Milestones of mathematical model for business process management related to cost estimate documentation in petroleum industry

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Abstract. The paper is devoted to milestones of the optimal mathematical model for a business process related to cost estimate documentation compiled during construction and reconstruction of oil and gas facilities. It describes the study and analysis of fundamental issues in petroleum industry, which are caused by economic instability and deterioration of a business strategy. Business process management is presented as business process modeling aimed at the improvement of the studied business process, namely main criteria of optimization and recommendations for the improvement of the above-mentioned business model.

1. Introduction
In modern production, managers and workers address various innovative methods, which will undoubtedly increase labor productivity and business efficiency. This ultimate thesis has always been relevant since different people have different understanding of the term ‘innovation’.

Construction and reconstruction of oil and gas facilities in unstable economic conditions are critically important and thus cause many problems. Oil and gas facilities do not simply require high-quality infrastructure, but also initial cost estimate and correct budget of the construction. The conducted study [1] made it possible to conclude that not more than 1/5 of the largest oil and gas projects can be safely called successful in terms of their compliance with the declared cost and time frames. Preparation of initial construction phases, which include cost estimate and correct calculation of all norms and price policy, is vitally important.

Such cost estimate in engineering is called cost estimate documentation, which covers a complete set of construction cost calculation within design, construction, assembly and repair organizations.

This kind of activity can safely be called a business process. It is necessary to recall that the business process as such represents “a set of interrelated or interacting activities, thus forming business input and output”. At the same time, the results of the output process shall by all means present a certain value for the consumer (client) and be in demand. Hence, the budget activity covers everything mentioned above. Considering the structure of a business process covering the budget activity it is possible to draw a conclusion that it represents a set of interacting organizational units (links, operations), performing various types of activity aimed to achieve a single production target. The main objective of cost design includes interrelated organizational and functional operations resulting in the final and valid product, i.e. the cost estimate. A process approach to cost estimate management in the construction of oil and gas facilities will support detailed consideration of such processes. Authors [2] and [3] clearly illustrate the process approach to operational management, which includes diverse organizational units or, to put it differently, to functional operations. All these
components pursue a common goal and actively develop their scientific and practical aspects. Unlike traditional process management, the process approach in the organization is aimed at management of targeted flow of interrelated activities (operations, works, procedures) transforming input flows of material, information, and financial resources into output flows being the final product presenting a certain value to a consumer (ISO 9001:2000).

All of the aforesaid leads to the final conclusion, i.e. to the need of applying the process approach to management of business processes related to cost estimate documentation. It should be noted that the process approach includes not only regulatory measures concerning some activities but also its mathematical and economic optimization.

2. Materials and methods
Some managers of design institutes consider the business process of cost estimate documentation as a labor-intensive and complicated process [4]. Estimating engineers engaged in the implementation of this process deal with enormous amount of data, which cannot always be processed quickly, and hence, they make the best use of application software products that ensure the success of this process.

However, such software products simply represent an engineering tool, but the quality of the process is not always ideal. If to analyze these activities, to collect modeling data and to find optimal solutions, then all this combined will serve a powerful tool for sound management and implementation of this process [5].

Mathematical modeling and optimization is required for high-quality design of business processes. Meanwhile, business process modeling is generally descriptive [6] and is fulfilled as texts, tables, diagrams and other tools (notations) to describe work flows and information. In this case, business process modeling is understood as the regulation of processes, their documentation and relevant paperwork, while business process optimization, declared in different manuals, includes the fulfillment of certain actions aimed at their coordination and partial improvement.

Such fulfillment of organizational actions on regulation and functioning of a business cannot be called optimization. The recent study showed that all these actions do not guarantee optimal management of certain business processes. Descriptive business process modeling via such famous notations as IDEF0, DFD, and BPMN cannot ensure optimization and automation of business processes. Optimization shall be performed through mathematical modeling of a business process where the business process itself, presented as a model, will be explicitly explored and studied. Besides, the business process model will be supplemented by all necessary criteria of its optimization [7]. The scientific community does not pay much attention to mathematical modeling of business processes, especially it does not consider such factors as work ambiguity, process breakdown into subprocesses to ensure its prompt study and thorough analysis [8].

Optimization of cost estimate documentation, which includes the assessment of resource levels and production output (estimates, rates, services) within every process link and in the entire business process, is a primary goal in any business process design (production, maintenance, service, distribution, etc.). In view of uncertainty of prospective demand for the final product (on account of which the business process is organized), uncertainty of future sales and purchase prices for production resources, uncertainty of investments and their consequences, the relevant optimization of business processes shall be performed under uncertainty conditions of the future. In order to build a mathematical model of business process optimization, there is a need to set criteria reflecting uncertainty of the future and potential outcomes of the business process. All these criteria shall be brought up to date only in the future both with regard to financial results and to the resulting product of the whole process.

The paper suggests the concept of mathematical optimization model of business process management under conditions of uncertainty and unstable economy. The final state of a business process shall satisfy all economically viable options to implement the construction project or reconstruction of support facilities in petroleum industry. The aim of mathematical optimization is to
ensure management of such business processes, which will undoubtedly provide for high-quality construction.

3. Model structure of the studied business process and its mathematical interpretation

The structural model of the studied business process considers all work aspects related to this kind of activity. The model is based on process links (each separate operation) with input flows of resources, requirements and other regulating factors divided into two parts: \( Z = \{X; Y\} \). Flow vector \( X = \{x_1, x_2, ..., x_n\} \) at the input to the \( i \)-process link includes the flows of production factors or external requirements; flow vector \( Y = \{y_1, y_2, ..., y_k\} \) includes products, services, and operations performed within the previous \( i \)-process links, which serve as input production resources within the given \( i \)-link. Within the model, such flows of resources are expressed as circles, process production links as rectangles, service links as rhombuses, influx of resources and/or products as arrows (Fig. 1a).

\[ F_i = f_i((x_1, x_2, ..., x_n, y_1, y_2, ..., y_k)). \]  

(1)

A certain PF type is established for each link and operation (activity) using regressive econometric methods based on available statistical data relevant to both the undergoing production process and to the applied technology in this link. Physical transformation of production factors getting into the input of a process link to the output product is simultaneously followed by a cost increase of the input flow by the costs of work performance in a link (further costs are understood as the so-called average costs or unit costs [9]). Considering that the resources coming to \( i \)-link in volumes \( x_1, x_2, ..., x_n \) and \( y_1, y_2, ..., y_k \) have costs (per unit volume) \( p_1, p_2, ..., p_n \) and \( q_1, q_2, ..., q_k \) respectively, it is possible to get the overall cost of resources incoming to \( i \)-process link:

\[ \sum_{i=1}^{n} p_i x_i + \sum_{l=1}^{k} q_l y_l. \]  

(2)

In each \( i \)-link of a business process, the cost (2) of the input flow will be transformed into the cost at the output flow caused by expenses \( \Delta q_l \) incurred by production within the \( i \)-link. Then, the overall cost of the output flow of an \( i \)-link can be presented as follows:

\[ \sum_{i=1}^{n} p_i x_i + \sum_{l=1}^{k} q_l y_l + \Delta q_l F_i. \]  

(3)
Modeling of a business process for its further optimization shall consider optimal requirements of production factors in order to receive the final product. The demand and prices of production factors are uncertain and unknown in advance. The real source data will include characteristics of economic and financial state, the developed market conditions necessary for cost estimate documentation with prices \( c_1, c_2, \ldots, c_i \) for production factors \( x_1, x_2, \ldots, x_i \) \((x_i \geq 0, \quad j = 1, \ldots, i)\) and sales prices \( c_i \) of the final product received at the output of final \( i \)-process link, known quantity of financial resources \( j \) assigned for the business process. In the assumption that the structure of a business process and the structure of the corresponding organizational units are chosen, the following optimization problem is solved: to define the optimal cost of the final product – cost estimate \( F_i \) at the output of the final \( i \)-link and optimal volumes of production factors \( x_1, x_2, \ldots, x_i \) maximizing the profit of the entire business process. The corresponding mathematical model is as follows:

\[
c_i \cdot F_i(x_1, x_2, \ldots, x_i) - (c_1x_1 + c_2x_2 + \cdots + c_ix_i) \rightarrow \max. \quad (4)
\]

To ensure optimization, the output of final product \( F_i \) shall be preliminary expressed through PF of all previous links of a business process and contain finite dependence on volumes of production factors \( x_1, x_2, \ldots, x_i \). This is achieved through the composition (inclusion of one into another) of PF of the previous links into PF of final link \( F_i(x_1, x_2, \ldots, x_i) \) in the sequence, which begins with PF of the last process link and ends with PF of the first link.

**4. Results and discussion**

This business process is designed to achieve the global purpose, which covers the output of the final product (cost estimate), therefore the business process optimization shall be performed as a system for the entire structural model of a process (Fig. 1) in general. Besides, the output volume and sales price of a product, as well as volumes of purchased production factors, represent factors managed by the owner of a business process and, therefore, variables of mathematical model optimization.

This mathematical interpretation of business process management encompasses the economy and structure of this process management. All obtained values will be relevant provided certain process links are performed.

It is also noteworthy that the study of this issue shall not only consider economic features of business process management but also integral functioning of all process links. Such parameters as, performance frequency \((\lambda)\) of a certain process link and its time \((t)\) will be used for this purpose. This may increase the business process efficiency and identify weaknesses in performance of a certain operation in the overall structure.

All these factors will be considered in the modeling of assessment of labor cost of software users that create cost estimate documentation. This method will make it possible to assess the random nature of a process link performance and will allow designing a model of a relatively complex system, which undoubtedly will foster model testing and evaluation of certain decisions, for example, when choosing the universal software product (SP) to tackle optimization or areas of automation [10].

**5. Conclusions**

Being extremely relevant, the modeling of business process management, understood as numerical optimization synthesis of the structure, factors and parameters of a business process, remains not fully developed. The approaches to modeling and the so-called optimization of business processes, being descriptive in nature according to some literature sources, fail to meet this criterion, since they do not ensure their quantitative optimization.

The developed concepts of mathematical modeling of business process management are focused on a single construction project, i.e. cost estimate documentation and project costs. Depending on the nature and characteristics of every single project, the source data for the developed model alongside with its structure and obtained results can change considerably throughout modeling.
All this combined provides for detailed evaluation of the model sufficiency and its improvement with certain criteria under uncertainty. Uncertainty conditions play a key role in cost estimate of the construction project. Petroleum industry will undoubtedly benefit from mathematical management aspects of economically vital processes, which will supplement it with a powerful tool to manage and simplify all processes.

References

[1] Hamidullin R I, Senkevich L B 2017 About necessity of mathematical modeling of the business process of cost estimate calculations in the construction of oil and gas facilities Higher educational institutions news. Neft I Gaz 6 139-145

[2] Conforti R, Leoni de M, La Rosa M, Aalst van der W M P & Hofstede ter A H M 2015 A recommendation system for predicting risks across multiple business process instances. Decision Support Systems 69 1-19

[3] Dumas M, Aalst, van der, W M P & Hofstede, ter, A H M 2005 Introduction. In M. Dumas, W.M.P. Aalst, van der & A.H.M. Hofstede, ter (Eds.), Process-aware information systems: bridging people and software through process technology (Hoboken: Wiley-Interscience) pp. 3-20

[4] Hofacker I and Vetschera R 2001 Algorithmical approaches to business process design. Computers & Operations Research 28 1253-1275

[5] Powell S G, Schwaninger M, Trimble C 2001 Measurement and control of business processes. Syst. Dyn. Rev. 17-1 63-91

[6] Madera A 2015 Interval uncertainty of estimates and judgments of subject in decision making in multi-criteria problems. International Journal of the Analytic Hierarchy Process 7 (2) 337–348

[7] Tiwari A, Vergidis K, and Turner C J 2010 Evolutionary multi-objective optimisation of business processes. In: Gao, X.Z., Gaspar-Cunha, A., Köppen, M., Schaefer, G., Wang, J. (Eds.), Advances in Intelligent and Soft Computing: Soft Computing in Industrial Applications, (Springer, Heidelberg) pp. 293-301

[8] Sawicki P, Sawicka H 2014 Logistics process improvement using simulation and stochastic multiple criteria decision aiding. Procedia Social and Behavioral Sciences 111 213–223

[9] Turner C J, Tiwari A, Olaiya R and Xu Y 2012 Business process mining: From theory to practice. Business Process Management Journal. 18(3) 493–512

[10] Hamidullin R I, Senkevich L B 2015 Automation of the work price calculation engineer construction of estimated LLC «Tobolstroyservis» (in Russian), Fundamental research. 11(1) 110-114