Qualitative risk approach in the construction of electric power facilities

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Abstract. The main issue of the study is the problem of risk management in the planning and implementation of projects for the construction of electric power facilities. Projects for the construction of such facilities, which are characterized by high technological complexity and uniqueness, at the stages of design, equipment delivery, construction and commissioning, face unforeseen circumstances and, often, the project management is not ready to solve the problems that have arisen. The purpose of this article is to describe a methodology for qualitative risk assessments in relation to projects for the construction of electric power facilities with the determination of levels of responsibility, analysis of stakeholders, and distribution of risks among stakeholders. The proposed method can be used for risk analysis and making informed decisions at the stages of planning and implementing projects for the construction of electric power facilities.

1 Introduction
Risk management is an important area in Project Management. It is generally accepted that the quality of management in the functional areas of the Project, including the quality of Risk management, directly affects the success of Projects [1,2]. What is the percentage of projects for the construction of electric power facilities that are completed successfully, namely, within the originally planned time frame, within the initial budget and without changing certain parameters during construction? Many studies on this topic have been carried out, and there are various estimates [3,4]. However, finding an answer to this seemingly simple question is a non-trivial task. And it's not just the problem of collecting statistical information, bringing it to a common denominator and analyzing it. The problem is much deeper and covers a wide range of areas of knowledge in both technical and humanitarian fields [5,6].

2 Methods
First, you need to understand the interpretation of the term project success. It is known that different Project participants have their own expectations about the Project results, which characterize the
success of a particular event or task within the Project from their point of view. That is, to determine the success of the Project, it is necessary to consider in more detail the goals and criteria for satisfaction of project stakeholders.

Fig. 1 presents a hierarchy of energy Project stakeholders, their goals, and their participation in the Project.

As a rule, the need to implement a particular Energy Project is determined by the needs of Society. It is the company that will be the final consumer of the created product and it is the Company that will give the final assessment of the project being implemented. At the same time, the Company has a significant impact on the implementation of the Project. On the one hand, it performs controlling functions directly or through state institutions, such as technical control, environmental control, supervision of safety and labor protection, etc. [7,8]. On the other hand, the Company provides resources for the implementation of the Project, namely, human resources. For planning and implementation, quality risk management [4], it is important to understand the socio-economic situation in the Society, including labour costs, features of legislation of a particular country in relation to the organization of labor, etc.

![Diagram of Project Stakeholders](image-url)

**Figure 1.** Main stakeholders of the power plant construction Project

As a rule, an energy Project is part of a comprehensive infrastructure development program. Thus, large electric power facilities are being built both to provide electricity to the population and to industrial enterprises, including new industrial enterprises such as mining and processing plants, metallurgical enterprises, etc. [9,10]. The construction of such enterprises and electric power facilities is usually part of a comprehensive development program for the region. In such Projects the Society is extremely difficult to assess the success of the Project of Construction of an object, since this assessment will take some time of operation of objects in which Society will be able to form an opinion in relation to the success of the Program as a whole [11-13]. Moreover, this opinion will be based more on such estimates as the level of salaries at the enterprise, the amount of deductions to the local budget, the impact of the enterprise on the environment, etc. These estimates will largely contain
a subjective component and will probably depend on the overall socio-economic situation in the society [14-17].

However, the Company has its own representative in the form of State institutions that are able to assess the feasibility of a particular infrastructure development Program and formulate criteria for evaluating the success of the Program as a whole, as well as the main requirements for the components of the Program, including projects for the construction of electric power facilities. At the level of state institutions (ministries), the success of an electric power Project is determined by its ability to maintain the functioning of the production complex created within the framework of the infrastructure development Program [17,18].

Moving on to the direct implementation of an electric power Project, it is necessary to determine the project's vision on the part of the Customer, which is usually the generating company. The customer-generating company expects a return on investment with some profit as a result of the Project implementation. Thus, at the Customer level, we are talking about an Investment Project whose success indicators are such parameters as net discounted income NPV, internal rate of return IRR, etc. [19,20]. It should be noted that when implementing a large investment project, the Customer attracts banking organizations for financing, whose interests are also focused on the above-mentioned parameters of the Investment Project. In such a Project, we can distinguish the investment and operational stages. For Fig. 2 presents a graphical representation of the distribution of costs and revenues over time, indicating the main stages of the Investment Project.

![Figure 2. Integral discounted cash flow from investment and operating phases.](image)

The graph shows that the net discounted NPV income that determines the success of an Investment Project depends equally on the amount of capital expenditures and the amount of income received from the operation of an electric power facility. Within the framework of the Investment Project, the main capital investments are made during the construction phase, which is allocated to the construction Project of the Electric power facility.

2.1 Levels of management of power plant construction project

There are many strategies for organizing a Construction Project. One of the most common are organizational schemes involving an EPC or EPCM Contractor. As a rule, the terms of contracts with EPC / EPCM Contractors are formulated in such a way as to encourage the execution of Project work on time, within the agreed budget and in accordance with the requirements for the quality of the Project product. Thus, the criterion for the success of the EEO (Electric power facility )Construction
Project at the EPC / epsm level of the Contractor is the amount of deviation of the above parameters from the planned values.

Each project for the construction of an electric power facility is unique and technologically complex. Today, the competition between equipment suppliers is unfolding in improving equipment performance such as efficiency, turnaround time, automation, the required number of operating personnel, etc. of Construction companies competing in the field of resource efficiency, mechanization of construction operations to optimize cost, time, quality and safety of work execution [19]. It should be noted that these parameters have a direct impact on the economic performance of the Investment Project and are of exceptional importance to the Customer. As a rule, contracts with subcontractors set penalties for failure to achieve the guaranteed parameters, as well as for failure to meet deadlines. Thus, the criterion for the success of work at the EPC / EPCM level of the contractor is the amount of deviation of the guaranteed parameters, terms and quality of work from the planned values.

Thus, we see that each interested party has different expectations from the Project implementation. Moreover, as described above, the understanding of the Project content differs at different levels of management. It is obvious that the risks at different levels of management will not be equal. Control levels can be displayed as a hierarchical structure of Program operations (see Fig. 3). Let's examine in more detail the level of Project management for the construction of an Electric power facility. Work packages corresponding to the construction Project of an Electric power facility in Fig.3 are highlighted in orange.

![Figure 3. The work packages at different levels of management](image-url)

2.2 Model of power plant construction project

In order to analyze the risks of a project for the construction of an Electric power facility, it is necessary first of all to create a Project model based on a certain structure of work decomposition. Let's take a breakdown of the work breakdown structure at the top level according to the division of work between subcontractors. An example of the upper level of the work breakdown structure of an EEO (Electric power facility) Construction Project is shown in Fig. 4.
Figure 4. Structure of decomposition of works at the top level of the project for the construction of an Electric power facility.

Each top-level work package is further decomposed at least to the level where you can determine the time and cost for each element. By assigning links between elements, you can get a network model of the Project—the basis for conducting a risk analysis of the project for the construction of an Electric power facility.

The following designations are used to identify the works:

WP<sub>i</sub> - work package in the work decomposition structure, where i is the ID of the work package;

an - is an elementary work that is not subject to further decomposition within the framework of the model under consideration, where n is the sequence number of the work in the work package.

2.3 Qualitative risk assessment in the Projects

As noted earlier, at the level of project management for the construction of an Electric power facility, the expectation of successful implementation of the Project is the minimum deviations in quality, cost, and timing from the planned values (see Fig. 1). We introduce the notation:

R<sub>Q</sub> – a set of risks associated with quality deviation from the planned value. In practice, these risks are associated with not achieving the object of power guaranteed parameters and presenting with any of the interested parties Discrepancies in quality of a project product;

R<sub>C</sub> – a set of risks associated with the deviation of the cost of equipment and work from the planned value;

R<sub>S</sub> – a set of risks associated with the deviation of work completion dates from the planned value.

The first type of R<sub>Q</sub> risk is largely determined by the technological features of the Project and requires separate detailed consideration, which is beyond the scope of this article.

Consider in more detail the second and third types of risk R<sub>C</sub> and R<sub>S</sub>.

One of the tools for Project risk analysis is the method of qualitative risk assessments. To be able to aggregate qualitative risk assessments, it is necessary to enter a score scale, which will determine the probability p of a particular risk factor and the impact u of the implemented risk factor on the Project results. At the same time, the model identifies two types of risk sources:
- accuracy in determining the cost/ timing of work;
- events that may cause deviations from planned targets

To assess the risks associated with the degree of accuracy in determining the cost/ timing of work, it is proposed to use a scale that determines the minimum, most likely, and maximum values of the value under consideration for each level of assessment accuracy.

The levels of accuracy of cost and time estimates are denoted by \( V_c \) and \( V_s \), respectively. Each level of evaluation accuracy corresponds to a predetermined set of coefficients that allow you to determine the minimum, most likely, and maximum cost of the work / package of works - \( k_{C_{\text{min}}} \), \( k_{C_{\text{mp}}} \) and \( k_{C_{\text{max}}} \), as well as the timing of the work/ package of works \( k_{S_{\text{min}}} \), \( k_{S_{\text{mp}}} \) and \( k_{S_{\text{max}}} \).

An example of the accuracy scale for cost estimation is shown in table 1.

| Table 1. Scale for evaluating the accuracy of determining the cost / timing of work on the Project. |
|---------------------------------------------------------------|
| The accuracy of the estimation \( V_c \) | Min value, \( k_{C_{\text{min}}} \) | Most likely value, \( k_{C_{\text{mp}}} \) | Maximum value, \( k_{C_{\text{max}}} \) |
|---------------------------------|-----------------|-----------------|-----------------|
| Conservative                   | 70%             | 90%             | 100%            |
| Realistic assessment           | 90%             | 100%            | 110%            |
| A risky rating                 | 100%            | 110%            | 150%            |

Taking the law of probability distribution, for example, a triangular probability distribution or the PERT distribution, one can obtain the integral function \( P(C) \) distribution \( C \) - cost of the Project, due to the accuracy of the estimation.

Similarly being an integral function \( P(S) \) distribution of \( S \) – period of work on the Project, due to the accuracy of the estimation, with the difference that instead of summing the values you want to calculate the calendar-network schedule for the minimum, most likely and maximum durations of work.

To assess the risks associated with the implementation of adverse events, the following scales have been adopted for the probability and impact of the risk:

| Table 2. Scale for assessing the probability of risk \( p \). |
|-------------------------------------------------------------|
| Probability of occurrence | Designation. | Description | Probability of occurrence, % |
|---------------------------|--------------|-------------|-----------------------------|
| High                      | [H]          | The event will come sooner than it won't. | \( >66\% \ (83\%) \) |
| Moderate                   | [M]          | The probability of occurrence is significant. | \( 33\%-66\% \ (50\%) \) |
| Low                       | [L]          | The event is not likely to occur and the probability of occurrence is small. | \( <33\% \ (16.5\%) \) |
Table 3. Scale for assessing the impact of risk on the cost of C and on the timing of S.

| Impact      | Designation | Description                        | Cost impact $C$ | Time impact $S$ |
|-------------|-------------|------------------------------------|-----------------|-----------------|
| High        | [H]         | Risk leads to a cost increase of more than 10% (12.5%) | Risk leads to delays of more than 10% (12.5%) |
| Moderate    | [M]         | Risk leads to a cost increase from 5% to 10% (7.5%) | Risk leads to delays from 5% to 10% (7.5%) |
| Low         | [L]         | Risk leads to a cost increase of no more than 5% (2.5%) | Risk leads to delays of no more than 5% (2.5%) |

By calculating the average values for the ranges specified in Table 2, the probability value for each qualitative estimate is determined. Similarly, the amount of risk impact on the cost and timing of project work is determined.

Based on the results of the identification procedure and qualitative risk assessment, we obtain a set of random events $R_1, R_2, \ldots, R_n$, characterized by the probability $p(R_i)$ and the impact on the cost of the $u_c(R_i)$ and the timing of the $u_s(R_i)$ project [1].

3 Results and Discussion

So, we have distribution functions for the cost and timing of work on the project, due to the accuracy of the calculation $P(C)$ and $P(S)$, respectively, as well as events $R_1, R_2, \ldots, R_n$, for each of which the probability $p(R_i)$ and the impact on the cost $C(R_i)$ and timing $S(R_i)$ of the project are determined. The model can be supplemented with logical functions that link events that lead to the implementation of risks.

To determine the distribution functions of the cost and timing of work on the project as a whole, we use the stochastic method, which implies:

1) multiple project risk modeling experiments with different combinations of project cost / time estimates and random events;

2) determining the number of hits of the calculation result in predetermined intervals between the minimum and maximum values of the considered value.

As a result of the above calculations, you can get diagrams of the distribution of the cost and timing of the project $P(C)$ and $P(S)$, respectively. For rice. 5 an example of the results of calculating the probability distribution for the random variable $C$ - project cost is presented. In this example, the range of possible project cost values is divided into 10 intervals. Based on the results of numerous calculations of the project cost performed for various combinations of risks [21, 22], the frequency of hits of results in a particular range is determined and a distribution density diagram and a graph of the integral distribution of the value $C$ is constructed.

In this example, the highest probability occurred in the interval 4. The average value of the cost in the interval 4 is denoted by $C_4$. Using the integral distribution schedule, you can determine the numerical value of the probability that the project cost will not exceed the value of $C_4$.

A similar calculation is performed to determine the probability distribution function with respect to the project implementation time.

Using the scales shown in Tables 1 and 2, you can return to qualitative risk assessments of the Project. To do this, based on the distribution density diagram, it is necessary to determine the probability of "hitting" a random variable (C or S) in the intervals specified in Table 2. Integrating the density function of the random variable distribution over the specified deviation intervals ($<5\%, 5\%-10\%, >10\%$) the values of the probability of hitting a random variable in each interval $P<5\%, P5\%-10\%, P>10\%$. are determined. The maximum value of $P_{\text{max}}=\max [P<5\%, P5\%-10\%, P>10\%]$ and the corresponding deviation interval are determined; qualitative estimates of probability and influence are determined from Tables 1 and 2.
This approach involves the use of combined techniques of qualitative and quantitative risk assessment, allows to obtain a more complete picture of the risks of project implementation, which significantly improves the base justifications for the subsequent decision-making approach allows for a transition from qualitative risk assessment work package, for example, any separate subcontractor, to the assessment of risks on a construction Project as a whole.

4 Conclusions
This paper analyzes the expectations of Project stakeholders at different levels of management. Three risk categories are identified for the level of EEO Construction Project management in accordance with the contractor's EPC/EPCM expectations:
- R_Q - risk of quality deviation;
- R_C - risk of price deviation;
- R_S – the risk of deviations in timing.

For the risks associated with the deviation of the cost and timing, the method of qualitative risk assessment of the Project is described. A mechanism for switching from qualitative risk assessments for individual work packages to risk assessment for the Project as a whole is proposed.

A promising direction is to develop a mechanism for switching from qualitative risk assessments of the Construction Project to risk assessments of the Investment Project and, subsequently, to the risk assessment of the Program, as well as to develop a methodology for qualitative risk assessments related to deviations in the quality of work performed.

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