Improving Quality and Increasing the Efficiency of Construction and Installation Works of Objects Trunk Pipeline Transport in Russia

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Abstract. For organizations which operate a system of pipeline transport of hydrocarbons, improving the quality of its construction means reducing the cost of diagnosis and repair, liquidity accidents and its consequences during operation, improving reliability, durability and environmental safety of facilities in service. Taking into account the increasing need for the construction of hydrocarbon pipeline transport systems in Russia, the issues of improving the theoretical approaches and methods of practical implementation of the tasks of improving its quality are getting particular relevance and importance. The most promising method for solving the problems of improving the competitiveness of products and services while reducing production costs is functional cost analysis (FCA). It is based on the following statement: each object is made or exists in order to meet certain needs (to perform its functions). It requires certain expenditures to create these functions in the object. It is obvious that if the functions are not needed, then the cost of their creation is also unnecessary.

In the research we tried to show the advantages of using the FCA in the investment holding company "IHC "Tatgazinvest", which carries out work on the gasification of industrial and social objects of the Republic of Tatarstan under the program of OJSC "Gazprom". As a result, we revealed some functions where the share of costs exceeds its importance and represents zones of disproportions. It is also revealed that the decisive factor of disproportions zones appearance is the influence of secondary functions. The discovered areas of disproportions were analyzed in order to eliminate it. As a result of the analysis, we put forward proposals to improve the quality of construction and installation works and evaluated their organizational and economic importance.

1. Introduction

According to customs statistics, traditionally the basis of Russian exports is fuel and energy products, which compose for more than 60 % of the commodity structure of exports. The gas industry is the main sector of the fuel and energy complex of the Russian Federation. The share of the Russian Federation accounting for 28% of global gas production [1]. Effective satisfaction of domestic and external demand for gas, ensuring foreign exchange and tax revenues to the country's budget depends on the successful functioning of this industry. This sector plays an important role in ensuring Russia's energy security and political interests.

The large network of oil and gas pipelines operates to transport gas and hydrocarbon to Russia, Europe, Turkey, Southeast Asia. Therefore, the share of pipeline transport in the freight turnover is more than 48 % of the entire transport system of Russia [2]. The reliability and safety of pipeline systems...
are closely related to their quality of construction and use. This is especially important at the present stage of construction and commissioning of new gas pipelines. Thus, according to Rostekhnadzor, the percentage of accidents on trunk pipelines is 24.7% of the total number. This happens due to violations of the rules and regulations of construction and installation works, as well as deviations from design solutions [3]. Improving the quality of construction of the pipeline transportation system of hydrocarbons means reducing the cost of diagnosis and repair, elimination of accidents and their consequences during operation, improving reliability, durability and environmental safety of facilities during operation—all these factors are important for organizations that use the pipeline transportation system of hydrocarbons.

Thus, the issues of improving theoretical approaches and methods of practical implementation of quality improvement tasks in the construction of trunk pipeline transport facilities are of particular relevance and importance, taking into account the significant scale of the long-term need for the construction of pipeline transportation systems of hydrocarbons in Russia.

2. Problem statement, object and method of research

Currently, the main emphasis is on intensification and improvement of control methods in order to ensure the required level of quality of construction of trunk pipelines, that is, to identify deviations from the requirements of normative documents and eliminate the identified defects, and not to prevent it. This leads to an increase in non-production costs [4]. The method of functional cost analysis (FCA) is the most promising for solving the problems of increasing the competitiveness of products and services while reducing production costs [5-7].

Products of the main and auxiliary production and processes of activity such as (preparation, assembly, control, storage, transportation) all can be the objects of FCA [8]. Structures and processes of organization and management can be considered a specific object of the FCA [9]. The essence of functional and cost analysis is a comprehensive technical and economic study of the functions and parameters of objects (products, materials, processes, production and management structures) and the development of recommendations to minimize costs at the stages of design, creation and use (operation) of these objects while maintaining or improving the quality of their functions. The main purpose of the method is to achieve optimal utility ratios, that is, consumer properties of the object, and the cost of its creation, production and use [10].

Tasks are determined with the choice of the FCA object:
• improving the quality of the object or its components;
• reduction of production costs;
• reduction of material consumption, capital intensity, labor intensity, energy intensity;
• increased productivity;
• the elimination of "bottlenecks" in the production;
• reduced operating and transportation costs;
• improve its environmental performance;
• improvement of technological processes, labor organization and production management systems;
• improving the organizational structure of the organization, clarifying the functions of individual employees, etc.

In this study, we are trying to show the advantages of using the FCA in the investment holding company "IHC"Tatgazinvest", which carries out work on the gasification of industrial and social facilities of the Republic of Tatarstan under the program of OJSC "Gazprom". The main activity of the company is the construction of engineering networks, gasification and overhaul of trunk pipelines, diagnostics and inspection of pipelines, production of concrete weighting. Over last years, CJSC "IHC"Tatgasinvest" made a complete replacement of insulation and pipes in the sections of the trunk pipelines "Torzhok-Minsk-Ivanteveich", "Urengoy-Center", "Almetyevsk-Gorkiy", "Central Asia-Center-2", "Yamburg-Yelets", "Elec-Serpukhov", "Shebelinka-Belgorod-Kursk-Bryansk"; work was carried out on the territory of the Smolensk, Tver, Saratov and Nizhny Novgorod regions, republics of
Tatarstan, Chuvashia and Udmurtia, Tambov, Orel and Tula regions. The contractor was LLC "Gazprom Transgaz (Moscow, St.-Petersburg, Kazan, Nizhny Novgorod, Saratov, Tchaikovsky, Yugorsk)".

Functional and cost analysis will be carried out in a corrective form because the object of the study is construction and installation works. The purpose of this analysis is to eliminate unnecessary functions, elements and costs while maintaining (improving) the quality of work. According to the methodology of the FCA, during the search for reserves for improvement, it is necessary to determine the composition of the functions that the investment holding company "IHC "Tatgazinvest" conducts when performing construction and installation works. What is function? Functional-cost analysis is based on the following statement: each product, object, etc. is produced, exists in order to meet certain needs (to perform their functions) [11]. Some funds are spent to create these functions in the object. Obviously, if the functions are not needed, then the cost of their creation is also unnecessary. Therefore, functional-cost analysis divides all costs into functionally necessary (for the object of its functional purpose) and excessive costs (generated by the wrong choice or imperfection of actions) [12]. Therefore, the main practical task of the study is to build a functionally ideal model of an improved object, devoid of all or part of the identified harmful functions.

3. Results of the study

3.1. Functional model of construction and installation works

The functional approach that forms the basis of the FCA allows us to present the studied object as a set of functions. The functional model of construction and installation works is presented in the picture №1 in the form of a tree with several hierarchical levels. The first level is the main function F (pipeline laying), the second – the main (F1, F2, F3, F4, F5, F6), and the third – the secondary functions of the first (F11, F12, F21, F22, etc.) and the second rank (F111, F221, F311, etc.). The main functions are the functions that ensure the performance of the main function. Auxiliary functions are functions that support the basic (sometimes called support functions).

Six functions providing performance of the main function of construction and installation works are allocated as the main functions:

- preparatory work;
- earthwork;
- assembly, welding and quality control of welded pipe joints;
- transportation of pipes and pipe sections;
- to protect the pipeline from corrosion;
- laying pipe in a trench.

Figure 1. Functional model of construction and installation works.
3.2. Determination of the significance of functions, taking into account the costs of their provision

Determination of a function cost is the next step. The costs of construction and installation work include the cost of materials, fuel, energy, wages of employees, compensation for wear and tear of fixed assets and other costs. The cost determination showed that the costs of the main functions vary in a wide range (Pic. 2) the greatest contribution to the cost of construction and installation works is made by the function F3 (assembly, welding and quality control of welded joints of pipelines) and F1 (preparatory works) and the smallest – by the function F2 (earthworks).

![Pie chart showing the percentage of costs for different functions](image)

**Figure 2. The percentage spent on the main functions.**

An expert group was engaged to identify opportunities to reduce the cost of the main and support functions. Experts were asked to compare all functions in terms of importance and their contribution to the quality of construction and installation work. According to experts, the most important function is the function F3, the significance is 0.3 or 30%.

Table 1 presents the results of determining the significance of functions in the ratio of the cost of their provision and calculated the cost factor for the function (CF/f), which is the ratio of the proportion of the cost of the function in the total cost (A) to the significance of the function (B). Optimum CF/f = 1; CF/f <1 more desirable than CF/f >1.

| Function name                                  | Cost, % (A) | Significance, CF/f, % (B) | CF/f | A/B |
|------------------------------------------------|-------------|----------------------------|------|-----|
| **F1** Preparatory works                       | 25,67       | 20,00                      | 1,28 |     |
| F11 Control of the geodetic framework for the  | 1,35        | 4,00                       | 0,34 |     |
| construction                                     |             |                            |      |     |
| F12 Track preparation                            | 24,32       | 16                         | 1,52 |     |
| F121 To clear the right of way of the pipeline | 1,69        | 2                          | 0,85 |     |
| from the forest                                   |             |                            |      |     |
| F122 To cut steep longitudinal slopes            | 1,09        | 2                          | 0,55 |     |
| F123 Protective anti-landslide measures          | 0,11        | 4                          | 0,03 |     |
| F124 To prepare a temporary production places    | 8,3         | 4                          | 2,08 |     |
| F125 To build temporary settlements for workers  | 13,14       | 4                          | 2,29 |     |
| **F2** Earthworks                                | 1,91        | 5                          | 0,38 |     |
| F21 Trenching                                    | 1,33        | 3                          | 0,44 |     |
| F22 Development of trenches                      | 0,58        | 2                          | 0,29 |     |
| **F3** Assembly, welding and quality             | 46,04       | 30                         | 1,53 |     |
| control of welded pipe joints                    |             |                            |      |     |
| F31 A qualification test of welders             | 0,36        | 5                          | 0,07 |     |
| F32 Assembly, welding                            | 45,68       | 25                         | 1,83 |     |
### Table 1: Summary of Costs and Functions

| Function | Cost | Significance | Importance |
|----------|------|--------------|------------|
| F321 Control of welded joints | 21.52 | 7 | 3.07 |
| F322 Production of pipeline turns | 10.3 | 9 | 1.14 |
| F323 To carry out the installation of the pipeline turns | 13.86 | 9 | 1.54 |
| F4 Transportation of pipes and pipe sections | 3.6 | 5 | 0.72 |
| F41 Pipe loading | 1.8 | 2.5 | 0.72 |
| F411 Unload pipes | 1.8 | 2.5 | 0.72 |
| F5 Protection of pipelines against corrosion | 12.05 | 20 | 0.6 |
| F51 Cleaning and priming of pipelines | 11.98 | 15 | 0.8 |
| F511 Protection of pipelines against soil corrosion | 5.69 | 5 | 1.14 |
| F512 Protection of pipeline against atmospheric corrosion | 5.69 | 5 | 1.14 |
| F513 Electrochemical protection of pipelines against underground corrosion | 0.59 | 5 | 0.12 |
| F52 Quality control of insulation coatings | 0.07 | 5 | 0.01 |
| F6 Laying the pipeline in the trench | 10.72 | 20 | 0.54 |
| F61 Ballasting and fastening of pipelines | 5.6 | 7 | 0.8 |
| F62 Cleaning of the pipeline cavity | 0.26 | 6 | 0.04 |
| F63 Testing of pipelines | 4.87 | 7 | 0.7 |

### 3.3. Creation of the functional-cost diagram

The data presented in table 1 were used to build a functional-cost diagram, where the significance (relative importance) of each function is compared with the share of its implementation costs in the total cost of the object (Pic.3). The diagram is built in a single scale (in percentage) and reflects the basic principle of the FCA correspondence of the importance of functions to the cost of their implementation.

The constructed diagram allows you to visualize the functions, the share of which in the costs exceeds their importance and represent the zones of disproportions. The analysis of the functional-cost diagram and the calculated cost factor for the function allowed to identify the areas of disproportions in the performance of the main functions of construction and installation works:

- preparatory work (F1);
- assembly, welding and inspection of welded joints (F3).

The coefficient of the cost function \( CF/f > 1 \), i.e. the costs exceed the importance of the functions. Therefore, the functions F1 and F3 are discussed in detail. Picture 4 and 5 show that the disproportion of the main function F1 arises due to the prevalence of cost over the significance of auxiliary functions F12, F124, F125, and the disproportion of the main function F3 arises due to the disproportions in functions F32, F321, F323.
4. Conclusions and proposals

It is revealed that the decisive factor in the appearance of zones of disproportions is the influence of secondary functions. These zones have been analyzed with a purpose to eliminate them. Proposals were put forward to improve the quality of construction and installation works and their organizational and economic evaluation was carried out too (table 2). The real organizational conditions for the implementation of a particular option in a particular organization is an organizational assessment, and the level of reducing the complexity and improving the quality of performance of functions is an economic assessment. Plus (+) marked the predominance of advantages over disadvantages; minus (-) means the predominance of disadvantages over advantages; minus-plus (-/+ ) – an equal ratio of advantages and disadvantages.
Table 2. Organizational and economic evaluation of quality improvement measures construction and installation.

| Function name | Suggestion for Improvement | Organizational assessment | Economic assessment |
|---------------|----------------------------|---------------------------|---------------------|
| F12 4 To prepare a temporary production places of functions | - | + |   |
| F12 5 Build temporary set To use modular construction for multiple use | + | - | +/- |
| F32 1 Control of welded joints | To introduce an electronic register of defects | + |   |
| F32 2 Production of pipeline turns | The use of modern materials and technology | +/- |   |
| F32 3 To carry out the installation of the pipeline turns | | | |

Suggestions for improving the quality of construction and installation works and improving their efficiency can be combined into the following recommendations:

• it is necessary to rationally distribute the functions among the units and eliminate the identified duplications;

• in the process of developing plans, it is necessary to provide for the maximum use for the needs of construction of existing buildings and structures (household, roads, railways, energy facilities, etc.), which reduces the cost of construction of temporary buildings and structures;

• it is necessary to organize strict incoming control of the supplied products; to provide equipment upgrade in order to improve equipment performance and reduce maintenance costs, as well as the introduction of modern technologies;

• minimize the cost of construction and installation stages, which have a small contribution to the overall quality;

• to carry out activities for the prevention of the defects of construction works with the aim of improving their quality and reducing the cost of their correction.

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