Reengineering of manufacturing processes in the construction organization

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Abstract. The introduction of advanced technological solutions in modern conditions becomes a paramount problem for industrial enterprises. In relation to Russia where the digitalization of the construction industry is proclaimed, the priority of introducing information technologies is forming a new goal for the country, the one to join the global process of a new technological revolution. This cannot be achieved without a fundamental re-planning of the key production processes of the construction enterprise. We consider this procedure as “reengineering of production processes”. An approach to assess the validity of the reengineering of production processes of a construction enterprise, implemented with the involvement of an engineering company, is presented. The benefits due to the involvement of an engineering company are given. The proposed approach allows calculating the reengineering console, which makes it possible to make an informed decision on the implementation of the reengineering project by both the enterprise and the engineering company. This study can be demanded by both potential participants in the process, and scientists who conduct research in this area.

Keywords: construction, enterprise, technological revolution, BIM, reengineering, production process.

1 Introduction

Since the beginning of this decade, the structure and specifics of modern industrial production has undergone dramatic changes under the influence of intensive development and the subsequent introduction of advanced technological solutions, the growth of high technology products. The nature of the transformation is so significant that it is interpreted as a new technological revolution [1]. In this regard, the production activity of industrial enterprises, especially traditional industries, creates an increased demand for the services of engineering companies. A special place here belongs to the enterprises of the construction industry, which along with engineering, create new fixed assets. Considering the engineering company we mean an expert with professional competencies in a certain field, provides intermediary services in the framework of integration and coordination of work in the framework of the introduction of new technological solutions [2]. These services cover all stages of the technological chain of production of goods and the provision of services.

The large-scale changes that the production sphere is undergoing now are called the new technological revolution. It is based on the transition from the production of standardized products to customer-oriented adaptable production [3]. In Russia, construction has traditionally been characterized by a high level of resource and energy intensity [4]. As a result, in the long term, the key challenge for the industry is to increase the effectiveness of monitoring the timing and progress of production of construction products. Here, according to the Centre for Strategic Research, digitalization, BIM, and construction management based on digital models should be the breakthrough...
factors of the new technological revolution [5]. This necessitates resolving a range of issues of a technological and organizational nature, which should be the task of an engineering company. Thus, it is possible to achieve growth in the competitiveness of the construction company. At the same time, Russian builders show low motivation for the use of engineering services due to the low stability of doing business [6] and the low evidence of achieving an effect [7]. So, there is a mismatch between the high costs of attracting an expert intermediary to the expected return [8].

The introduction of digital technology including BIM in the construction industry has been interesting for scientists over the past decade. Nowadays there is no common position regarding what is the priority effect of such digitalization. However, the diversity of opinions can be divided into three groups. Some scientists believe that saving time is the main one, time should be saved while designing, verifying [9, 10] and coordinating the project [11]. It should be saved also during construction and installation works [12, 13]. Other scientists think that key effect of digitalization of construction is improving the quality of organization of construction production in terms of reducing errors and inaccuracies in project documentation [14, 15], reducing the error of the budget for financing the project [16], and the optimal selection of contractors and suppliers [17]. Reducing construction costs [18], reducing operating costs [19, 20] and increasing investment attractiveness [21] as a priority effect of digitalization of construction unites representatives of the third group of scientists. In our opinion, the introduction of digital technologies in the construction industry leads to a comprehensive saving of resources at all stages of the life cycle of a property as a product of the construction industry such as concept, planning, construction, operation. This approach does not contradict the considered positions, but at the same time it combines them together, forming a comprehensive view of the need to introduce BIM-technologies in the practice of a construction enterprise.

The concept of “reengineering” was introduced into scientific circulation in the early 1990s. The pioneers in the field of software were Chikofsky E. and Cross J. [22], the ones in the field of business processes were Henry J. Johansson, Patrick McHugh, A. John Pendlebury, William A. Wheeler [23], Richard C. Dorf [24]. In 1994 a study by Betts, M., Wood-Harper, T. was published [25]. This study dealt with reengineering in construction. Relying on the aforementioned fundamental research, as part of this study, by reengineering production processes we mean a radical replanning of key production processes in order to qualitatively improve their implementation in terms of cost, quality of service and speed. In relation to enterprises in the construction industry, the tools for reengineering production processes should be the use of information models of capital construction projects implemented on the basis of BIM technologies. The intermediary services in this matter are provided by engineering companies specializing in putting reengineering into practice. We should notice that in the world practice such services are provided by reengineering companies [26]. But due to the fact that the Russian market for such services is in its infancy, most of them are engineering companies that have not gained yet a narrow specialization. However, in Russia, companies that are engaged in reengineering can be divided into three groups. Firstly, these are the consulting companies that provide, first of all, audit services. Secondly, the design companies that develop an optimal business project, but do not provide reengineering services. Thirdly, these are the engineering companies engaged in the practical implementation of reengineering. The task of the companies of the third group is to reorganize the management system and its optimization [27].

The object of research is the reengineering of production processes of a construction organization, and the subject of research is the assessment of the feasibility of reengineering of production processes of a construction enterprise. In the framework of this article, with the aim of formalizing the assessment of the feasibility of reengineering the production processes of a construction enterprise, implemented with the involvement of an engineering company, the following tasks are set: determining the main benefits of using a building company services of an engineering company, establishing the degree of impact on the value of the profit of the construction company of the benefits as cumulative and individually.
2 Materials and methods

The study is based on the practice of reengineering the production processes of a construction enterprise. In the context of the transitive economy of Russia, reengineering is associated with a complex of effects that are provided by the transition to the construction management based on digital models. These effects in terms of attracting an engineering company are identified and subject to the quantitative measurement.

The solution of the tasks given in the study is based on the application of the following methods: analysis, synthesis, classification, modeling. The quantitative determination of the amount of profit provided by a construction company attracting an engineering company is based on the use of Net Present Value (NPV), which is calculated using the well-known Eq. (1):

$$NPV = \sum_{i=1}^{n} \frac{NCF_i}{(1 + I)^i} - \sum_{i=1}^{n} \frac{Inv_i}{(1 + I)^i},$$

where $NCF_i$ – is net monetary flow of $i$-period of the investment project;

$Inv_i$ – is investments made in the $i$-period of the investment project;

$I$ – is the value of capital which is necessary to realize the investment project;

$n$ – is the period to realize the investment project (the level of calculation).

3 Results

Some researchers believe that the involvement of an engineering company provides the customer with a range of advantages. They include such advantages as reducing the time frame for the implementation of the project, the application of best practices in the implementation of technological solutions, increasing the efficiency of the organization of the production process, the reduction of production risks, increasing the availability of project finance. The latter advantage is especially important in the context of the transition of housing to banking project financing, which, in comparison with the collateral one, has significant potential for discount [9].

In order to quantify the amount of profit provided by a construction company engaging an engineering company, we suggest using the concept of reengineering console (abbr. from consolidated annuity). The reengineering console is formed for a number of reasons: the engineering company has unique competences; a systematic approach to the organization of the process; the possibility of a reasonable choice of suppliers and contractors with a high degree of fulfillment of contractual conditions. The total effect of these ones causes a positive effect on the effectiveness of the project in terms of ensuring the organization of production processes.

As a rule, the implementation of reengineering projects takes a considerable period of time, which can reach several years, which necessitates taking into account the time factor. In order to assess the validity of the project, they resort to the indicator of net present value (NPV). It is the most common indicator that takes into account the time factor. Considering the interpretation of the reengineering console (hereafter referred to as $REC$), the specifics of its formation, within the framework of this study, we propose to calculate $REC$ as the net present value of the project which involves the use of the services of an engineering company (hereafter referred to as $NPV_{REC}$), not taking into account the net present value of the project without involving engineering company (hereafter – $NPV_o$):

$$REC = NPV_{REC} - NPV_o.$$  

(2)

For the subsequent analysis, we will present the Eq. (2) as:

$$NPV = \sum_{i=1}^{n} \frac{(1 - IT_i)(P \times Q_i - VC_i - FC_i - MP_i - OE_i)}{(1 + I)^i} - \sum_{i=1}^{n} \frac{Inv_i}{(1 + I)^i},$$

(3)

where $IT_i$ – is corporate income tax rate (adopted in fractions of a unit);

$P_i$ – is the cost of a unit of production (in housing construction this means thousands of rubles per square meter of the total area of the flat);

$Q_i$ – is sales volume (square meters of total area);

$VC_i$ – is variable costs;

$FC_i$ – is constant costs;

$MP_i$ – is the sum of debts in form of percentage of loan service payments (if the loan exists);
OE – is other expenses referring to the financial result of the construction organization.

A study of the functioning practices of reengineering companies outside Russia [14-17] substantiated the formulation of the benefits that are provided by their attraction, in particular to ensure the transition to construction management based on digital models:

1. Reducing the duration of the project;
2. Partial leveling of risks;
3. Development of reengineering solutions;
4. The high level of business reputation of the engineering company, presented to the customer company.

It is necessary to consider in detail the impact of the involvement of an engineering company on the components of NPV.

3.1 Reducing the duration of the project
World experience in the application of information models in the capital construction projects indicates that the terms of the project are reduced to 40%, [12] and the design period is reduced by 20-50% [10]. Therefore, \( n_{rc} < n_{0} \). In other equal conditions, a project with a shorter implementation period has a larger net present value. In this case, a part of the reengineering console is formed due to the increase in intensification of the project.

3.2 Partial leveling of risks
The organization of production processes in the construction industry is characterized by a whole range of risks. At the same time, they directly affect the constituent elements in calculating the NPV of the project. We will classify the designated risks which are taken into account when determining the NPV. It is generally recognized that risks are divided according to the source of origin into the internal and external ones.

The following risks are among the risks of internal order.

*The risk of a mismatch between the qualification level of employees and those production processes to which they are involved.* Its consequence is the permanent growth of fixed and variable costs due to the adoption of incorrect decisions, a decrease in the level of product quality. We will denote it as \( R_{st} \).

*Production risk due to technological processes.* This risk is caused by technological processes, during the implementation of which the failure of the production equipment is possible due to untimely maintenance, improper operation. As a result of this, fixed costs and other expenses increase. We will denote this risk as \( R_{p} \).

*Money market risk.* Its genesis is the cost of external financing due to fluctuations in the value of money, inflation, changes in discount rates, etc. As a result, the company is faced with an increase in fixed and variable costs, debt burden, and other expenses. We denote this risk as \( R_{m} \).

The following risks are the external ones.

*Risk of non-compliance with the delivery time of materials.* This risk is caused by the inability to purchase the necessary material and technical assets for various reasons: logistical problems, one-sided changes in contractual conditions by the supplier, fraud. The result is an increase in fixed costs and other expenses. We will denote this risk as \( R_{s} \).

*Competitive risk.* It comes from the likelihood of competitive offers entering the market that are more in line with consumer demands, due to the use of non-market forms of sales struggle (exerting pressure on suppliers and consumers, misinforming them, disseminating false information about products, etc.). As a result, sales are falling. We will denote this risk as \( R_{r} \).

*The risk of force majeure.* It cannot be foreseen due to the unforeseen nature of the appearance, so we will attribute it to other expenses. We will denote this risk as \( R_{f} \).

*Risk of deterioration in market conditions.* This risk stems from the delayed, untimely introduction of innovative solutions and incomplete information about competing companies into production. As a
result, sales of products are slowing down, the selling price is decreasing. We will denote this risk as $R_c$.

Risk of rising cost of capital. It will inevitably accompany any project, therefore it is subject to mandatory accounting. We will denote it as $R_i$.

Thus, taking into account the Eq. (3), the cumulative effect of the described risks on the $NPV$ value can be determined using the Eq. (4):

$$NPV = \sum_{i=1}^{n} (1 - IT_i) \times \left( \frac{R_c \times R_i \times P \times Q_i - R_c \times R_i \times VC_i}{(1 + R_i \times I)^i} \right) - \frac{R_c \times R_i \times R_e \times FC_i + R_e \times MP_i + R_e \times R_i \times R_e \times OE_i}{(1 + R_i \times I)^i} - \sum_{i=1}^{n} \frac{Inv_i}{(1 + R_i \times I)^i}$$

Through these risk-benefit ratios the Eq. (4) can be transformed as:

$$NPV = \sum_{i=1}^{n} (1 - IT_i) \times \left( \frac{(1 - RC_i) \times (1 - RCI) \times P \times Q_i}{1 + (1 + RCI) \times I} \right) - \frac{(1 - RC_i) \times VC_i + (1 - RCI) \times FC_i + (1 - RC_i) \times MP_i}{1 + (1 + RCI) \times I} - \frac{(1 - RC_i) \times OE_i}{1 + (1 + RCI) \times I} - \sum_{i=1}^{n} \frac{Inv_i}{1 + (1 + RCI) \times I}$$

where $RC_i$ – is risk-benefit ratio of capital $I$ cost raising;
$RC_i$ – is risk-benefit ratio of price decreasing of unit production $P_i$;
$RC_i$ – is risk-benefit ratio of sales decreasing $Q_i$;
$RC_i$ – is risk-benefit ratio of growth of variable costs in the net cost of production $VC_i$;
$RC_i$ – is risk-benefit ratio of growth of variable costs in the net cost of production $FC_i$;
$RC_i$ – is risk-benefit ratio of growth of debt while loan service payments $MP_i$ (if the loan exists);
$RC_i$ – is risk-benefit ratio of growth of other expenses referring increase of other expenses concerning to financial result of the organization, $OE_i$.

The engagement of an engineering company reduces the impact of the considered risks. This is ensured by its high competence, the presence of significant experience in practical activities, the possession of an array of systematic data on possible risks, the level of their negative impact on the production process and potential ways to prevent and to minimize [28]. In this case, a reengineering console is being formed due to a reduction in risks.

3.3 Development of reengineering solutions

An engineering company, based on its experience and competences, has the opportunity to choose the best approaches when evaluating the technological solutions, equipment and software from the point of ensuring a given quality while minimizing costs. Ultimately, an increase in the cost of a unit of production and sales is accompanied by a decrease in cost in terms of variable costs and a decrease in the volume of required investments.

The inclusion of the ratio-benefit of influence of the development of reengineering solutions $C_g$ in Eq. (3) makes it possible to present the general effect on the size of the $NPV$ in the next Eq. (6):

$$NPV = \sum_{i=1}^{n} (1 - IT_i) \times \left( \frac{(1 + C_g) \times P \times Q_i - (1 - C_g) \times VC_i - FC_i}{(1 + I)^i} \right) - \frac{MP_i + OE_i}{(1 + I)^i} + \sum_{i=1}^{n} \frac{(1 - C_g) \times Inv_i}{(1 + I)^i}$$

In the Eq. (6) the reengineering console is formed caused by the development of reengineering solutions.
3.4 The high level of business reputation of the engineering company, presented to the customer company

An engineering company, having a high level of business reputation and well-functioning business relations, is able to provide a reduction in the cost of financing a reengineering project which results in a reduction in the debt of a construction company. Substituting the risk-benefit ratio of the image of the engineering company $C_{img}$ into Eq. (3), we will be able to determine the influence on the $NPV$ of the reputation advantages of the engineering company:

$$NPV = \sum_{i=1}^{n} \left( (1 - IT_i) \times \frac{(1 + C_i) \times (1 - RC_i) \times (1 - RC_i) \times P_i \times Q_i}{(1 + (1 - C_{img}) \times (1 + RC_i) \times I')} - \frac{\sum_{i=1}^{n} Inv_i}{(1 + (1 + RC_i) \times I')} \right)$$

In the Eq. (7) we can reveal the reengineering console caused by the high level of business reputation of engineering company.

Thus, having examined the four advantages such as reducing the duration of the project, partial leveling of risks, development of reengineering solutions and the high level of business reputation of the engineering company, presented to the customer company and having presented the equations, we can say that general effect which is exerted on the project’s net present value by these advantages can be represented in the Eq. (8):

$$NPV = \sum_{i=1}^{n} \left( (1 - IT_i) \times \frac{(1 + C_i) \times (1 - RC_i) \times (1 - RC_i) \times P_i \times Q_i}{(1 + (1 - C_{img}) \times (1 + RC_i) \times I')} - \frac{\sum_{i=1}^{n} Inv_i}{(1 + (1 + RC_i) \times I')} \right)$$

We accepted that the value of the reengineering console is defined as the net present value of the project which includes the use of the services of an engineering company ($NPV_{REC}$) without the net present value of the project without attracting it ($NPV_0$). Since the value of $NPV_0$ is unchanged, it is necessary to maximize the value of $NPV_{REC}$ to maximize the reengineering console:

$$NPV_{REC} = \sum_{i=1}^{n} \left( (1 - IT_i) \times \frac{(1 + C_i) \times (1 - RC_i) \times (1 - RC_i) \times P_i \times Q_i}{(1 + (1 - C_{img}) \times (1 + RC_i) \times I')} - \frac{\sum_{i=1}^{n} Inv_i}{(1 + (1 + RC_i) \times I')} \right)$$

by taking into account the limits: $0 \leq i \leq n$.

4 Discussions

The reengineering of production processes which we consider as radical re-planning of key production processes in order to qualitatively improve their implementation in terms of costs, quality of service and speed is strategically necessary for Russian construction companies. In the modern conditions of the new technological revolution and regardless of the size of the costs caused by the use of the services of an engineering company, a positive effect is formed, which we designate as a reengineering console. Our approach to determine the value of the reengineering console takes into
account four advantages achieved by a construction company by engaging an engineering company such as shortening the duration of the project, partial leveling of risks, development of reengineering solutions, high level of business reputation of the engineering company, presentation to the customer company. The author’s approach is applicable in the development of management decisions by construction companies both in Russia and in other countries with similar business conditions. Along with this, engineering companies can apply the proposed approach in their practice as a tool to promote their services.

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