state, event, position, etc.

At the same time F. K. Klashanov [9], in his study of the prospects for the application of metasystem analysis in construction, points to the fact that the enormous possibilities of modern computer technologies successfully solving problems on a large scale, which requires the development of theoretical foundations of a design methodology based on the transformation of a subjective design process into an objective, amenable the introduction of algorithms with the subsequent widespread use of both standard and specific software for an electronic computing machine (ECM). This opinion echoes the assessment voiced in a joint study by A. A. Zuenko, A. Ya. Fridman, B. A. Kulik [27] drawing attention to the fact that with the advent of the era of electronic computing, the issue of finding a preferred approach to modelling reasoning on a computer was again raised, the choice between algebraic methods and the theory of factor systems (TFS) is still not obvious The language of mathematical logic is a special case of TFS. In artificial intelligence systems, the concepts of TFS are embodied in a declarative approach, where knowledge is in the form of statements (or rules) written in some formal language, and problems are solved by applying logical inference processes to knowledge. At the same time, N. K. Samal [17], in his study of the methodology for determining the cost of construction in the context of the design documentation used, notes that the economic effect of using indicators of the cost of functional groups of premises to determine the estimated cost of construction work at the stage preceding investment in the activities of construction organisations is achieved through reductions the duration of the formation of estimated construction documentation, increasing the reliability of calculations of the estimated cost at the current level of prices for construction products, with a theoretical justification of the liquidity of investments, as well as by creating an information basis for the implementation of variant design. At the same time, V. Singh and S. Mirzaeifar [28] in their joint study note that the creation and practical application of the methodology for determining the estimated cost of construction work based on the functional groups of premises is relevant and necessary, since they remain intact and properly unanalysed issues of reflecting architectural and planning solutions in the estimated cost, as well as ways to improve the calculation of the cost of construction, based on a detailed study of groups of rooms as combined models of the designed building.

Notably, D. Simeone, S. Cursi and M. Acierno [29] in a joint study note that when determining the estimated cost of building an object in local estimates and local estimate calculations, the data is grouped according to design and technological modules, taking into account the grouping of costs by type of work and design solutions, i.e., by identifying complexes of homogeneous construction and installation works, technologically related to each other. This approach is focused on the sequence of construction work. Thus, the discussion of the findings of this study in comparison with the developments in this line carried out by other authors indicates a fundamental coincidence of the researchers ‘ views on the issues submitted for consideration, which generally confirms the relevance of the stated topic of scientific research and the objectivity of the results obtained during it.

5. CONCLUSIONS

The application of the methodology of artificial intelligence methods for the development of a construction management system compared to conventional information systems is that the user interface can be implemented in natural language, using business concepts specific to software and user decision-making tasks in an unstructured game. An artificial intelligence system is a model of the object under study and its environment in the form of a knowledge base and means of deductive and plausible conclusions. In combination with the ability to work with incomplete or inaccurate information, such a system can explain its actions and tell the user how to correctly input the necessary indicators and how to select the necessary model parameters and the ability to automatically detect patterns in previously accumulated facts and include them in the knowledge base. At the same time, in this context, multi-variant design should be understood as the development of alternative functional planning solutions, i.e., solutions for floor plans, where a set of objects, their purpose and functional relationships are defined.

The use of this method requires further research and is relevant since the calculation of the market value of the immovable property is carried out both in numerous cases of mandatory assessment of the value of the property provided for by law and in the resolution of property disputes and for other purposes. In modern conditions, the implementation of the principles of formalisation of the methodology of construction design documents, taking into account fuzzy logical solutions, is necessary for the establishment of a clear structure of the construction operations performed at each stage of construction work. Determining the final cost of construction in this context is of secondary importance. In general, the issues of creating a high-quality formalised methodology for construction design documents using artificial intelligence require further detailed study, in the context of finding additional opportunities to improve the system, taking into account fuzzy logic, which is the prerequisite for further scientific research in a given direction.

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