Energy modeling and quality management systems in high-rise construction

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Abstract. Currently, there was a contradiction between practice that recognizes the objective need for a periodic assessment of the efficiency of the quality management system in the organizational structures of construction companies and the state of the scientific and methodological base for resolving these issues. International experience in the implementation of objects using 3D printing technology was studied. Issues of energy modeling are also discussed in the paper. The advantages and disadvantages of various methods in the manufacture of building structures by the layered method are revealed. The technology of layer-by-layer construction of high-rise buildings will provide a solution to affordable housing issues, as well as quick restoration of houses in case of natural disasters (floods, earthquakes, fires and other emergencies). The need has arisen for creating an automated system for choosing rational organizational and technological solutions based on modern design technologies. The most crucial factor in the modeling of key performance indicators of the system-target approach to estimation of the sustainability level of net assets on the basis of IPSAS is a multicriterial evaluation of the basic management strategy for quality system elements used in operational and strategic planning projects in construction operations.

1. Introduction

As part of the automation of the choice of a method for performing construction work on the basis of totality of implementation plans (IP), a multi-criteria optimization model based on genetic algorithms was developed to select the most suitable analogue of a standard IP. In the conditions of risk and uncertainty, there is a need for continuous management of economic processes in the public sector. Changes of the last decades have shifted the focus financial and managerial accounting from cost management and financial flows onto economic processes' management (financial standing, risks, backup enterprise system, reorganization processes, value added control), based on the use of accounting engineering tools (monitoring, financial, hedging, or other derivative reports). The net assets indicator, in conjunction with net liabilities, represents one of the most important measures of assessing economic processes, efficiency, and sustainable development of a nonprofit enterprise. However, as concerns businesses that are not focused on profit-making or satisfaction of public demand for services as the outcome of investment, this indicator is difficult to determine. Therefore, a lot of proven models and methods of accounting for net assets cannot be directly applied in this area. This situation leads to a mismatch between the urgent need for scientific methodology in the field of information and analytical support of management and evaluation of the efficiency by using the net assets indicator. A significant enhancement of the financial information quality and the formation of

adequate information support for control and management processes to a wider audience, improving the decision-making process regarding the allocation of resources, ensuring greater transparency and accountability of decision-makers (Bellanca & Vandernoot, 2014). Application of these standards allows an improved control and supervision of the budget as well as development of communication tools for promoting dialogue and synchronizing the work of state institutions of different countries. (European Commission, 2012b; European Commission, 2012a). IPSAS have actually become international benchmarks for evaluation of accounting practices in the public sector throughout the world. For these reasons, IPSAS deserves attention of accounting policy makers, as well as practitioners and researchers (KPMG, 2013). Today, the development of national financial accounting and reporting standards is based exactly on this dynamic group of international standards applied worldwide. Organizational and technological design (OTD) is the most important element in the preparation of construction and includes the tasks of modeling building processes in the construction of facilities. Solving the problems of organizational and technological design of construction (both with or without using a computer) is fraught with a number of difficulties that are caused by insufficient consideration of the existing methods of organization and technology of construction production, real conditions of work, and the capabilities of modern computer technology [16-19].

2. Methods

Modern methods and techniques of organization of construction production involve the use of information modeling (BIM), which involves the creation of a single information model of a building object, the necessary base for its creation, and their use and development at various stages of design, as well as at the stages of construction and operation. Building Information Modeling (BIM) is a process of collective creation and use of building information that forms a reliable basis for all decisions throughout the life cycle of an object (from the earliest concepts to detailed design, construction, operation and demolition). The BIM toolkit is designed to eliminate redundancy, re-entry and loss of data, errors in their transmission and conversion. The study uses logical system, synthesis, analysis, and analogy methods, as well as the comparative analysis method. The purpose of analysis is to identify differences between IPSAS and the public sector standards published by the Ministry of Finance of Russia. The purpose also includes a system review of draft standards and draft resolutions on the basis of published information and opinions, surveys of the Ministry of Finance and the parties concerned (public sector executives, accounting and state control personnel). The surveys have been conducted in the form of a questionnaire. Of special interest are the respondents' views on the expedience of the use of IPSAS in the Russian Federation. We appreciate the loyalty of respondents to the prospects of using IPSAS as the IPSAS basis. We also research in the possibility of the accounting tools' synthesis based on IPSAS and of organization of state and public supervision, including that based on the "Electronic Budget" technology [1,3,4-8].

BIM technology of information modeling of objects is the development of the generally accepted computer aided design system (CAD) [16-25]. The main difference from the latter, in addition to three-dimensional drawing, is that the model has a database containing detailed information about the technological, technical, architectural, engineering and construction, estimated, economic characteristics of the object. Depending on the specific requirements, the base can be supplemented with legal, operational, environmental and other information, the most important for our case is the base of implementation plans for the performed work. In order to optimally choose the IP from the information base according to the studied criteria, a technique based on modified genetic algorithms (GA) has been developed. The GA technique offers the use of three optimization options:
• compliance with the required project duration,
• minimization of project cost indicators,
• minimization of indicators of mechanical equipment,
• minimization of indicators of the complexity of processes.
The objective function is as follows:

$$\sum_{i=1}^{n} \sum_{j=1}^{m_i} C_{ij} * K_{ij} + I * D + P * \sum_{i=1}^{n} \sum_{j=1}^{m_i} C_{ij} * K_{ij} \tag{1}$$

Under the constraint $D \leq T$, where n is the number of works in the project; m_i - the number of IP alternatives of the process i; C_{ij} - direct costs of the i-th process, when alternative j is selected; K_{ij} - the binary variable of process i, when alternative j is selected, then K_{ij} is 1, otherwise K_{ij} is 0; I - indirect project costs per unit of time; D - process execution time; T - the required process execution time; P - indirect percentage of costs.

One of the possible typical implementation plans, the most optimal one, should be selected for the process. In this case, it is necessary to observe time and resource restrictions, which can be represented as follows:

- relationship of the type (end-start)

$$S_B \geq S_A + D_{Aj} + L_{AB} \tag{2}$$

- relationship of the type (start-start)

$$S_B \geq S_A + L_{AB} \tag{3}$$

- relationship of the type (end-end)

$$S_B + D_{Bj} \geq S_A + D_{Aj} + L_{AB} \tag{4}$$

- relationship of the type (start-end)

$$S_B + D_{Bj} \geq S_A + L_{AB} \tag{5}$$

where S_B – start time of the process B; S_A - start time of the process A; D_{Aj} - duration of the process A when alternative j is selected; D_{Bj} - duration of process B when alternative j is selected; L_{AB} - routine break.

An automation model based on modified genetic algorithms was developed taking into account the acceleration of obtaining the optimal choice of IP due to the assessment of ineffective solutions during the operation of the algorithm and their exclusion. At the stage of forming the information base of the IP (population) for each technological process, its repeatability is checked. If the same individuals exist in the population, then the final choice of the best option will be carried out taking into account the studied criteria and the weights of their influence established by experts. In addition, each IP is tested for applicability and adaptability to specified conditions [16-20,25,26]. The population is assessed, selected, propagated and updated until the conditions for stopping the algorithm are met. Thanks to this, the individual with the best indicators for this project will be selected. In other words, the principle of the algorithm is as follows: after selecting the most suitable implementation plans by the name and design features, if there is a problem of further selection of the IP, the algorithm prefers the following IP:

- first of all, with a lower cost,
- secondarily, with the shortest duration,
- on a third-priority basis, with the lowest value of mechanical equipment,
- on a fourth-priority basis, with the lowest value of labor costs.

3. Results

Efficiency does not exist separately from the efficiency criterion. If, by definition, efficiency is an indicator of the degree of achievement of goals, then the criterion is a measure of the assessment of

this degree. For example, a solution that is optimal according to the criterion of cost of production may be unacceptable by the criterion of its demand in the market (nobody needs cheap, but unclaimed products).

The efficiency of the decision is divided into *expected* (predicted) and *actually achieved*. The first is assessed at the stage of development of projects (investment projects) of the construction organization, the second - after it is finished upon completion of tasks. Goals have a different nature. When making decisions on the construction of transport facilities, economic, industrial (technological), social, environmental and other goals are pursued. Therefore, the efficiency of decisions can be divided into economic, operational, industrial, social, and environmental.

The *operational* (or general) efficiency E_o is generally understood as the ratio of the scope of actually performed (or predicted) work Q_a to the planned (directive) indicators Q_{dir}:

$$E_o = Q_a/Q_{dir} \tag{6}$$

The *economic* efficiency of the decision E_E is assessed by the ratio of the economic effect (profit, profitability of production) P to the costs Z, due to which this effect was achieved:

$$E = P/Z. \tag{7}$$

All other types of efficiency are calculated similarly using dependencies of the type or [16-19]. At the same time, the appropriate indicator of the effect in monetary or physical terms should be set in the numerator. To work with the database, a set of QtSql classes is connected for working with databases using the SQL structured query language and the QSqlDatabase class to represent the connection to the database. To demonstrate the operation of the algorithm for improving the adoption of OTS in the production of stone work, a matrix of parameters was built from the information base of implementation plans (IP), which presents the parameters from the IP: cost, duration, mechanical equipment, labor costs.

Typical implementation plans are compared according to the weight of the influence of the criteria on the project. As a result, priority is given to the choice, and the total weight of the influence of the criteria on the project is greater for the selected IP, which will be selected by the algorithm for use in the construction and installation works in the building project.

In addition, the characteristics of workspaces (type, size, and location) and the work that occurs in the areas of activity during the construction process change in time and move in three dimensions. Without the use of 4D modeling, conflicts of workspaces at the construction site are almost impossible to detect. The development of a visualization model of work with 3D workspaces based on the information model of the building and taking into account the time parameter from the construction schedule allows tracking the progress of work and determining any conflicts between their workspaces even at the design stage [19-25].

Selection of pile drivers is carried out on the basis of the selected standard size of piles. Pile drivers are selected from the information database, the technical characteristics of which allow the loading of piles of a selected diameter and mass. In addition, the database contains the following types of equipment: concrete mixer trucks; concrete pumps; lifting platforms; bulldozers; drilling rigs; machinery for bored piles; pipe layers; excavators. New functionality and filling the program databases can be a breakthrough in the development of organizational and technical documentation. Therefore, the priority for developers is the implementation of wishes received in feedback. As for the users, among the experts and constructive critics, the developers hope to see those who are directly connected with the development of implementation plans and the introduction of new construction technologies [11-15, 25-27]. The level of product quality and the construction period correspond to the directive ones. There were no environmental violations during the construction process, which implies that these indicators will be limitations. The efficiency of the processes included in the system is given in (Table 1).

Table 1. Process efficiency of the quality management system.

Process No. (P)	Quality management system processes	Rating	Normali-zed indicator	Weight coefficient
Management processes:				**0.33**
1	Strategic planning. Development of quality policies and goals	6	0.6	0.29
2	regulatory support	6	0.6	0.21
3	analysis of a system by management	5	0.5	0.37
4	bringing the requirements of consumers, legal and regulatory requirements to the personnel (internal exchange of information)	7	0.7	0.13
Main processes:				**0.5**
Provision of resources:				0.25
5	personnel management	7	0.7	0.5
6	infrastructure management	7	0.7	0.37
7	work environment management	6	0.6	0.13
Processes of project life cycle, interactions with consumers and subcontractors:				0.75
8	project life cycle processes planning (preparation of production)	6	0.6	0.23
9	consumer processes	7	0.7	0.16
10	subcontracting processes	7	0.7	0.09
11	procurement management	6	0.6	0.13
12	organization and implementation of construction and installation work	7	0.7	0.23
13	commissioning	7	0.7	0.16
Auxiliary processes:				**0.17**
14	document management	6	0.6	0.056
15	record management	6	0.6	0.056
16	inappropriate product management	7	0.7	0.072
17	customer satisfaction measurement	6	0.6	0.105
18	product monitoring and measurement	7	0.7	0.139
19	internal audit	5	0.5	0.139
20	management of devices for monitoring and measurement	6	0.6	0.117
21	corrective actions	7	0.7	0.083
22	preventive actions	6	0.6	0.094
23	continuous improvement	6	0.6	0.139

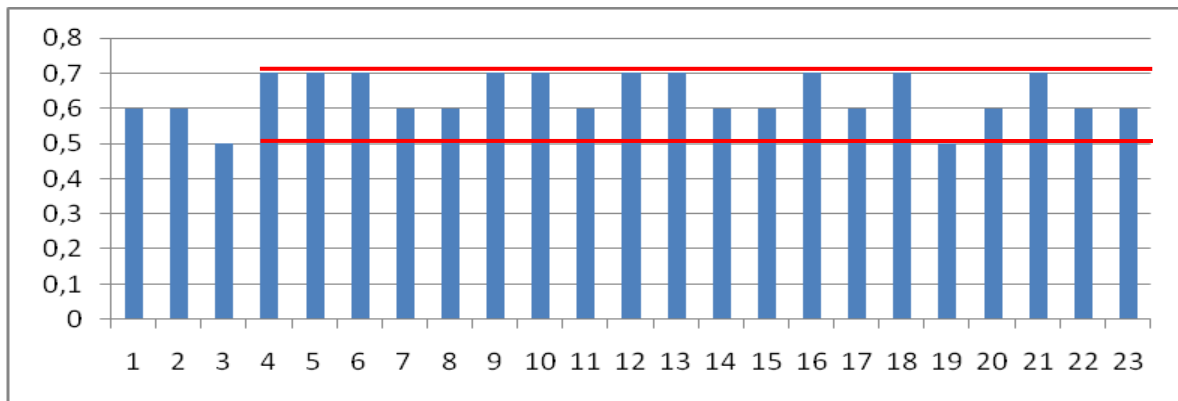The effectiveness of the processes is presented in the form of a diagram:

Figure 1. The effectiveness of the system processes.

Calculation of weighting coefficients was carried out by the method of relative preferences. The significance of the processes, groups of processes was determined by an expert survey of officials of the construction management. After the calculations, the efficiency of the system was: R_{Syst} = 0.62959. From which it follows (0.5 $<R_{Syst}<$0.7) that the level of functioning of the system is average and shows the need for corrective actions to improve the functioning of processes (improve the quality of processes). Figure 1 can help identifying the processes that need improvement. Due to the fact that no cost accounting for the quality management system is carried out in management, [16-19]. the calculation of economic efficiency was carried out as the ratio of actual indicators of economic efficiency to planned ones (revenue, profit), the significance of the criteria: $\alpha_1<\alpha_2$

$$K_{OE} = 0.25 \times \frac{157914}{178000} + 0.75 \times \frac{1478}{3000} = 0.59129 \rightarrow 1(max)$$

4. Discussion

1. Nowadays, quality management systems within a single technological cycle represent disparate quality systems of management and departments. There are no unified approaches to building systems. In order to increase the efficiency of quality management, it is recommended to create a unified quality management system, which should cover not only management bodies, but also subordinate units [31-35] (Figure 2).

2. To ensure the coordinated work of the quality services of management bodies and subordinated units, it is recommended to establish *uniform requirements* for the documentation of the quality management system, criteria for the effectiveness of processes and methods for assessing them. This will improve interaction on the issues of quality of processes and products of subordinate units, both among themselves and with management bodies.

3. In order to improve management efficiency, it is recommended that the issues of regulatory support, development and implementation of new documentation be assigned to the quality service.
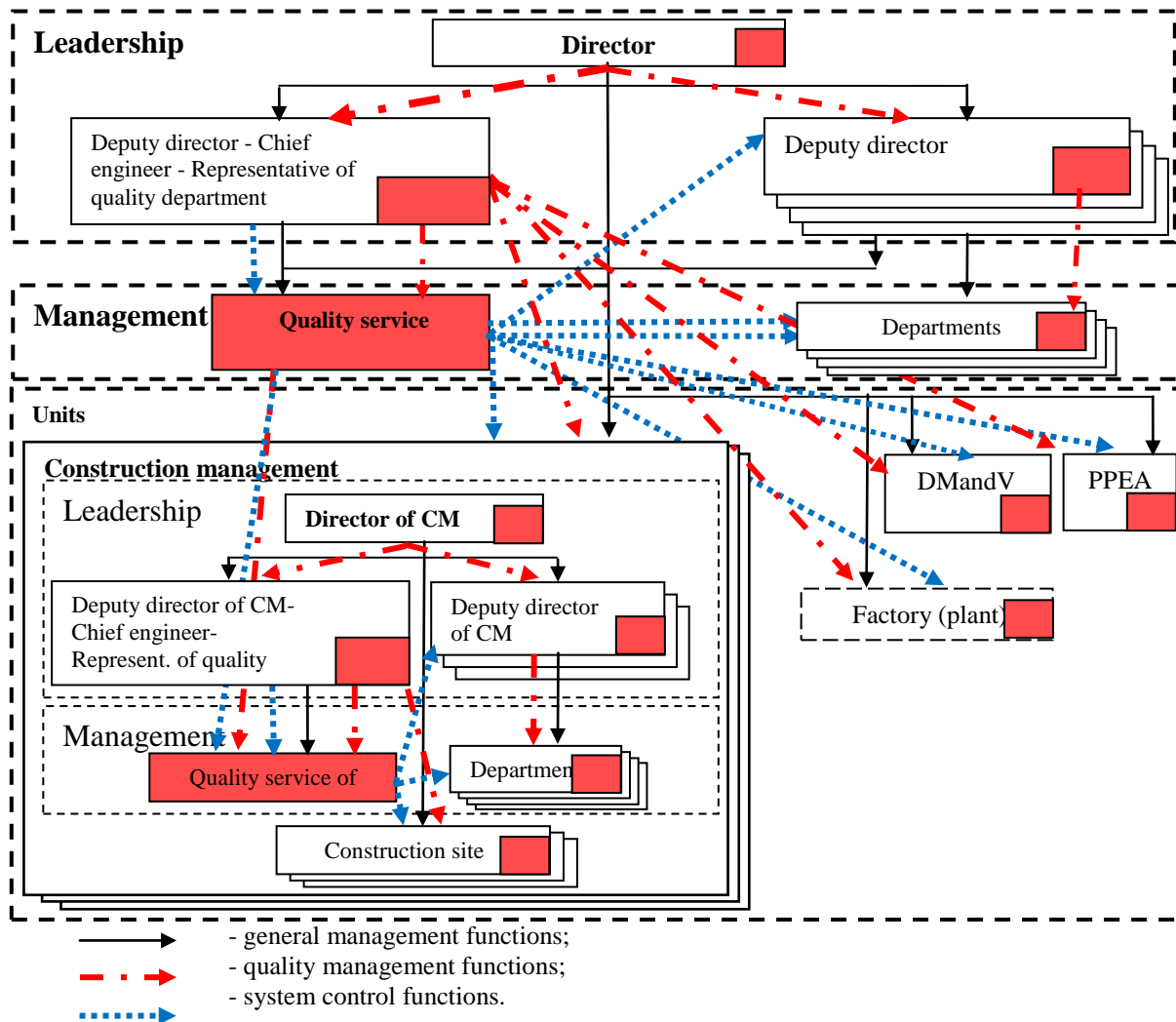
Figure 2. A variant of the recommended organizational structure of the quality management system (quality services - separate units).

4. In order to maintain the quality management system at a high level, it is recommended to periodically assess the efficiency of the system, taking into account the changing production conditions and requirements for the quality of construction products. The frequency of such an assessment should be linked to a periodic analysis of production and economic activity. At the same time, it is recommended to consider the assessment of the efficiency of the quality management system as a separate analysis task.

5. The normal functioning of the quality management system requires certain costs for the maintenance of the management system, as well as costs for measures to manage product quality. To date, such costs are either not determined or determined in the general financial reporting system. Due to the high complexity of the process of calculating these costs, it is recommended that a system of accounting for the above costs be allocated from the general financial statements. Calculation and analysis of costs should be carried out in the process of assessing the efficiency of the management of quality system elements. Systematic accounting and analysis of quality costs will allow determining the causes of occurrence in a timely manner, managing them, and determining the best methods to reduce them.

6. The application of the system-target approach in the developed methodology makes it universal and applicable to any organizational and functional building systems, regardless of the function and

the nature of the tasks performed. However, the objectivity of the information obtained as a result of an assessment of the efficiency of the system will largely depend on the correctness of setting goals and choosing indicators that determine their achievement. In the recommended system of goals, the goals of quality management should be linked to the general goals of production management and issues of the appropriateness of economic activity.

5. Conclusions

As part of the study, verification of the proposed methodology and its implementation was carried out in ICC "Zapad" and IC "Garant" [31-35]. The results are shown in Table 2.

Table 2. Efficiency calculation results.

No.	Company	R_{Syst}	K_{OE}	U_e	K_{soc}	K_o
	Significance of the criteria	0.29	0.29	0.29	0.13	
1	ICC "Zapad"	0.61758	1.28227	0.76	0.62	0.85196
2	IC "Garant"	0.62959	0.59129	0.72	0.7	0.65385

The efficiency criteria themselves have different significance ("weight") in the system of accepted criteria. The considered provisions can be regarded as the basis of the methodology for assessing the efficiency of the quality management system.

The proposed methodology is presented in four stages in figure 3.
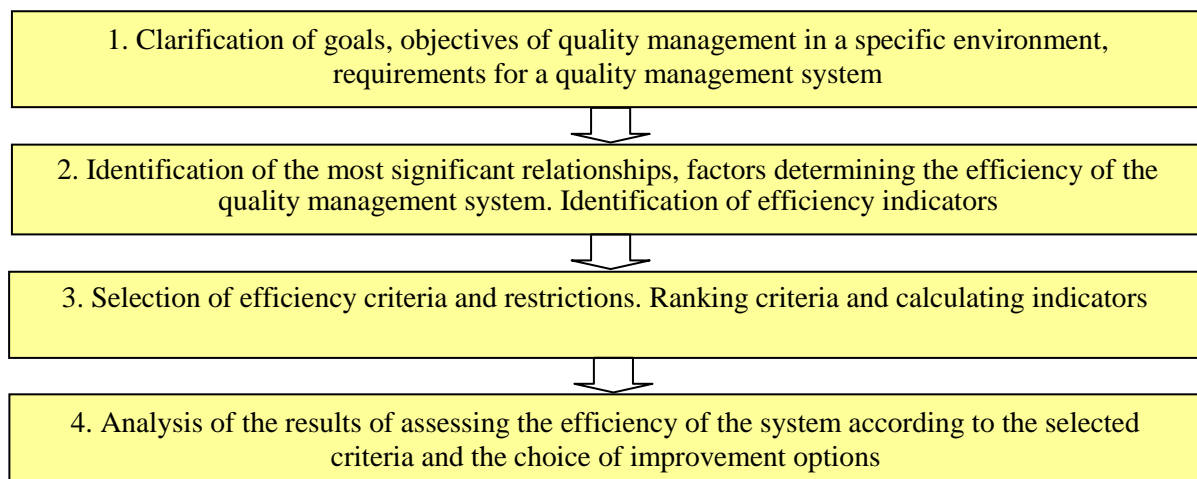

Figure 3. Algorithm for assessing the efficiency of a quality management system.

At the first stage, the first and second provisions of the formulated methodological foundations are implemented - the goals are specified and their decomposition is carried out.

Goals in different conditions can be formulated in different ways. In this case, the quality parameters of the object are predefined. In practice, when setting goals, they will indicate both operational and economic (cost) indicators, i.e. goals of various nature.

The second stage will be devoted to identifying the most significant relationships between the elements of the system, the factors that determine its efficiency. These elements and factors will be developed and presented in subsequent studies.

This stage will be organically connected with the first stage, since the conditions and factors will determine the order of implementation of the goals, as well as the very system of assessing the efficiency of QMS. The calculation of the necessary parameters for the construction, installation and special works as part of the implementation plan, the automated selection of methods of construction and installation works on the basis of the selection of the necessary technical specifications by means of BIM technology is correct, which is confirmed by theoretical analysis and the practice of using the choice of the method of construction work by the totality of implementation plans. The issues of the

integrated use of information resources, combining the functionality of different software tools, creating information models of various processes and objects, the development of methods and algorithms for processing and presenting information are widely discussed by the scientific community [16-19, 26-30, 31-35].

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