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# TECHNICAL SCIENCES

## RISK MANAGEMENT OF THE CONSTRUCTION PROJECT BASED ON A VALUE-ORIENTED APPROACH

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**Abstract**

The article presents the result of the application of the models and the risk management method for construction projects developed by the author on the basis of a value-oriented approach on the example of a project for the reconstruction of the out-of-school work center **(**OWC). The project was developed on the basis of regulatory support for the reconstruction of state property objects. The analysis of the project was carried out in the plane of value-oriented management and the developed approach to risk management.

**Keywords:** risk management approach, value-oriented management, stakeholder management, risks of construction projects.

**Introduction.** Value-Based management is based on meeting the expectations of the project stakeholders [1, 2]. In this case, project management should form such management influences, which will use the degree of stakeholder satisfaction as effective criteria [3, 4]. However, a significant number of construction project stakeholders can generate conflicting requirements. This means that there is a possibility of dissatisfaction with the expectations of stakeholders, and this entity is considered as the risks of value-based approach construction projects [5, 6].

**Review of publications on the topic.** Risk management processes for construction projects using a value-based approach (VOA) aim to ensure the satisfaction of each stakeholder, through ensuring harmonized project value [1, 2, 7, 8]. For this, the author proposed an approach that includes conceptual [9] and, mathematical [10] models of risk management in construction projects and a method for managing these risks [11]. All components of the approach have been previously published in various sources [9, 10, 11]. This article offers the results of using the developed approach in practice.

**The aim of this study** is to evaluate the developed models and methods of risk management in construction projects in practice and to assess the possibility of their use in making management decisions.

**Results and discussion.** Strategy $x_i$ means one of the alternatives of the project, the same project, the difference – the alternative is understood as different modifications of the project product, which will provide different sets of values for project stakeholders.

Thus, taking into account the developed technique, we will form a tuple of alternatives for reconstruction project (RP) $\{X^{RP}\}$ (1):

$$X^{RP} = \{x_1, x_2, x_3\}, \quad (1)$$

$x_1$ – elimination of structural flaws and destroyed structural elements;

$x_2$ – redecoration of the entire building of the OWC;

$x_3$ – energy saving and smart home.

This list of alternative project variants is compiled without taking into account the VOA and opinion of future consumers of the RP product.

This list is compiled by the decision maker, namely, the management of the OWC, taking into account the amount of possible funding.

Further, a tuple of stakeholders for the OWC RP was formed $\{St^{RP}\}$ (2):

$$St^{RP} = \{St_1, St_2, St_3, St_4, St_5, St_6\}, \quad (2)$$

$St_1$ – management of the OWC;

$St_2$ – city and region education department;

$St_3$ – team of the OWC RP;

$St_4$ – lecturers of the OWC;

$St_5$ – children and their parents, clients of the OWC;

$St_6$ – city residents.

Further, the result {So} [10] was determined, which will be received by each of the stakeholders from the implementation of the alternative project. It is more convenient to present the relationship of solutions on alternative project variants in tabular form. Below is an approved list of $So^{RP}$ solutions available to RP stakeholders.

Thus, the RP has a tuple of $So^{RP}$ solutions for stakeholders $\{So^{RP}\}$ (3):

$$So^{RP} = \{So_1, So_2, So_3, So_4, So_5, So_6, So_7, So_8\}, \quad (3)$$

$So_1$ – restored structural elements, extended the period of safe operation for the building;

$So_2$ – restored external and internal finishing of the premises of the OWC;

$So_3$ – restored comfortable conditions for study and work in the OWC;

$So_4$ – implemented modern energy saving technologies of the building;

$So_5$ – implemented a modern heating system of the building;

$So_6$ – the building is insulated;

$So_7$ – new energy saving windows are installed;

$So_8$ – a new space for teachers, students and waiting for parents is created;

In the RP, the number of variations of solutions $N$ was adopted $N=2$, the stakeholders received a solution to their problems $So_1 =1$, or did not receive $So_2 =0$, i.e. $So_j=(0,1)$.

It should be noted that when working with reconstruction project stakeholders, a new need was identified that was not taken into account during the initial study of the project. Teachers, parents, as well as students themselves noted that due to the peculiarities of the design of the OWC, there is no room where children can wait for their next lessons, teachers can relax and prepare for the next topic, and parents wait for their children. Previously, it took place in uncomfortable conditions "against the wall in the corridor".

As mentioned above, risk identification is carried out at the beginning of the project and when decisions are made that significantly affect the cost, timing and quality of results [12]. The project manager initiates the development of a list for possible risks, including through a survey and interviews of experts or stakeholders. Thus, as a result of the application of the developed technique, a survey of teachers and parents of children of the OWC was conducted and their desire for expectations from the reconstruction project was revealed.

Based on the concept of customer-oriented management, the author took into account the process of "risk identification" of data from stakeholders, namely their desire for a new space in the OWC, which was absent in the reconstruction project.

The results of the analysis are grouped in Table 1. Note that the table can take into account the results of personal communication with the stakeholders $\{St_1, St_3, St_4\}$, which can be conducted in the form of interviews, questionnaires, etc., and in the form of an expert estimation, which is carried out by relevant experts, or significant stakeholder representatives $\{St_2, St_5, St_6\}$. In any form of the survey, if the stakeholder is satisfied with the results of the solution, or the alternative project variant, then $\{1\}$ is entered in the table of stakeholder satisfaction with the solutions of the RP (Table 1), if not satisfied – $\{0\}$.

Table 1.

Stakeholders' acceptance of the RP solutions

| | $St_1$ | $St_2$ | $St_3$ | $St_4$ | $St_5$ | $St_6$ |
|---|---|---|---|---|---|---|
| $So_1$ | 1 | 1 | 1 | 0 | 0 | 0 |
| $So_2$ | 1 | 1 | 1 | 1 | 1 | 0 |
| $So_3$ | 1 | 0 | 1 | 1 | 1 | 1 |
| $So_4$ | 1 | 1 | 1 | 0 | 0 | 0 |
| $So_5$ | 1 | 0 | 1 | 1 | 1 | 0 |
| $So_6$ | 1 | 0 | 1 | 0 | 0 | 0 |
| $So_7$ | 1 | 0 | 1 | 1 | 0 | 0 |
| $So_8$ | 0 | 0 | 0 | 0 | 1 | 1 |

Within the framework of the proposed technique, we will assume that the conflict between stakeholders occurs when the expected values of their solutions do not match within a single $So_i$ solution (see Table 1).

However, the identification of conflicts between stakeholders within the framework of one solution is both cumbersome and impractical.

In addition, after working with stakeholders, the additional expected value was identified, which is not represented in the strategies developed by the management of the OWC at the initiation stage, namely the creation of comfortable conditions for study and work plus additional space for rest and waiting. Therefore, the author proposed a fourth alternative of reconstruction project, namely:

$x_4$ – new space for relaxation of teachers, students and waiting for parents.

In this regard, we supplement the tuple of alternatives $\{X^{RP}\}$ (1) with the fourth component (4):

$$X^{RP} = \{x_1, x_2, x_3, x_4\}, \quad (4)$$

Further, conflicts between stakeholders will be identified within the framework of alternative RP variants, for this, first, we will compile a Table 1. Note that the project team, as its stakeholder, in a rough gradation {0; 1} will be interested in the successful completion of any of the alternatives of the project, as they act as employees. In the case of a more sensitive estimation, {minimal; average; maximum}, the project team will already be able to express their preferences for various alternatives, in terms of their own benefit. However, due to the limited scope of the thesis research, for consideration, as mentioned above, we take the binary estimate {0; 1}. In this case, the project team, as a stakeholder, who is interested in the implementation of any of the alternative project variants, will be excluded from further consideration (Table 2).

Table 2.

Stakeholders' acceptance of PR alternatives

| | $St_1$ | $St_2$ | $St_4$ | $St_5$ | $St_6$ |
|---|---|---|---|---|---|
| $x_1$ | 1 | 1 | 0 | 0 | 0 |
| $x_2$ | 1 | 1 | 1 | 1 | 0 |
| $x_3$ | 1 | 0 | 0 | 0 | 0 |
| $x_4$ | 1 | 0 | 1 | 1 | 1 |

Analysis of the Table 2 shows that an integrated alternative $x_5$, which would include all four existing ones, would satisfy all project stakeholders. However, one of the project limitations is the limitation of the project budget. This means that in this project environment, it is possible to implement only one of the alternative project variants.

An undirected graph based on a stakeholder tuple (1), their expectations for each alternative (4) will characterize the value conflict for two stakeholders. But this will only be a visual representation. For further analysis, the matrix constructed for each alternative will be more informative. For example, in Table 3 shows the result for the alternative $x_1$.

Table 3.

Symmetric matrix of conflicts of mutual influence of PR stakeholders for an alternative $x_1$

| $x_1$ | $St_1$ | $St_2$ | $St_4$ | $St_5$ | $St_6$ |
|---|---|---|---|---|---|
| $St_1$ | 0 | 0 | 1 | 1 | 1 |
| $St_2$ | 0 | 0 | 1 | 1 | 1 |
| $St_4$ | 1 | 1 | 0 | 0 | 0 |
| $St_5$ | 1 | 1 | 0 | 0 | 0 |
| $St_6$ | 1 | 1 | 0 | 0 | 0 |

For the rest of the alternatives, matrices similar to those in Table 3 were constructed. However, if the stakeholders do not conflict, then there is no risk.

For this RP of OWC, the conflict between stakeholders has not brightly expressed, specific character. The point is that some of the stakeholders (teachers and the management of the OWC) depend on the parent organization, namely the decision maker on the amount of project funding. This is manifested in the fact that their opinion is not significant, and the degree of influence is insignificant. This limits the disclosure of the developed technique in full. However, the main conflict of the reconstruction project is between the limited amount of funding and the amount of comfort from the project product. That is, the project has a limitation determined by the source of funding, in this case, by government funding.

The assessment of the risks for value conflict of stakeholders was determined by experts for each alternative. As an example, in Table 4 shows the result for alternative $x_1$.

Table 4.

Matrix of risks of mutual influence of PR stakeholders for the alternative $x_1$

| $x_1$ | $St_1$ | $St_2$ | $St_4$ | $St_5$ | $St_6$ |
|---|---|---|---|---|---|
| $St_1$ | 0 | 0 | 0,01 | 0,5 | 0,5 |
| $St_2$ | 0 | 0 | 0,01 | 0,5 | 0,5 |
| $St_4$ | 0,01 | 0,01 | 0 | 0 | 0 |
| $St_5$ | 0,5 | 0,5 | 0 | 0 | 0 |
| $St_6$ | 0,5 | 0,5 | 0 | 0 | 0 |

Then, according to the developed technique, a matrix of values $\{Va_j\}$ expected / obtained by stakeholders of the project $\{St_j\}$ for different alternatives $\{x_i\}$ taking into account the obtained solution of own problems / expectations $\{So_{ij}\}$ for each stakeholder $j$, which is given in Table 5 $\{Va_j\}$ = [0;10], that is, the value that the stakeholder acquires as a result of the project is estimated by experts in points, from 0 – received nothing, to 10 – full satisfaction of expectations.

Table 5.

Expected stakeholder value for the four RP variants

| $Va_j^i$ | $St_1$ | $St_2$ | $St_4$ | $St_5$ | $St_6$ |
|---|---|---|---|---|---|
| $x_1$ | 10 | 10 | 5 | 1 | 0 |
| $x_2$ | 10 | 10 | 10 | 10 | 5 |
| $x_3$ | 10 | 5 | 1 | 1 | 0 |
| $x_4$ | 5 | 1 | 10 | 10 | 10 |

The tuple of values for stakeholders of the $\{Va^{RP}{}_{ij}\}$ reconstruction project, taking into account the risks of structural disproportion $\{R_{ij}\}$, is determined in accordance with [10] and also presented in tabular form (see Table 6).

Table 6.

Predicted stakeholder value for the four risk-adjusted RP variants

| $Va_j^i$ | $St_1$ | $St_2$ | $St_4$ | $St_5$ | $St_6$ |
|---|---|---|---|---|---|
| $x_1$ | 9 | 9 | 4,5 | 1 | 0 |
| $x_2$ | 10 | 10 | 10 | 9 | 5 |
| $x_3$ | 8 | 5 | 1 | 1 | 0 |
| $x_4$ | 5 | 1 | 9 | 9 | 9 |

The expected harmonized value of the project for the *i*-th project alternative $x_i$, as the sum of the values of each stakeholder, taking into account [10], is presented in Table 7.

Table 7.

Expected harmonized value of RP, taking into account the risks

| $Va_j^i$ | $St_1$ | $St_2$ | $St_4$ | $St_5$ | $St_6$ | $G\{Va(x_i)\}$ |
|---|---|---|---|---|---|---|
| $x_1$ | 9 | 9 | 4,5 | 1 | 0 | 23,5 |
| $x_2$ | 10 | 10 | 10 | 9 | 5 | 44 |
| $x_3$ | 8 | 5 | 1 | 1 | 0 | 15 |
| $x_4$ | 5 | 1 | 9 | 9 | 9 | 33 |

**Results and discussion**. The choice of the *i*-th project alternative $x_i$, made on the basis of the maximum harmonized value from all alternative variants of the project, taking into account [10], will take the form (5):

$$G\{Va(x_i)\} = \max_{x_k} G\{Va(x_k)\} = 44(5)$$

that is, the maximum allowable harmonized value for a given project will be achieved with a found, manageable combination of RPVOA risks.

The decision was made for alternative option No. 2 – redecoration of the OWC building.

In case of non-acceptance of the decision (5) by the investor-customer, for any reason not considered earlier, the modeling of the solution begins anew [10], which will be presented in the further research.

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# THE ANALYSIS OF CONDITIONS FOR SEPARATION OF LIQUID METAL DROPS FROM ELECTRODE ENDS AT ARC METALLIZATION WITHIN THE CONDITIONS OF A PULSATING SPRAY FLOW EXPOSURE

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**Abstract**

The main problem that arises when parts are restored by the arc metallization method is to improve the quality of coatings by reducing the negative impact of oxygen in the spraying airflow. To reduce the oxidizing effect of air-spraying flow on the liquid metal of electrodes the method of arc metallization utilizing the pulsating spraying flow, obtained by introducing an additional element - a valve of the pulsator into the spray system of electroarc metallizer, was previously introduced.

The nature of forces acting on the liquid metal of electrodes at melting by an electric arc without consideration of spraying flow is reviewed.

Taking into account the findings presented in the works of V.I. Dyatlov, B.E. Paton a diagram of liquid metal formation on the cathode and anode depending on the parameters of the electric arc mode without considering the impact of the spraying flow is presented.

Under the impact of a pulsating spraying flow, a drop of molten metal of the electrodes will turn into a half-ellipsoid shape. The impact and distribution of forces acting on a drop of such shape and conditions of separation of a drop from the electrode ends are important.

Analytical calculation of forces acting on a drop of semi-ellipsoid form during arc metallization with a pulsating spraying flow was carried out in this paper.

**Keywords:** spraying flow, aerodynamic force, surface tension force, spherical drop, semi-ellipsoid drop.

**Articulation of issue.** analysis of forces acting on a drop under the impact of pulsating airflow during arc metallization, conditions of drop separation from the electrode surface considering the airflow pulsation.

**Analysis of recent publications.** Some researches of scientists are focused on studying the processes of formation of liquid metal drops [6,7], but they mainly consider the drops of spherical shape and the force of aerodynamic resistance acting on them due to the airflow, or drops in " tongue" shape, which have a high probability of fragmentation and transition into spherical form.

**Objective of the study.** To perform an analytical calculation of forces acting on a drop of semi-ellipsoidal shape during arc metallization with pulsating spraying flow.

**Statement of basic materials.** In order to clarify the basic laws of electrode melting at electrode arc metallization with a pulsating spraying airflow [1,2,4,5], a mathematical model of the electrode melting process at the pulsating effect of the spraying airflow using the Mathcad software was proposed. The basic simulation scheme is presented in Fig. 1.

Analytical calculation of forces acting on a drop of ellipsoidal or spherical shape during arc metallization by a pulsating spraying flow.

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