FORMATION OF A SYSTEM FOR MONITORING RISKS IN THE IMPLEMENTATION OF LIFE CYCLE CONTRACTS

Alexey Dorozhkin, Alexander Tsyganov, Ekaterina Dorozhkina, Anna Gorokhova, Vladimir Sekerin

ABSTRACT

Objective: In light of the current economic volatility and the need for sustainable development, the objective of this study is to develop risk management tools for construction companies involved in investment and construction projects, particularly those implemented through public-private partnerships.

Methods: The study examines the activities of construction companies in implementing risk management procedures for life-cycle contracts. It emphasizes the establishment of key risk indicators (KRI) and the development and implementation of measures to mitigate risks associated with life-cycle contracts, taking into account regulatory requirements and sustainable development principles.

Results: The study identifies the main risks faced by construction companies in the implementation of life-cycle contracts and provides lists of KRI grouped according to these risks. The proposed risk monitoring system enables effective risk management, ensuring compliance with regulations and promoting sustainable development practices.

Conclusion: The findings reveal the main activities of construction companies in the organization of risk management procedures for life-cycle contracts, including the establishment of key risk indicators, and the development and implementation of measures to mitigate the risks of life-cycle contracts.

Keywords: sustainable development, key risk indicators, risk limits, risk management, life cycle contracts.

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RESUMO

Objetivo: Diante da volatilidade econômica atual e da necessidade de desenvolvimento sustentável, o objetivo deste estudo é desenvolver ferramentas de gestão de risco para construtoras envolvidas em projetos de investimento e construção, particularmente aqueles implementados por meio de parcerias público-privadas.

Métodos: O estudo examina as atividades de empresas de construção na implementação de procedimentos de gerenciamento de risco para contratos de ciclo de vida. Enfatiza o estabelecimento de indicadores-chave de risco (KRI) e o desenvolvimento e implementação de medidas para mitigar os riscos associados aos contratos de ciclo de vida, levando em consideração os requisitos regulatórios e os princípios do desenvolvimento sustentável.

Resultados: O estudo identifica os principais riscos enfrentados pelas construtoras na implementação de contratos de ciclo de vida e fornece listas de KRI agrupadas de acordo com esses riscos. O sistema de monitoramento de riscos proposto permite uma gestão de riscos eficaz, garantindo o cumprimento dos regulamentos e promovendo práticas de desenvolvimento sustentável.

Conclusão: Os resultados revelam as principais atividades das empresas de construção na organização de procedimentos de gestão de risco para contratos de ciclo de vida, incluindo o estabelecimento de indicadores-chave de risco e o desenvolvimento e implementação de medidas para mitigar os riscos de contratos de ciclo de vida.

Palavras-chave: desenvolvimento sustentável, indicadores chave de risco, limites de risco, gerenciamento de riscos, contratos de ciclo de vida.

1 INTRODUCTION

The state bodies of the Russian Federation are facing budget deficits and problems with the long-term management of large infrastructure projects in the context of the development of the economic recession, which is intensifying due to the global pandemic (Komarova, & Bondarenko, 2023). The new economic conditions force the state authorities to search for and apply in practice new forms of implementation of large socially significant projects. One of these forms that have proven their effectiveness abroad is the life cycle contract (LCC) (Barbos 2022). The term design-build-finance-maintain (DBFM) is sometimes used (Fadyushin 2019).

The construction of highways, the purchase and use of medical equipment, and other infrastructure projects are always associated with the implementation of social tasks, the use of LCC in this process contributes to increasing the social responsibility of business. This will lead to an improvement in the quality of project implementation in the long term since the project itself is implemented by a contractor who will also carry out
post-maintenance of the project – which will ensure permanent employment of personnel in maintenance, and not on one-time contracts, which means it will provide permanent, not one-time, jobs. For government agencies, the use of LCC reduces costs by eliminating intermediaries and ensures an increase in the quality of service (Ministry of Economy, Finance and Industry of France 2011; National Audit Office 2012; Sekerin et al. 2014; Zhilenko et al., 2021).

Life-cycle contracts are changing the idea of public-private partnerships. The implementation of large infrastructure projects is an important social task, and the use of LCC in this process will contribute to increasing the social responsibility of business in such a state-important industry as the construction of social facilities (OECD 2008). This will lead both to an increase in the quality of construction and to an increase in the quality of service in the long term since it will be carried out by the contractor. The service will ensure the constant employment of staff, which will ensure stable interaction, unattainable on one-time contracts. For the project implementation system itself, the introduction of LCC will entail a reduction in costs due to the exclusion of intermediaries and an increase in the quality of service (Vaslavskaya et al., 2022). Thus, the use of LCC is an illustrative example of how social responsibility is mutually beneficial to all parties: contractors receive guaranteed sales of their services and related products, and buyers receive long-term guarantees for the uninterrupted and long-term operation of the facility/equipment.

The customers of the LCC projects are interested in establishing new requirements for the organization of LCC projects, which are aimed at monitoring the achievement of long-term project goals (budget, timing, and quality of the project), due to a transparent risk management system and their risk limitation. Considering the long-term nature of the LCC projects, the work suggests tools for monitoring and controlling the risks of LCC projects that are necessary for the customer to ensure end-to-end control over the achievement of the goals of the LCC project. The key risk indicators of LCC projects are proposed that provide a flexible mechanism for monitoring risks in the conditions of rapid changes in the external environment of projects. This risk monitoring mechanism will be able to guarantee the customer the ability to make operational decisions in logistics matters and localize construction resources considering the individual characteristics of the LCC projects.
2 LITERATURE REVIEW

The theoretical issues of LCC in the implementation of public-private partnerships have been studied by many scholars, including A.V. Kireeva (2020) and other Russian and foreign authors (Khoruzhy et al., 2022; Kiseleva et al., 2023). These works describe the general principles of public-private partnership. Thus, private issues of practical implementation of public-private partnership projects, as well as risk management of LCC, are not given special attention in the works of these authors. The issues related to the risks of implementing PPP projects are studied from the perspective of managing private investment projects in the scientific works of A.A. Tsyganov (2016, 2020), N.V. Kirillova (2015), and other Russian and foreign authors. The works of these authors reflect the issues related to the identification of certain types of risks in public-private partnerships. However, the issues of managing the totality of risks of PPP projects by these authors are limited to the framework of certain types of LCC of public-private partnership and are considered from the position of an exclusively private partner of the project.

The project management systems of LCC in the Russian Federation, including the risk monitoring systems of LCC projects, are also not sufficiently developed yet, since the number and cost of LCC significantly lag behind similar indicators for LCC projects in the countries of the European zone and the North American zone. The development of LCC projects in the Russian Federation is limited by many factors (Gurinovich et al., 2023; Belova et al., 2023). The main factors include:

- the high risk of projects associated with high costs for LCC projects;
- insufficiently developed procedures for the distribution of risks among the participants of the LCC project;
- the immaturity of the Russian legislative framework and constant changes in the Tax Code of the Russian Federation constrain the application of the LCC projects.

The benefits of LCC projects are mainly considered one-sidedly in studies by Russian authors (Kireeva 2020; Alimbekova et al., 2021), from the position of one of the participants in the LCC project, which makes it difficult to justify the distribution of risks among all participants in the LCC project.

It is noted in Russian and foreign studies of LCC projects (Beasley et al. 2010; Bezpalov et al., 2022) that the intensity of construction in the LCC project increases with each stage of construction, processes arise in the project that needs to be implemented in
parallel in conditions of limited resources and production base, while the uncertainty of the external environment does not decrease, but tends to increase. It becomes critically important in such a situation to solve the task of monitoring the risks of LCC projects, the tools of which are presented in detail in the work. Timely identification of project risks will allow resources to be redistributed between processes and participants in an unstable external environment (Tatibekova et al., 2022; Dolgopolov et al., 2022). Therefore, the above-mentioned studies refer to the term – key risk indicator (KRI), but the KRI themselves and approaches to their limitation are not proposed. Thus, for the practical application of KRI in LCC projects, the development of the following is necessary:

– KRI monitoring schemes,
– determination of KRI for specific risks of LCC,
– a methodology for determining the permissible limits of KRI, the relationship with KRI, and the risk assessment of LCC.

For the development of the mechanism of management of LCC projects in the Russian Federation, it is necessary, first of all, to develop mechanisms of relationships between participants of the LCC project, to justify approaches to monitoring and risk management at all stages of the life cycle, to create risk indicator systems (KRI) that will allow timely identifying LCC risks and promptly developing measures to manage them.

The execution of the LCC is associated with the realization of several risks caused by the long-term obligations of the parties to the LCC, which, in the conditions of the crisis development, attaches particular importance to a systematic approach to managing the risks of the LCC (Dudin et al. 2016; OECD 2008; Berdibekova et al., 2022).

The characteristics of LCC are associated with the participation of the contractor at all stages of the project, including the design and construction or reconstruction of a social infrastructure facility, and then the maintenance of this object throughout the entire life cycle (on a long-term basis, on average from 15 to 30 years) generate several risks, which in case of insufficient and low-risk management efficiency can lead to bankruptcy of the contractor, and, as a result, the customer will not receive high-quality services for the LCC project (Vinichenko et al., 2022).

The key risks of LCC include the following risks for the contractor of the LCC project:

- Funding shortfall risk.
- The risk of errors in the design of LCC projects.

- Risks of shifts in the timing of the implementation of the LCC project.
- Risks of accidents and incidents during the CAR.
- The risks of additional costs during the operation of the infrastructure of the LCC project.
- Risks of non-fulfillment of obligations by subcontractors in the LCC project.
- The risk of incorrect determination of the project cost.
- The risk of non-compliance with the quality requirements of the purchased products (goods, works, services).
- Risks of rising costs in the operational phase of the LCC project.

These risks will indirectly affect, among other things, the Customer of the project, since due to the implementation of these risks, there may be a failure to fulfill the obligations of the contractor and a decrease in the quality of the functioning of the LCC project.

Thus, the contractor under the contract bears the main risks throughout the entire life cycle, but on a long-term basis gets the opportunity to receive payment for maintenance and service, which should be guaranteed throughout the entire life cycle of the contract implementation.

In these conditions, the participants of the LCC projects need first of all to implement a flexible system for monitoring the risks of LCC projects, to ensure the implementation of preventive measures to achieve the goals of the LCC projects.

The monitoring system for LCC projects should be based on the development of KRI – key indicators that reflect the current level of risk ahead of time (Association for Advancement of Cost Engineering (AACE) International 2011).

The purpose of this study was to increase the efficiency of LCC through the formation of a risk monitoring system. The following tasks were identified to achieve the purpose of the study:
1. Identification of LCC risks;
2. Development of separate lists of key risk indicators for identified risks.
3. Formation of proposals and approaches to monitoring the risks of the LCC project.
3 MATERIALS AND METHODS

The methodological basis of the study was the main provisions, concepts, and approaches of risk management theories. The methods of expert assessment, analysis, synthesis, comparison, and grouping were used as research methods (Beasley et al. 2010; Yembergenov et al., 2022). The information base of the research included legislative and regulatory acts of the Russian Federation, international and Russian risk management standards, the results of scientific and practical research by foreign and domestic authors on risk management, insurance, and LCC, statistical data published in Russian and foreign periodicals, information provided on the Internet, the results of research on the potential application of the research results.

The development of the KRI presented in the paper has been tested for projects implemented by LCC mechanisms by large energy companies represented in the Russian Federation. The processes of LCC projects were analyzed for the development of the KRI database: project financing, the process of construction and installation works, logistics processes; the processes of operation of LCC projects, the processes of organizing work with contractors, and other formulations of KRI were discussed at operational meetings during the implementation of LCC projects at Russian energy companies.

Decision trees were developed to determine the KRI weights that describe and establish the relationship between the goals of individual LCC projects and the risks affecting these goals, while an adaptive mechanism was proposed for changing the KRI weights when identifying new risks of LCC projects.

The purpose of the development of KRI for the key risks of the LCC project: the implementation of regular monitoring of changes in the level (dynamics) of risks.

The KRI for the key risks of the LCC Project should reflect the advanced information about the change in the level of risks.

Properly developed KRI will allow the Executor of the LLC project to predict in advance the change in the level of risks for the timely development and/or implementation of corrective measures to manage key risks based on the results of monitoring key risk indicators.

The paper proposes to divide the KRI into two types:

1. A change in the value of KRI characterized by a change in the probability of risk.
2. A change in the value of KRI characterized by a change in the impact of risk.

The basic requirements for the KRI of the LCC project are proposed.

1. Quantitative measurability. KRI is measured in absolute or relative terms.
2. There must be a direct link to the risk. The change in KRI values should characterize the dynamics of the risk factor (root cause) and/or the risk impact values.
3. KRI is developed for each factor if several factors may influence risk.
4. Predictive nature. The predictive nature of the KRI can be determined both based on historical statistics and by expert analysis.
5. Comparability. It is possible to compare the KRI with the previous values and track the trend of its change during the previous monitoring periods.
6. Easy to calculate and monitor. When developing KRI, it is necessary to use the most accessible, transparent, and understandable information.

A scientific approach to the development of KRI is needed, corresponding to the following principles:

1. According to KRI, information is available that allows quantifying the amount of risk;
2. KRI is developed for each factor of each key risk;
3. The information used in the development of KRI must be accessible and reliable;
4. The KRI is developed considering the possibility of its subsequent regular monitoring, as well as the minimum reaction time to a change in the indicator.

It is necessary to review and update the KRI in order for the project management mechanism of the LCC to be effective:

1. Annually: KRI of key risks, threshold values are updated during the annual updating of the list of key risks.
2. In case of realization of key risks without preliminary change of values of previously developed KRI.
3. When changing/identifying new factors of key risks.
4. When changing the limit values of deviations of the Risk Readiness parameters.
In the study, we proposed lists of KRI for individual key risks of the LCC project. The lists were compiled based on the analysis of existing experience, expert assessment, and original developments.

4 RESULTS

Lists of KRI are grouped by key risks and are given in Tables 1-10.

Table 1. KRI for the risk of non-fulfillment of obligations by subcontractors in the LCC project

<table>
<thead>
<tr>
<th>LCC risks</th>
<th>KRI list</th>
</tr>
</thead>
<tbody>
<tr>
<td>Risk of non-fulfillment of obligations by subcontractors in the LCC project</td>
<td>Non-fulfillment of obligations by subcontractors to the Contractor</td>
</tr>
<tr>
<td></td>
<td>Deterioration of the main financial indicators of the Contractor and subcontractors</td>
</tr>
<tr>
<td></td>
<td>Information about critical nonconformities of products (goods, works, services) supplied within the framework of the project</td>
</tr>
<tr>
<td></td>
<td>Suspension/revocation of licenses/permissions from a subcontractor, event units</td>
</tr>
<tr>
<td></td>
<td>The amount of the provision for doubtful debts by group subcontractors and terms</td>
</tr>
<tr>
<td></td>
<td>The share of unsecured accounts receivable from the total amount of accounts receivable</td>
</tr>
<tr>
<td></td>
<td>Percentage of employees of contractors who have qualifications following the TOR, are on staff, and are engaged in the work of the CAR</td>
</tr>
<tr>
<td></td>
<td>Overdue accounts receivable to the total amount of accounts receivable (broken down by counterparty groups and terms)</td>
</tr>
</tbody>
</table>

Source: Prepared by the authors (2023)

Table 2. KRI for the risk of unreliable determination of the project cost

<table>
<thead>
<tr>
<th>LCC risks</th>
<th>KRI list</th>
</tr>
</thead>
<tbody>
<tr>
<td>Risk of unreliable determination of the project cost</td>
<td>Deviation of the actual cost of the project by the cumulative total from the plan</td>
</tr>
<tr>
<td></td>
<td>Forecasts of growth in the cost of construction of the LCC project</td>
</tr>
<tr>
<td></td>
<td>The volume of the verified estimated documentation of the Project</td>
</tr>
<tr>
<td></td>
<td>The number of approved technical solutions with changes to the design and construction documentation</td>
</tr>
</tbody>
</table>

Source: Prepared by the authors (2023)

Table 3. KRI for the risk of a funding shortfall

<table>
<thead>
<tr>
<th>LCC risks</th>
<th>KRI list</th>
</tr>
</thead>
<tbody>
<tr>
<td>Risk of a funding shortfall</td>
<td>Deviation of the actual interest rates from the average rates budgeted for the LCC project</td>
</tr>
<tr>
<td></td>
<td>Contractor's liquidity ratio</td>
</tr>
<tr>
<td></td>
<td>Reduction of the Contractor's credit rating (if any)</td>
</tr>
<tr>
<td></td>
<td>The ratio of overdue accounts payable to the total amount of accounts payable</td>
</tr>
</tbody>
</table>

Source: Prepared by the authors (2023)

Table 4. KRI for the risk of shifts in the timing of the LCC project

<table>
<thead>
<tr>
<th>LCC risks</th>
<th>KRI list</th>
</tr>
</thead>
<tbody>
<tr>
<td>Risk of shifts in the timing of the LCC project</td>
<td>Deviation of the period of actually performed work from the planned deadlines (broken down by factors)</td>
</tr>
<tr>
<td></td>
<td>The number of unplanned repairs during the functioning of the infrastructure of the LCC project</td>
</tr>
</tbody>
</table>

Source: Prepared by the authors (2023)
Violations, failures in the operation of the equipment/infrastructure of the LCC project

Deviations of the terms of preparation of the DED, regulatory documents on the LCC project

Deviations of the actual deadlines and volumes of the implementation of the project plan of the LCC (shifts in the timing of control events of the project planned for completion in the reporting year under the influence of risks)

Forecast of the achievability of key milestones of the LCC project

Table 5. KRI for the risk of errors in the design of LCC projects

<table>
<thead>
<tr>
<th>LCC risks</th>
<th>KRI list</th>
</tr>
</thead>
<tbody>
<tr>
<td>Risk of errors in the design of LCC projects</td>
<td>The sum of the days behind the schedule for each of the current stages of all projects</td>
</tr>
<tr>
<td></td>
<td>The level of growth in the cost of production/performance of work</td>
</tr>
<tr>
<td></td>
<td>The share of employees who have qualifications following the terms of reference, are on staff, and are engaged in the project, from the total number of employees engaged in the project</td>
</tr>
<tr>
<td></td>
<td>Information about submitted claims to suppliers/contractors</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
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</tr>
</tbody>
</table>

Table 6. KRI for the risk of additional costs during the operation of the infrastructure of the LCC project

<table>
<thead>
<tr>
<th>LCC risks</th>
<th>KRI list</th>
</tr>
</thead>
<tbody>
<tr>
<td>Risk of additional costs during the operation of the infrastructure of the LCC project</td>
<td>Dynamics of prices for raw materials and materials/project services</td>
</tr>
<tr>
<td></td>
<td>Deviations of the forecast values of prices of raw materials and materials/services from the planned ones</td>
</tr>
<tr>
<td></td>
<td>Deviation of the actual inflation rate from the one set in the parameters for calculating the weighted average cost of capital</td>
</tr>
<tr>
<td></td>
<td></td>
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<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 7. KRI for the risk of non-compliance with the quality requirements of purchased products (goods, works, services)

<table>
<thead>
<tr>
<th>LCC risks</th>
<th>KRI list</th>
</tr>
</thead>
<tbody>
<tr>
<td>Risk of non-compliance with the quality requirements of purchased products (goods, works, services)</td>
<td>Non-fulfillment of obligations by its subcontractors to the general contractor</td>
</tr>
<tr>
<td></td>
<td>Information about critical nonconformities of products (goods, works, services) supplied within the framework of the project</td>
</tr>
<tr>
<td></td>
<td>Suspension/revocation of licenses/permissions from a subcontractor, event units</td>
</tr>
<tr>
<td></td>
<td>Percentage of identified nonconformities</td>
</tr>
<tr>
<td></td>
<td>Percentage of employees of contractors who have qualifications following the TOR, are on staff, and are engaged in the work of the CAR</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 8. KRI for cost risks in the operational phase of a project LCC

<table>
<thead>
<tr>
<th>LCC risks</th>
<th>KRI list</th>
</tr>
</thead>
<tbody>
<tr>
<td>Risks of rising costs in the operational phase of the LCC project</td>
<td>Dynamics of prices for raw and other materials/project services</td>
</tr>
<tr>
<td></td>
<td>Deviations of the forecast values of prices of raw and other materials/services from the planned ones</td>
</tr>
</tbody>
</table>
An example of an integrated assessment of the LCC risks associated with accidents during the implementation of the LCC project is presented in Table 10.
Table 10. Integral assessment of the LCC risks

<table>
<thead>
<tr>
<th>Ser.</th>
<th>Risk factors</th>
<th>The weight (significance) of the factor in the risk an accident</th>
<th>Name of the KRI</th>
<th>The share KRI in the risk factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Faulty fire extinguishing systems, automatic fire alarm systems</td>
<td>20%</td>
<td>Number of fires at the industrial site of the LCC project</td>
<td>0.33</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>The number of comments from fire services on the functioning of the fire extinguishing and fire alarm systems</td>
<td>0.33</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>The number of months that have passed since the last fire safety certification</td>
<td>0.33</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Total weight of the KRI in the risk factor</td>
<td>1.0</td>
</tr>
<tr>
<td>2</td>
<td>High utilization of production capacities</td>
<td>20%</td>
<td>The level of capacity utilization</td>
<td>1.0</td>
</tr>
<tr>
<td>3</td>
<td>Poor quality/postponement or cancellation of capital and scheduled preventive repairs</td>
<td>20%</td>
<td>The share of postponed repairs in the total volume of planned repairs</td>
<td>0.33</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>The share of canceled repairs in the total volume of planned repairs</td>
<td>0.33</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Number of incidents caused by contractors</td>
<td>0.33</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Total weight of the KRI in the risk factor</td>
<td>1.0</td>
</tr>
<tr>
<td>4</td>
<td>Violation of TI requirements and rules of equipment operation by personnel</td>
<td>20%</td>
<td>The number of downtimes associated with the violation of TI in production units</td>
<td>0.33</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Percentage of vacant staff positions</td>
<td>0.33</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>The number of incidents related to the supply of substandard raw and other materials</td>
<td>0.33</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Total weight of the KRI in the risk factor</td>
<td>1.0</td>
</tr>
<tr>
<td>5</td>
<td>Equipment wear and tear</td>
<td>20%</td>
<td>Equipment wear and tear</td>
<td>1.0</td>
</tr>
</tbody>
</table>

Source: Prepared by the authors (2023)

In the absence of sufficient statistical information on the implementation of the risks of LCC by both Russian and international companies, equal ranges of indicators were used in the scales to assess the risk level for the boundary values of quantitative indicators of KRI of LCC projects, which provided standardization and smoothing of the ranges for the selected quantitative indicators of LCC projects. The practice of establishing uniform boundaries of ranges has also been confirmed by the practice of international and domestic (AACE International 2011) companies that use scales with the same boundaries for risk assessment when assessing the risks of their investment projects.

Depending on the value of the KRI, three levels of response can be distinguished (traffic light system):

- Basic ("green zone").
- Warning ("yellow zone").
- Responsive ("red zone").
KRI monitoring should be carried out for key risks with a set frequency to identify changes in the KRI value that lead to a change in the risk level.

In the case when the actual KRI value according to the monitoring results is below the base value, the KRI is in the "green zone". In this case, it is not necessary to take any additional actions or develop additional risk management measures.

In the case when the actual KRI value according to the monitoring results is above the basic value, but below the responsive value, the KRI is in the "yellow zone" (warning value). In this case, it is necessary to take the following actions:

- notify interested parties about the change in the KRI value;
- conduct a detailed analysis of the reasons for exceeding the KRI basic value, if necessary, increase the frequency of KRI monitoring;
- check the relevance of the developed key risk management measures;
- review the risk assessment, and determine measures for self-insurance of risk.

In the case when the actual KRI value is higher than the responsive value, the KRI is in the "red zone". In this case, it is necessary to take the following actions:

- notify interested parties about the change in the KRI value;
- conduct a detailed analysis of the reasons for exceeding the KRI of the reacting value, if necessary, increase the frequency of KRI monitoring;
- update the risk assessment;
- decide on the priority of transferring risk to insurance;
- check the relevance of the developed key risk management measures. If necessary, update the activities;
- implement the developed action plan for managing the key risk to reduce the level of risk/compensate for the consequences of risk and notify interested parties about the results of the implementation of the plan.

The KRI monitoring system allows determining which risks can be transferred to insurance companies to reduce the overall risk profile of the contact life cycle for both the customer and the contractor.

The sources of information for determining KRI can be:

- performance indicators of the contractor and subcontractors;
- project documentation;
reporting of internal audits;
results of regular monitoring of equipment reliability.

External sources:
macroeconomic and industry indicators of projects;
comparative analysis of project implementation;
independent reports and claims of insurers;
requirements of state regulators;
international standards.

The paper identifies the key risks of LCC and proposes a scheme for monitoring the risks of LCC projects based on the development of risk indicators (KRI) presented in Figure 1.

Figure 1. Scheme of functioning of the risk monitoring system of the LCC

- Risk of funding shortfalls.
- The risk of errors in the design of life cycle projects.
- Risks of shifts in the timing of the life cycle project.
- Risks of accidents and incidents during construction and installation work.
- Risks of additional costs when operating the infrastructure of the life cycle project.
- Risks of non-fulfillment of obligations by subcontractors in the life cycle project.
- The risk of inaccurate determination of the project cost.
- The risk of non-compliance with the quality requirements of the purchased products (goods, works, services).
- Risks of rising costs in the operational phase of the life cycle project.

Key risk indicators (KRI) are indicators that are used to provide an early signal of increased risks.

Source: Prepared by the authors (2023)

The formation of the KRI risk monitoring system makes it possible to develop timely measures to compensate for deviations in the planned deadlines of the LCC project, through the development of risk management measures for LCC projects. Figure 2 shows the time frame without considering the risk management measures of the project.
and considering the implementation of risk management measures identified with the help of KRI.

Figure 2. Compensation for deviations in project deadlines identified by the KRI monitoring system

![Diagram showing compensation for deviations in project deadlines identified by the KRI monitoring system.](source)

Table 11 shows the results of KRI monitoring for LCC projects.

<table>
<thead>
<tr>
<th>No.</th>
<th>Stage of the LCC project</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Identification of the goals of the LCC project</td>
<td>KRI are defined for the risks of LCC</td>
</tr>
<tr>
<td>2</td>
<td>Development of scenarios for the implementation of the LCC Project</td>
<td>Boundary values of KRI are determined</td>
</tr>
<tr>
<td>3</td>
<td>Preparation for the implementation of the LCC project</td>
<td>KRI monitoring of identified risks is organized</td>
</tr>
<tr>
<td>4</td>
<td>Implementation of the LCC project</td>
<td>Reporting has been formed within the framework of KRI monitoring and risk management measures</td>
</tr>
<tr>
<td>5</td>
<td>Analysis of the result of the LCC project</td>
<td>Analysis of the realized risks that affected the achievement of the goals of the LCC project was carried out Creating the KRI database of the LCC project for &quot;working on errors&quot;</td>
</tr>
</tbody>
</table>

Source: Prepared by the authors (2023)

5 DISCUSSION

It was noted (Andrada-Félix et al. 2022) that it is necessary to identify risks at the early stages of projects, which makes it possible to reduce the cost of creating an LCC facility even under conditions of a high rate of changes at the design stage and a corresponding increase in costs at this stage. The works devoted to risk monitoring studies mainly investigate the financial industry with the help of KRI, so examples of KRI for the financial sector are considered in (Hartwig et al. 2020), as well as: the dynamics of the bank's assets, the dynamics of the bank's reserves, the dynamics of the bank's capital adequacy ratios, etc. This detailed study of risks and KRI is related to the regulatory
requirements for risk management of the banking sector by international and national banking regulators. Thus, sufficient attention has been paid to the monitoring of project risks, including the risks of LCC projects, but the risks of LCC have been identified, and specific KRI for their monitoring have not been proposed.

Also, several scientific studies are devoted to the theoretical aspects of the use of KRI, as well as in the literature sources (Committee of Sponsoring Organizations of the Treadway Commission (COSO) 2017; Gain et al. 2022), theoretical approaches to monitoring risks through KRI are described. It is indicated that they can be used to identify and assess risks, but they are not reflected exactly how they should be used for monitoring project risks.

Thus, our research has allowed developing a mechanism for identifying and controlling risks, which is insufficiently researched and described in Russian and international sources. The mechanism for controlling and monitoring the risks of the LCC projects allows shifting the costs of changes at an early stage and also allows reducing the total cost of the LCC project. The growth of the risk profile of the LCC project is inversely proportional to its manageability, thus making changes to the LCC project at the early stages of the project ensures optimal risk management of LCC and reduces the cost of changes to the LCC project at the stages of construction and operation.

The trends considered during the study allow formulating actual external challenges for Executors and Customers of LCC projects:

- the growth of competition in the market of LCC projects;
- lagging behind the deadlines for the creation and launch of LCC projects from the deadlines of competitors;
- the growth of environmental uncertainty factors.

In addition to external (market) challenges, the participant of the LCC project is experiencing internal challenges:

- active growth in the volume of contractual obligations on a limited resource (engineering and production) basis;
- the general decline in staff competencies due to the departure of key employees upon reaching retirement age and the lack of an effective system of accumulation and transfer of experience and knowledge, the so-called "mentoring" ("retirement of competencies");
- barriers and "functional wells" of the participants of the LCC project.
The following conditions should be met to implement a system for monitoring and controlling the risks of LCC projects:
- the risk control and monitoring system should be aimed at working both with related participants in the project life cycle and with participants in their ecosystem performing design, production, and supply of equipment, construction, installation, and commissioning;
- the risk monitoring and control system should be focused on most stages of the project life cycle and cover both related participants in the project life cycle, as well as suppliers of spare parts, contractors for repair and maintenance of equipment, etc.

The need to develop key risk indicators is the requirement of international risk management standards (COSO 2017), which declare the use of key risk indicators as a tool for monitoring and providing the company's management with information on the dynamics of the risk level, including project risks. Thus, algorithms have not been disclosed and described on exactly how the KRI should be installed and which KRI should be formulated. The study presented in the article describes an integrated approach to monitoring and controlling the risks of LCC by means of KRI, which allows getting a comprehensive understanding of the risk profile for projects of LCC energy companies of the Russian Federation. The KRI which systematically takes into account the risks in all key areas of LCC projects and enables project management to be targeted about the risk level of individual project elements has been proposed in this article.

Another problem solved in this study is the requirement for the decomposition of KRI (COSO 2017; Hartwig et al. 2020). The study suggests specific KRI for the key risks of LCC projects, which reflect the exposure to the implementation of LCC risks at the level of the entire project, while the proposed KRI, in turn, is decomposed to the level of individual key risks to be able to manage risks at the level of individual parts (elements) of LCC projects. Thus, the KRI indices in our study are proposed to be grouped according to the key risks of LCC projects. The depth of this KRI decomposition makes it possible to cover all the key risks of the LCC projects.

Approaches to monitoring the dynamics of KRI are insufficiently described in studies related to the development of KRI. It is proposed to set threshold values of KRI, which can be divided into several intervals. These intervals characterize the risk levels of LCC: green zone (the risk level is acceptable, no additional actions are required); —
yellow zone (risk should be monitored regularly, and measures should be developed to reduce the risk level to the green zone); red zone (unacceptable level; information about the risk level should be communicated to the project management and measures should be developed to reduce the risk level to the green zone) (Tolkachev et al., 2023). The purpose of each of the levels for the threshold values of the boundaries of the intervals is to determine the general approaches to risk management of LCC, depending on the KRI assessment obtained.

6 CONCLUSION

Summing up the results of the study, it is necessary to state that the proposed risk control and monitoring system allows for planning and carrying out the maximum number of changes at the early stages of the project, which reduces the risks of additional costs for eliminating project changes at the stages of construction and operation.

The paper identifies the main risks of the LCC project and defines KPIs for the organization of monitoring the risks of LCC, which will increase the likelihood of achieving the goals of the LCC projects.

Based on the above, it can be concluded that the implementation of LCC in socially significant areas of the economy is associated with many risks for both the contractor and the state customers of LCC. A flexible system for monitoring the risks of LCC projects is necessary for their effective management. The formation of a risk prevention and response system based on the development and monitoring of KRI will allow obtaining a synergistic effect from combining the efforts of business contract performers and government customers in achieving all the goals of implementing LCC. The described risks and KRI were limited to research in energy companies of the Russian Federation, and in this regard, further study requires the formation of unified databases on the risk of projects in related energy sectors (mining, processing, etc.), which provided research on risk transfer mechanisms throughout the value chain of the product.

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