Risk Management of Construction of Industrial Buildings and Structures

M. N. Shutova, A. I. Shagina, and S. I. Evtushenko

Abstract When developing design and estimate documentation for construction projects, it is mandatory to determine the estimated cost of construction and the duration of work. This is due to certain regulatory values and aggregated indicators, but it does not take into account possible risks. Risks, in turn, can not only lead to a failure of deadlines and increase the cost of construction, but also results in deterioration in the operational properties of buildings and structures, which entails a significant reduction in the service life of the construction project.

The article provides a qualitative assessment of the risks arising during the construction of industrial buildings and structures, using the example of the design and construction of an industrial workshop for the production of native starch in the Rostov region. Potential and realized risks were considered, the mechanism of their influence on the increase in the duration of construction and the cost of the object was established.

The implementation of this mechanism in the form of a network graph can be possible with the help of probabilistic methods and allows, at the pre-project stage, estimating the most probable terms of construction and design work (with the maximum duration of work in the implementation of adverse risks).

Keywords Risk management · Life cycle of construction projects · Industrial construction · Construction's cost · Construction's time

M. N. Shutova (✉) · A. I. Shagina
Platov South-Russian State Polytechnic University (NPI), Platov SRSPU (NPI), Prosvesheniya Street 132, Novocherkassk 346428, Russia

S. I. Evtushenko
National Research University Moscow State University of Civil Engineering (MGSU), NRU MGSU Yaroslavskoe Shosse, 26, Moscow 129337, Russia

A. Ginzburg and K. Galina (eds.), *Building Life-cycle Management. Information Systems and Technologies*, Lecture Notes in Civil Engineering 231,
https://doi.org/10.1007/978-3-030-96206-7_44

1 Introduction

Risk management is an integral part of the management of organizational processes in construction. The peculiarities of risk management in the construction of industrial buildings and structures are the presence of specific factors related to both the technological process, for which the construction object is intended, and constrained construction conditions, dependence on the technological equipment of a particular supplier, as well as the tight deadlines for construction work.

If earlier there was a significant impact of risks associated with the deterioration of the technical condition of building structures due to miscalculations at the design stage or non-compliance with installation technology, now the proportion of risks has increased—errors in estimates, non-compliance and penalties for obligations (mainly temporary) contracts [1].

The risk management process in construction consists of six stages.

The first stage: identification of risks. In particular, the following risks might arise in projects: quality risks; personnel risks; price risks; risks of failure to meet deadlines; risks of strategic decisions; external risks.

Second stage: risk analysis. At this stage, an analysis of the priority of risks and the degree of their impact on the life cycle of the construction project as a whole is carried out.

The third stage: risk measurement. Mathematical and statistical accurate methods commonly used in risk assessment in other industries cannot adequately reflect typical risks in the construction industry.

The fourth stage is risk control. Risk management strategies are adopted as follows: avoidance, reduction, transition to risk, taking risk on yourself.

The fifth stage represents risk monitoring, that is, continuous operational control of the effectiveness of risk management and the adoption of timely measures.

The sixth stage is goal control. After recognizing, analyzing and assessing risks, measures should be taken to control the goals. The whole management process can be divided into subprocesses: determination of the target value, the actual value, comparison of values and analysis of variance [2].

The risk management methodology at the procurement stage was reviewed in [3]. A simple and unified methodology has been successfully tested in determining the systematic risks of the construction of a real construction object.

When determining the risks directly from work on the construction site, the authors [4] proposed a method for calculating: weight factor; weighted average value of risk; exceeding the value of the weighted average risk value; the additional value of exceeding the weighted average risk value; the total amount of risk.

In modern risk management models, the following basic actions are proposed [5]:

risk avoidance (risk prevention, risk avoidance, risk elimination), that is, avoidance of activities that cause the realization of risk. Often the level of this risk is too high, it needs to be brought to an acceptable level; risk minimization (risk reduction, risk optimization and control over it), that is, risk reduction through a system of anti-crisis measures; the use of risk (risk acceptance, risk neglect, risk limitation) is characteristic of minor risks that cannot be eliminated, but with successful management, the realization of this risk makes it possible to increase the profitability of construction.

Risk management in construction mainly depends on intuition, judgment and experience [6]. Formal risk analysis and management methods are rarely used due to lack of knowledge and doubts about the suitability of these methods for activities in the construction industry.

The authors [7] suggest using a construction risk management model (CRMS) based on the method of constructing impact diagrams and Monte Carlo modeling. Alternative risk management strategies include: risk prevention, risk transfer, risk retention, loss reduction, insurance.

As one of the methods for assessing the implementation of risks, a model.

(RMMS) was proposed—a system for implementing the risks of large-scale projects based on the use of the Analytical Network Process (ANP) method to measure the overall effectiveness of risk management in relation to the main risk factors [8].

An approach to decision–making based on fuzzy multiple criteria (FMCDM) was also proposed, in particular for the construction of critical structures such as subways. At the same time, the assessment was carried out on 20 risk factors identified at four sites [9]. To analyze the probability of occurrence of multiple risk factors, the method of direct ranking of fuzzy multiple attributes (FMADR) is used.

Another approach is the use of fuzzy Bayesian networks (FBN) based on the analysis of the risk mechanism to investigate the cause-effect relationships between the stress–strain state of the foundation soil caused by the construction of the tunnel and the variables affecting it [10].

The problem of the impact of failures in construction on the cost of production and on the quality of construction projects was studied by Abdul-Rahman [11].

The security risks at the construction site have a fundamental impact on the lines and construction costs, and the reliability of building structures. Research on this topic was carried out by scientists from China [12], Pakistan [13], North Korea [14].

To assess the risks of increasing the cost and predict the real cost of construction contracts, a method was proposed in terms of a construction cost index [15].

Some opportunities for better risk allocation mechanism and contracting strategies that are based on a trust relationship between the contracting parties were analyzed using the data from the surveys of Canadian developers [16].

When building global facilities, specific risks should also be accounted for:

- social sustainability (on the example of researching survey data from 120 leading Pakistani experts [17]);
- political risks for multinational contractors [18];
- specific risks of geotechnics for underground structures [19] or extreme climatic influences [20].

Minimization of the consequences of the manifestation of the main risks can be carried out using the Cost Contingency Reserve (CCR) for a project. Post-mitigation simulations show that value of CCR is 2.88% of project cost [21].

2 Methodology of Risk-Management of Construction of Industrial Buildings and Structures

All the described studies were taken into account in the process of risk management of the construction of a dry starch production workshop in the Rostov region.

The decision to open the project: "Construction of a starch drying shop with a capacity of 300 tons/day" was made by the management of Amilco in December 2018 in order to expand the production capacity of the enterprise and further release of new products.

At the same time, the design deadlines were extremely tight. In this regard, there were additional risks of errors in design decisions due to lack of time for detailed study.

In addition, the design of building structures had to be developed taking into account the ready-made scheme of engineering communications and ready-made technological equipment, which also increased the risk of errors in the design of structures (Fig. 1).

When searching for a contractor, another non-obvious risk was revealed: due to the reduction in the pace of construction of industrial buildings in Russia, the number of design organizations specializing in this area has also significantly decreased.

The main requirements for the tender among contractors were: experience in the design and construction of industrial facilities, reliability and high quality of the work performed by the counterparty; minimum project implementation time; optimal price/quality ratio; sociability, mobility and quick response to changes while taking into account the wishes of the customer company with the full implementation of the turnkey project; legal and tax audit of the counterparty.

All the considered phases of the project are included in Table 1.

Similar assessment methods were used when searching for an organization that conducted pre-project surveys (geological, geodetic, environmental and hydrometeorological).

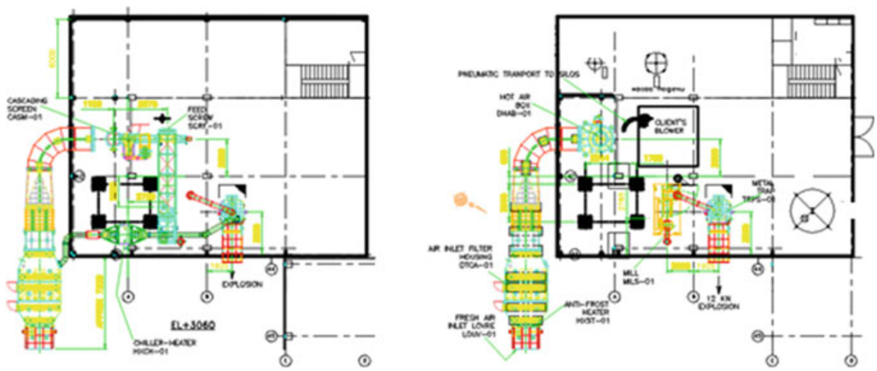

Fig. 1 Technical specification for design—engineering

Table 1 Project phases

	Stage 1	Stage 2A	Stage 2B	Stage 3	Stage 4
Result	Approve that the project complies with the company's strategy	Confirmation of preferred solutions (options)	Final confirmation of the scope (boundaries) of the project and tasks (goals)	Confirmation of fulfillment of financial promises	Project acceptance
Important questions	Does the project correspond to the company's strategy? What problems are being solved by the project?	Does the project continue to comply with the company's strategy?	Does the project continue to comply with the company's strategy?	Does the project continue to comply with the company's strategy?	Does the project continue to comply with the company's strategy?
Risk assessment issues	Is there an economic justification for the project? Is there a financial justification, strategic compatibility, customer orientation, competitive advantages?	Have all the alternative solutions of this project been adequately evaluated? Is there a single agreement on the chosen solution?	Are there changes in the list of works on the project and the project, schedule, budget, key economic indicators, project managers or the composition of the project team?	Project solution management plan Are there changes in the list of works on the project and the project, schedule, budget, key economic indicators?	Is it possible to implement the project on site and is the company ready for implementation? Is the organization and the project team ready for implementation?
General conclusion	How can shareholders help? Should this project be cancelled?	How can the shareholder team help? Should this project be cancelled?	How can the shareholder team help? Should this project be cancelled?	How can the shareholder team help? Should this project be cancelled?	How can the shareholder team help? Should this project be cancelled?

The process of selecting a general contractor for the construction of the facility was carried out at a time when the design was not yet fully completed, and was based not on estimates, but on the prices of enlarged types of work. A tender with enlarged cost indicators was very risky for concluding a contract, so a decision was made:

1. Selection of a general contractor, with the possibility of involving subcontractors by agreement for the full implementation of the project;

2. On the approval of prices for enlarged types of work (i.e. the estimate is not "solid" because there is no full explication of the project).

3 Result of Approbation of Methodology of Determining of Potential Risks of Construction of Industrial Buildings

In addition to the risks that appeared directly in the specified phases of the project (pre-design, design and construction), there are also hidden risks—those whose implementation is possible only at the next stage.

For the customer, the main criterion for evaluating the effectiveness of decision-making and consequently risk minimization was the earliest possible time for putting the workshop into operation.

The mechanism of the relationship of risks at different cycles of the building's life is presented in the form of a directed graph (Fig. 2), where the initial vertex is risk, the final vertices differ depending on the impact of risks—M (money) is the risk of financial losses, T (time) is the risk of temporary losses, MT is the combined risk of time and material losses.

The risks are grouped depending on which stage of the vital cycle of buildings this risk is laid: the pre-project stage (group RI), the project stage (group RII), the project stage (group RII), the construction and operation stage (group RIII).

The types of risks are indicated in Table 2.

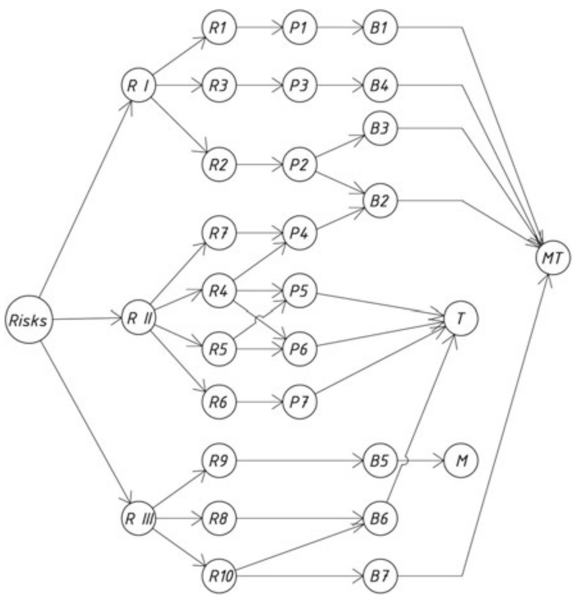

Fig. 2 Oriented graph of the system "Risks of life cycles of a building under construction"

Table 2 Types of risks in the construction of an industrial building

Causes (risks)	Investigations at the stage of		Remove
	Project	Building/building operation	
Pre-project stage (RI)			
Error in engineering-geological surveys (R1)	Incorrect structural solutions of foundations (P1)	Cracks, rolls (B1)	Reinforcement design and reinforcement of foundations
Errors in engineering at the technical task stage (R2)	Errors in the design of engineering systems and technological equipment (P2)	Impossibility and inefficiency of operation (B2)	Engineering Change
		The inability to “fit” technological equipment into a given structure (B3)	Changing design solutions with unchanged engineering
Errors in geodetic surveys (R3)	Errors in the design of SPOSU (P3)	Inability to land on the ground (B4)	Changing the land plan and sections of the design
Designing (RII)			
Low qualification and unreliability of the project contractor (R4)	Project errors (P4)	Impossibility and inefficiency of operation (B2)	Redesign of the project
	Delayed execution (P5)		Change of performer
	Inability to execute (P6)		
Lack of experience in the performer (R5)	Delayed execution (P5)		Collaboration of several contractors
	Inability to execute (P6)		
Delayed response to changes and consideration of customer’s wishes (R6)	Long response to operational changes (P7)		Collaboration of several contractors
			Search for other communication channels
Incorrect determination of the cost and timing of work (R7)	Errors in the estimate (P4)	Inability to complete the scope of work at the specified time (B2)	Adjustment of the estimate

(continued)

The calendar schedule without taking into account the implementation of risks is shown in Fig. 3.

The main stages of construction are shown in Fig. 4.

Table 2 (continued)

Causes (risks)	Investigations at the stage of		Remove
	Project	Building/building operation	
Building (RIII)			
Incorrectly estimated possible-Contractor's news (R8)		Delay and disruption of work deadlines (B6)	Simultaneous work of several subcontractors
«Unsteady» estimate (R9)		Change in the cost of work in the process (B5)	The contract on the enlarged rates taking into account the cost of works and materials
Low qualification and unreliability of the SMR performer (R10)		Mounting errors (B7)	Change of performer
		Delayed execution (B6)	Collaboration of several contractors
		Impossibility and inefficiency of operation (B2)	Change of performer
The operation of the building (RIV) has not been considered in this article			
The dismantling of the building (R V) was not considered in this article			

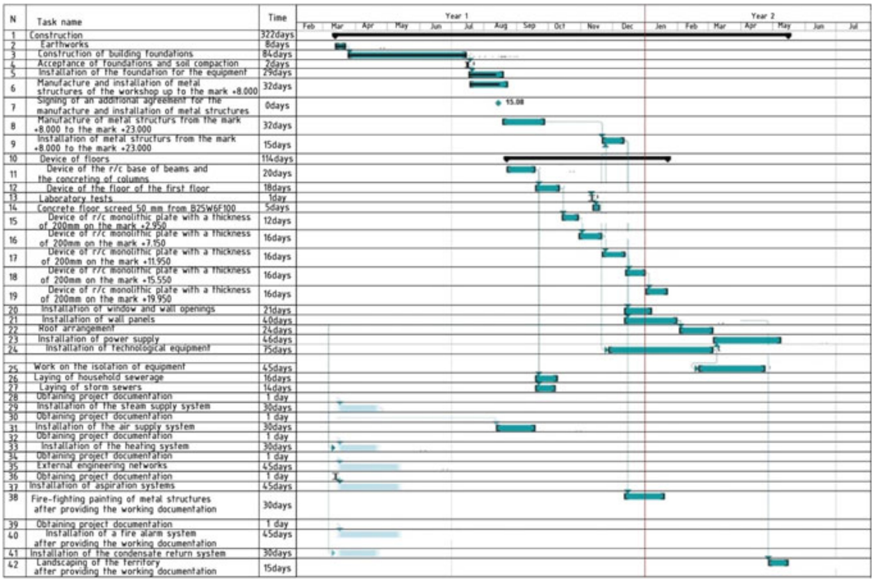

Fig. 3 Calendar schedule without taking into account the implementation of risks

Fig. 4 The main stages of the construction of an industrial workshop

4 Discussion of the Method of Risk Management of Building Construction, Using Oriented Graph

The proposed method of risk management of industrial buildings using the graph theory apparatus is relevant and new in comparison with existing methods. Currently, it is possible to assess the possibility of risk manifestation only on the basis of an expert's subjective assessment based on his experience. And this experience is associated only with a narrow field of work, and cannot be extended to objects with dissimilar specifics.

During the implementation of this project, several risks were realized at once at different cycles of the building's life, as a result of which:

- the design stretched from the planned period of 6 months to a year (with the receipt of a positive expert opinion);
- the construction period has increased from 10 to 19 months.

5 Conclusion

This hierarchy and risk system, as well as the implementation of a risk interaction mechanism in the form of a network graph, allows us to estimate the most likely production dates for construction and design work at the pre-design stage.

Such an assessment can be possible thanks to probabilistic methods, as well as a simplified version: the introduction of a system of coefficients (by analogy with reliability coefficients) that enable to determine the most probable timing of construction and design work.

References

1. Schieg M (2006) Risk management in construction project management. J Bus Econ Manag 7(2):77–83
2. Shlapakov AV (2013) Risk management in the implementation of investment construction projects. Russ Entrep 3 (225)
3. Mills A (2001) A systematic approach to risk management for construction. Struct Surv 19(5):245–252. https://doi.org/10.1108/02630800110412615
4. Staseva EV, Pushenko SL, Strakhova NA (2012) Improving and improving the efficiency of the organization of labor protection in construction on the basis of a risk management system. Volgograd State University of Architecture and Civil Engineering
5. Selyutina LG (2019) Methodological approaches to risk management of innovation and investment processes in construction. Econ Comput Sci 46(1)
6. Akintoye AS, MacLeod MJ (1997) Risk analysis and management in construction. Int J Project Manag 15(1):31–38
7. Al-Bahar JF, Crandall KC (1990) Systematic risk management approach for construction projects. J Constr Eng Manag 116(3):533–546
8. Jia G et al (2013) Measuring the maturity of risk management in large-scale construction projects. Autom Constr 34:56–66
9. Kuo Y-C, Shih-Tong L (2013) Using fuzzy multiple criteria decision making approach to enhance risk assessment for metropolitan construction projects. Int J Project Manag 31(4):602–614
10. Zhang L et al (2014) Bayesian-network-based safety risk analysis in construction projects. Reliab Eng Syst Saf 131:29–39
11. Abdul-Rahman H (1997) Some observations on the issues of quality cost in construction. Int J Qual Reliab Manag 14:464–481
12. Cheng EW, Li H, Fang DP, Xie F (2004) Construction safety management: an exploratory study from China. Constr Innov 4:229–241
13. Azhar S, Choudhry RM (2016) Capacity building in construction health and safety research, education, and practice in Pakistan. Built Environ Project Asset Manag 6:92–105
14. Yoon JH, Cha HS (2017) An empirical study of facility management performance on commercial office building in South Korea. In: Civil engineering and urban planning: proceedings of the 5th international conference on civil engineering and urban planning (CEUP 2016), pp 151–159
15. Wilmot CG, Cheng G (2003) Estimating future highway construction costs. J Constr Eng Manag 129(3):272–279
16. Zaghloul R, Hartman F (2003) Construction contracts: the cost of mistrust. Int J Project Manag 21(6):419–424
17. Maqsoom A et al (2021) Influence of construction risks on cost escalation of highway-related projects: exploring the moderating role of social sustainability requirements. Iranian J Sci Technol Trans Civ Eng 43:2003–2015
18. Al-Tabtabai H, Alex AP (2000) Modeling the cost of political risk in international construction projects. Proj Manag J 31(3):4–13
19. Potapova EV (2020) Expert-statistical approach to the analysis of geotechnical risks in the construction of metro facilities. IOP Conf Ser Mater Sci Eng 962(4):042052
20. Li Y, Stewart MG (2011) Cyclone damage risks caused by enhanced greenhouse conditions and economic viability of strengthened residential construction. Nat Hazard Rev 12(1):9–18
21. Eldosouky IA, Ibrahim AH, Mohammed HED (2014) Management of construction cost contingency covering upside and downside risks. Alex Eng J 53(4):863–881