LIFE CYCLE MANAGEMENT OF CONSTRUCTION FACILITIES

УПРАВЛЕНИЕ ЖИЗНЕННЫМ ЦИКЛОМ ОБЪЕКТОВ СТРОИТЕЛЬСТВА

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Problems and Prospects of Risk-Oriented Management in Construction: a Review of Current Research

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Abstract

Introduction. The construction industry has a major role to play in the global economy due to its multiplier effect, high volatility and complexity of production relations, however, existing risk management techniques, particularly those at the stage of investment justification, are still insufficiently developed. The aim of the study is to systematize modern approaches to risk-based lifecycle management of construction facilities, identifying gaps and promising areas of development, including the use of digital technologies. The main tasks include an analysis of the regulatory framework, a review of risk assessment methods and development of strategies for minimizing them for different types of real estate.

Materials and Methods. A comprehensive bibliometric study of modern approaches to construction risk management using VOSviewer software has been performed. The most authoritative publications from the international Scopus and Web of Science databases, as well as prominent Russian scientific papers, have been selected to be analyzed. The study covered peer-reviewed articles, monographs, and dissertations from the last decade for a representative sample. Special attention is paid to a critical analysis of methodological approaches to risk assessment at the pre-project stage, where traditional methods show the greatest limitations. The study makes use of a systematic approach combining a quantitative analysis of publication activity with a qualitative assessment of the research content. On top of that, successful cases of the introduction of modern risk-oriented practices in real construction projects are explored.

Research Results. The analysis has enabled the key trends in the field of construction risk management over the past decade to be identified. The results of the analysis are indicative of a stable relationship between the quality of the risk management system and success of construction projects, which comes to the fore while investigating modern digital technologies, including artificial intelligence and machine learning methods that are increasingly used for processing large amounts of data in the construction industry. The greatest methodological difficulties are faced with at the stage of investment justification, where traditional expert approaches require mandatory addition of digital analysis tools as confirmed by the practical cases of implementation of risk-oriented approaches explored in the study. The development of adaptive techniques is particularly relevant that takes into account both traditional types of construction risks and new challenges associated with the digital transformation of the industry and taking into account ESG factors, while bridging the existing gap between scientific developments and their practical implementation is becoming a major condition for successful modernization of risk management, which calls for taking coordinated actions by all involved in the construction industry and improving the regulatory framework in compliance with modern technological capacities.

Discussion and Conclusion. The bibliometric analysis has displayed the transition from traditional risk management methods to digital solutions, while indicating the continuing gap between theory and practice, particularly at the stage of investment justification. Modern approaches are actively integrating BIM, decision support systems and AI, but there is a problem of the lack of qualified employees. Hybrid methods combining expert assessments with machine learning and considering new risk factors such as sanctions and environmental requirements are becoming particularly relevant, which calls for modernization of the regulatory framework and professional standards.

Keywords: risk-oriented construction management, capital construction objects, ISO 31000 standards, bibliometric analysis, VOSviewer, investment justification, life cycle of an object

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Оригинальное эмпирическое исследование

Проблемы и перспективы риск-ориентированного управления объектом строительства: обзор современных исследований

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Аннотация

Введение. Строительная отрасль играет ключевую роль в мировой экономике благодаря мультипликативному эффекту, высокой волатильности и сложности производственных взаимосвязей, однако существующие методики управления рисками, особенно на этапе инвестиционного обоснования, остаются недостаточно разработанными. Цель исследования — систематизировать современные подходы к риск-ориентированному управлению жизненным циклом строительных объектов, выявив пробелы и перспективные направления развития, включая применение цифровых технологий. Основные задачи включают анализ нормативной базы, обзор методик оценки рисков и разработку стратегий их минимизации для различных типов недвижимости.

Материалы и методы. Проведено комплексное библиометрическое исследование современных подходов к управлению строительными рисками с использованием программного обеспечения VOSviewer. Для анализа отобраны наиболее авторитетные публикации из международных баз Scopus и Web of Science, а также значимые российские научные работы. Исследование охватило рецензируемые статьи, монографии и диссертации последнего десятилетия, что обеспечило репрезентативность выборки. Особое внимание уделено критическому анализу методологических подходов к оценке рисков на предпроектной стадии, где традиционные методы показывают наибольшие ограничения. В работе применен системный подход, сочетающий количественный анализ публикационной активности с качественной оценкой содержания исследований. Дополнительно рассмотрены успешные кейсы внедрения современных риск-ориентированных практик в реальных строительных проектах.

Результаты исследования. Проведенный анализ позволил выявить ключевые тенденции в области управления строительными рисками за последнее десятилетие. Результаты анализа демонстрируют устойчивую взаимосвязь между качеством системы управления рисками и успешностью реализации строительных проектов, что особенно заметно при рассмотрении современных цифровых технологий, включая методы искусственного интеллекта и машинного обучения, которые находят все более широкое применение при обработке больших массивов данных в строительной отрасли. Наибольшие методологические сложности сохраняются на этапе инвестиционного обоснования, где традиционные экспертные подходы требуют обязательного дополнения цифровыми инструментами анализа, что подтверждается рассмотренными в исследовании практическими кейсами внедрения риск-ориентированных подходов. Особую актуальность приобретает разработка адаптивных методик, способных учитывать как традиционные виды строительных рисков, так и новые вызовы, связанные с цифровой трансформацией отрасли и учетом ESG-факторов, при этом ключевым условием успешной модернизации риск-менеджмента становится преодоление существующего разрыва между научными разработками и их практическим внедрением, что требует согласованных действий всех участников строительной отрасли и совершенствования нормативной базы в соответствии с современными технологическими возможностями.

Обсуждение и заключение. Библиометрический анализ показал переход от традиционных методов управления рисками к цифровым решениям, выявив при этом сохраняющийся разрыв между теорией и практикой, особенно на этапе инвестиционного обоснования. Современные подходы активно интегрируют BIM, системы поддержки решений и ИИ, но сталкиваются с проблемой нехватки квалифицированных кадров. Особую актуальность приобретают гибридные методы, сочетающие экспертные оценки с машинным обучением, и учет новых факторов риска, таких как санкции и экологические требования, для чего требуется модернизация нормативной базы и профессиональных стандартов.

Ключевые слова: риск-ориентированное управление строительством, объекты капитального строительства, стандарты ISO 31000, библиометрический анализ, VOSviewer, инвестиционное обоснование, жизненный цикл объекта

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Introduction. The construction industry has a strategically important position in the global economy due to its three major characteristics. Firstly, it has a distinct multiplier effect, stimulating the development of related sectors from production of building materials to financial services. Secondly, the industry is characterized by high volatility of market conditions due to cyclical demand, dependence on the investment climate and regulatory changes. Thirdly, the construction complex is a n intricate system of industrial relations that unites numerous participants at all stages of the life cycle of objects - from design to operation. These characteristics are corroborated by modern economic studies [1] that accentuate the system-forming role it plays in the global economy.

The aim of the study in the framework of the research specialty 2.1.14 "Life Cycle Management of Construction Objects" is to develop and improve methods of risk-based management of real estate at all stages of their life cycle — from design and construction to operation, reconstruction and decommissioning [2].

The following research tasks can be addressed:

1. Analysis and systematization of risks typical for different stages of the life cycle of construction facilities with a focus on gaps in assessment methods at the investment justification stage.
2. Development of methods for assessing and ranking risks considering their impact on the economic efficiency and sustainability of construction projects.
3. Design of risk management algorithms, including methods for minimizing, transmitting, and monitoring risks.
4. Exploring the capacities of using digital technologies (BIM, Big data, AI) for forecasting and risk management, including the development of investment risk analysis tools.
5. Development of differentiated risk management strategies for different types of real estate (residential, commercial, industrial) considering their specific vulnerabilities and life cycle features.

The aim of the study is to review modern methods of risk-based lifecycle management of capital construction objects (CCO) with a focus on analyzing gaps in risk assessment methods at the stage of investment justification.

The key question is how risk management methods are to be developed in order for them to effectively cover all stages of the life cycle, particularly at the stage of pre-design solutions.

Materials and Methods. In an increasingly intricate business environment, risk management is becoming a major element of strategic management. It is to be noted that different international standards offer their own interpretations of the basic concept of risk. Based on the methodology of bibliometric analysis, this study is thus aimed at systematically identifying key trends in developing a risk-based approach to managing construction objects at all of their life cycle stages.

The analysis of international standards displays considerable differences in conceptual approaches to defining the basic concept of risk. E.g., ISO 31000:2018 Risk Management — Guidelines (ISO 31000) defines risk as "the impact of uncertainty on achieving goals, where impact is seen as any deviation from expected outcomes, both positive and negative ones." This definition accentuates the dual nature of risks that can not only jeopardize, but also create new opportunities for an enterprise.

In contrast, the Enterprise Risk Management — Integrated Framework (COSO ERM) focuses on negative aspects seeing risks as "events that might hinder value creation or cause its reduction." This approach reflects the traditional orientation of the American model towards protecting shareholder value and business sustainability.

The European standard of the Federation of European Risk Management Association (FERMA) actually offers a more neutral definition, "the combination of the probability of an event and the scale of its consequences." Unlike COSO ERM, this does not divide risks into "good" and "bad" ones, but focuses on the mechanisms of their quantification instead.

The practical importance of these differences becomes obvious while analyzing specific cases. E.g., while implementing ESG strategies (environmental, social and management factors), ISO 31000 allows companies to take into consideration environmental initiatives not only as costs, but also as an opportunity to create a new value. At the same time, COSO ERM is still preferred for financial institutions where minimizing losses is a key objective.

It should be noted that modern organizations are increasingly combining the above approaches. Hence 67% of Fortune 500 companies are employing COSO ERM in order to assess traditional risks, while simultaneously applying ISO 31000 to manage innovative projects, where "positive" risks might become a source of competitive advantages.

Hence the choice of risk definition depends not only on regulatory requirements, but also on the strategic priorities of the organization, which is a testimony of the need for a flexible approach to building risk management systems.

The current Russian regulatory and methodological framework for risk management in the construction industry is a multi-level system based on the principles of consistent detail and specialization.

The system relies on three key regulatory documents forming the methodological foundation for effective risk management. The first and fundamental is GOST R ISO 31000-2019 "Risk Management. Principles and Guidelines" that establishes the conceptual framework and principles for risk management. This standard defines fundamental approaches to identying, analyzing and assessing potential threats, sets forth a methodology for developing and implementing preventive measures and formulates requirements for integrating risk management into the overall management system of an organization. Special attention is paid to forming a risk-oriented corporate culture, which is of particular importance for construction companies operating in high-risk environments.

The second critical element of the system is GOST R 51897-2021 "Risk Management. Terms and Definitions" is an adapted international standard ISO Guide 73:2009. Its major function is to ensure the terminological unity and clarity of the conceptual framework. The document contains rigid definitions of key terms helping to avoid discrepancies and ensure consistency in interpreting the fundamental concepts of risk management at all levels of management of a construction organization. On top of that, the standard assists harmonization of Russian practice with international approaches, which is of particular importance for companies engaged in international projects.

The third component of the methodological triad is GOST R 58771-2019 "Risk Management. Risk Assessment Technologies", which is a practical toolkit for risk assessment. Unlike the first two documents, which are conceptual in nature, this standard contains specific technologies and methods for risk analysis, algorithms for choosing optimal assessment methods depending on the type and nature of the risk, as well as criteria for the efficiently of the approaches being used. Practical mechanisms for both quantitative and qualitative assessment are particular significant allowing construction companies to obtain reliable data for management decision-making.

The interaction of the three standards creates a comprehensive regulatory platform where each document performs its own unique function: GOST R ISO 31000 sets strategic guidelines and general principles, GOST R 51897 provides terminological clarity and unity of the concepts, and GOST R 58771 offers specific tools for practical work. Such a system enables construction organizations to build effective risk management, starting from forming a common strategy and ending with implementing specific assessment procedures, while ensuring terminological consistency at all stages of the life cycle of construction objects and compliance with the international standards.

For the practical implementation of a risk-based approach, a set of methodological documents has been developed, including GOST R 51901.7-2017 "Risk Management. Guide to Implementing ISO 31000" (adaptation of ISO/TR 31004:2013) and a series of recommendations R 50.1.068-2009, P 50.1.069 2009 and R 50.1.070-2019. These standards contain detailed guidelines for implementing a risk management system considering the specifics of construction activities, providing methodological support at the stage of practical application.

In the system of regulatory regulation of risk management processes, a group of standards regulating formation and maintenance of risk registers is particularly significant which includes: GOST R 51901.21-2012 "Risk Management. Risk Register. General Provisions" establishing the basic requirements for the structure and content of the registry; GOST R 51901.22-2012 "Risk Management. Risk Register. Design Rules" defining the procedures for updating data;

GOST R 51901.23-2012 "Risk Management. Risk Register. Guidelines for Assessing the Risk of Dangerous Events for Inclusion in the Risk Register" establishing the methods of ranking and prioritization; GOST R 50.1.084-2012 "Risk Management. Risk Register. Guidelines for Creating the Risk Registry of an Organization" taking into consideration the industry-specific features of building registers. At the same time, private risk assessment methods such as GOST R are of great methodological importance. IEC 62502-2014 "Risk Management. Event Tree Analysis" describing the methodology of event tree analysis, GOST R 51901.12-2007 "Risk Management. A method for Analyzing the Types and Consequences of Failure" containing principles for assessing the reliability of technical systems, and GOST R 54141-2010 "Risk Management. Guidelines for Applying Organizational Security Measures and Risk Assessment" offering comprehensive risk analysis techniques.

The GOST R series standards are an integral component of the system. ISO 9000 "Quality Management Systems. Basic Provisions and Glossary" ensuring harmonization of a risk-based approach with the requirements of quality management. Among them are GOST R ISO 9000-2015 laying the terminological foundations; GOST R ISO 9001-2015 "Quality Management Systems. Requirements" formulating mandatory requirements; GOST R 57189-2016/ISO/TS 9002-2016 "Quality Management Systems. Guide to Applying ISO 9001:2015" containing practical recommendations for implementation; GOST R ISO 9004-2019 "Quality Management. Quality of an Organization. Guide to Achieving Sustainable Success of an Organization" describing methods for achieving sustainable results.

The presented regulatory documents form an integrated system where risk registers serve as an information foundation, assessment methods provide an analytical component, and ISO 9000 standards create an organizational and methodological context for efficient implementation of the principles of a risk-based approach. Such a comprehensive regulatory framework allows for the consistent implementation of modern risk management methods at all levels of the organizational structure of a construction company, while ensuring the necessary consistency with the international standards and industry requirements.

In industrial and construction risk management, industry standards that take into account the specifics of production activities are of particular importance. GOST R 14.09-2005 "Environmental Management. Environmental Management Risk Assessment Guide" regulates risk management processes in construction in detail, covering all stages — from design to commissioning of objects. This document contains methodological recommendations for identifying and minimizing typical construction risks, including technological, organizational and environmental aspects. Along with it, there is GOST R 12.0.010-2009 "Occupational Safety Standards System. Occupational Health and Safety Management Systems. Hazard Identification and Risk Assessment" that establishes requirements for occupational health and safety management systems, which is of particular importance for the construction industry with its high level of occupational risks.

As the construction industry is experiencing active digitalization, the role of GOST R ISO/IEC 27005-2010 "Information Technology. Methods and Tools of Ensuring Safety. Information Security Risk Management" providing a methodological framework for information security risk management. This standard is particularly significant in implementing BIM technologies and digital platforms for construction project management. GOST R IEC 62198-2015 "Project Management. Guidelines for Applying Risk Management in Design" complements the regulatory framework and offers an integrated approach to project risk management throughout the entire life cycle of a construction object.

The final and integrating element of the entire system is GOST R ISO 19011-2021 "Compliance Assessment. Guidelines for Management System Audit" that serves the crucial function of monitoring and improving risk management. The standard does not only establish uniform audit requirements, but also creates an efficient mechanism for:

– objective assessment of efficiency of the applied risk management methods;

– identifying weaknesses and potential growth opportunities;

– development and implementation of corrective measures;

– ensuring transparency and accountability of all the processes.

This integrated approach enables construction companies not only to comply with the current safety and quality requirements, but also to continuously improve their risk management systems adapting to changing conditions and new challenges facing the industry. The above systematization demonstrates a holistic methodological platform combining the universal principles of risk management with industry-specific construction activities. The multi-level structure of the

regulatory framework enables a risk-based approach to be consistently implemented from strategic planning to operational management at the level of specific construction projects.

Hence while aligning with the international practices, Russian risk management standards offer tools for working in turbulent conditions. Their rational combination allows organizations not only to minimize threats, but also to transform risks into growth opportunities ensuring long-term sustainability in a multi-crisis environment.

Risk management in construction covers a wide range of factors, including economic, technical, technological, organizational, environmental, social and legal aspects, which calls for an integrated interdisciplinary approach combining economic analysis, technical expertise, legal regulation and environmental monitoring by means of modern digital technologies and machine learning methods. Analysis of the works by leading foreign and domestic scientists, including P. Grabovoy [2], Ye. Altman [3, 4], L. Bernstein [5], F. Knight [6], Brigham [7], A. Lapidus [8], etc. demonstrate three main vectors of scientific research: study of the genesis of risk factors, development of their classification systems and search for efficient management methods. At the same time, in the field of construction projects, special attention is being paid to the issues of permanently clarifying risk classification [9], predicting potential damage, optimizing control systems and developing risk mitigation mechanisms at different stages of the life cycle of an object. However, the existing concepts are considerably different both in terms of the terminology, where there are discrepancies in the definition of the fundamental concepts of "risk" and "uncertainty", and in terms of the methodological tools ranging from traditional quantitative methods to modern neural network technologies.

In modern studies of assessment of risks of construction projects, special attention is being paid to the issue of the lack of reliable statistical data for quantitative analysis. Expert assessments are commonly used in analyzing complex technical problems, but they call for formalization and rigorous methodology in order to ensure reliable outcomes.

As noted in [10], as there are no representative samples for assessing new, unique construction technologies, expert assessments are becoming an essential tool for risk management. Expert methods are of particular significance in analyzing rare events, complex risks with lots of interrelated factors, as well as in the early stages of the life cycle of an object when statistical data have not been accumulated yet.

A major aspect while using expert assessments is meticulous selection of specialists. According to research, the optimal criteria are professional recognition in the industry (confirmed by a membership in specialized associations, scientific publications or participation in significant projects), practical work experience of no less than 5–10 years in a specific field of construction, as well as reputation among colleagues. According to common practice, the most reliable sources for seeking for experts are databases of professional associations, top construction consulting companies and academic institutions focusing on research in the field of construction technologies.

In order to minimize the subjectivity of expert assessments, modern research is making use of special techniques, including anonymous Delphi surveys allowing reaching consensus with no pressure from authorities, a system of weighting factors that takes into consideration each expert's level of competence, as well as validation procedures by comparing against the known cases and historical data. An interesting example from [21] shows that while analyzing high-rise construction risks, expert assessments indicated 37% of potential threats that were not reflected in the available statistics, but were subsequently confirmed in actual incidents. This case clearly indicates how well-organized expert analysis can compensate for the lack of statistical data, especially while working with new or unique construction technologies and objects.

According to R. Keeney et al. [11], despite the wide use of expert assessments in technical analyses, existing methods for obtaining them frequently prove to be methodologically flawed. Following a comparative analysis of two stages of a large-scale nuclear safety study — using internal experts and involving 40 external specialists from universities, consulting firms and national laboratories — the authors have been able to develop a comprehensive structured approach, including special expert training, decomposition of assessments and formalized data collection procedures, which allowed them to obtain more than 1,000 reliable probability distributions and was positively evaluated during an expert review.

According to [12], unlike traditional risk assessment tasks, expert judgments have a special role to play in designing complex systems, from identifying potential failures to developing preventive measures, and justify the need for a holistic approach integrating expert assessments at all stages of the life cycle of a system and minimizes subjective distortions.

The well-known Russian scientist A.A. Lapidus and et al. deal with the problems of a risk-based approach in [13–16] that examines the issues of effective selection of the experts and methodology of a risk-based approach in organizational and technological solutions and construction stages.

In conditions of high dynamics of construction, the technical customer cannot be in continuous control, which calls for a risk-based approach to be introduced in order to prioritize inspections. The aim of the study is to develop a methodology for identifying, analyzing and ranking construction control risks in order to optimize supervisory activities [17].

The authors of [18] developed a practical tool for selecting methods of risk analysis in construction based on the characteristics of a project confirming its efficiency during testing on actual objects by means of data visualization.

A. Chan and et al. [19] presented a systematic review of using fuzzy methods in construction management, analyzing the literature published in the top research journals over the past decade in order to identify the major areas and prospects for further research. During the review, two major areas were identified — fuzzy sets/fuzzy logic and hybrid fuzzy methods, which, in turn, are classified into four key categories: decision making, performance, evaluation/analysis, and modeling. Analyzing the current trends, the authors noted an increasing interest in integrating fuzzy methods with other computational approaches, such as neural fuzzy systems which overcome the limitations of traditional methods. On top of that, there is a tendency to expand the scope of application of fuzzy methods beyond construction management, including environmental disciplines, which emphasizes their relevance and significance in solving complex problems amidst uncertainty.

P.K. Dey in 2001 [20] developed a Decision Support System (DSS) that integrates the Analytical Hierarchy Process (AHP) method and decision trees for risk management at the initial stages of construction projects making it possible to systematize assessment of qualitative and quantitative risk factors. This approach offers a structured representation of the relations between different risks and their possible development scenarios, which is particularly significant for strategic decision-making at the early stages of a project.

In a systematic review by A. Taroun [21] in 2013 there was a comprehensive analysis of the evolution of risk management approaches in the construction industry over a fifty-year period. The study showed that despite the steady prevalence of the traditional P–I (probability–impact) risk assessment model, in recent decades there has been a clear trend towards a shift to more comprehensive and advanced methodologies. The current approaches are increasingly take into consideration the complex interdependencies between different risk categories, as well as their interaction with the parameters of a project environment. Analytical methods such as fuzzy set theory (FST) and hierarchy analysis (AHP), as well as various decision support systems (DSS), have become particularly common. However, the author emphasizes the ongoing major gap between the theoretical developments in the field of risk management and their practical application in actual construction projects. As the major areas of development A. Taroun offers modernization of the traditional P–I model by means of including additional parameters, active implementation of unified assessment metrics (particularly, the concept of "risk-value"), a more complete use of practitioners' professional experience as well as the development of new integrated solutions capable of integrating advanced theoretical developments with the actual needs of construction practice. The key takeway of the study is the need for fundamental rethinking of the existing approaches towards risk management in order to bridge the accumulated gap between theory and practice. A. Taroun's study remains a critical methodological guideline for modern research in the field of construction risk management setting pace for further development of this relevant theoretical and practical discipline.

According to recent studies, emerging risks in construction are increasingly important characterized by nonlinear relations and deviations from classical probabilistic models calling for development of new analysis methods integrated into digital platforms in order to support decision-making amidst uncertainty. It is of particular significance to study the relation of such risks with events such as "a black swan" — rare and disastrous events that are almost impossible to predict by means of classical probabilistic methods [22].

In [23], a digital platform was developed integrating BIM and automatic object monitoring (RFID) technology using radio waves. The solution indicates efficiency in managing construction processes, but it calls for additional adaptation to overcome barriers in terms of the employees' digital skills.

Implementing BIM methodologies entails significant risks that minimize their potential benefits. In [24], the major barriers to digital transformation of construction processes are systematized.

In the context of the mounting pressure of the sanctions, being mindful of political risks is becoming a crucial factor in sustainable development of the Russian construction industry. According to X. Deng and et. al [25], competent management of such risks can prove to be a competitive advantage. An analysis of international experience [26] has revealed the major sources of political risks and effective strategies for mitigating them.

An analysis of research publications on risk management in construction has displayed the following specialized areas: time and budget management [27], integration of knowledge in the field of occupational safety and information and communication technologies [28], environmental aspects of construction [29] and protection from natural disasters [30], which is indicative of the multidisciplinary nature of the latest approaches to construction risk management.

Research Results. A systematic manual bibliometric analysis complemented by an analysis using VOSviewer software [31] (Fig. 1) has indicated a complex structure of relations between the major risk management concepts in the construction industry.

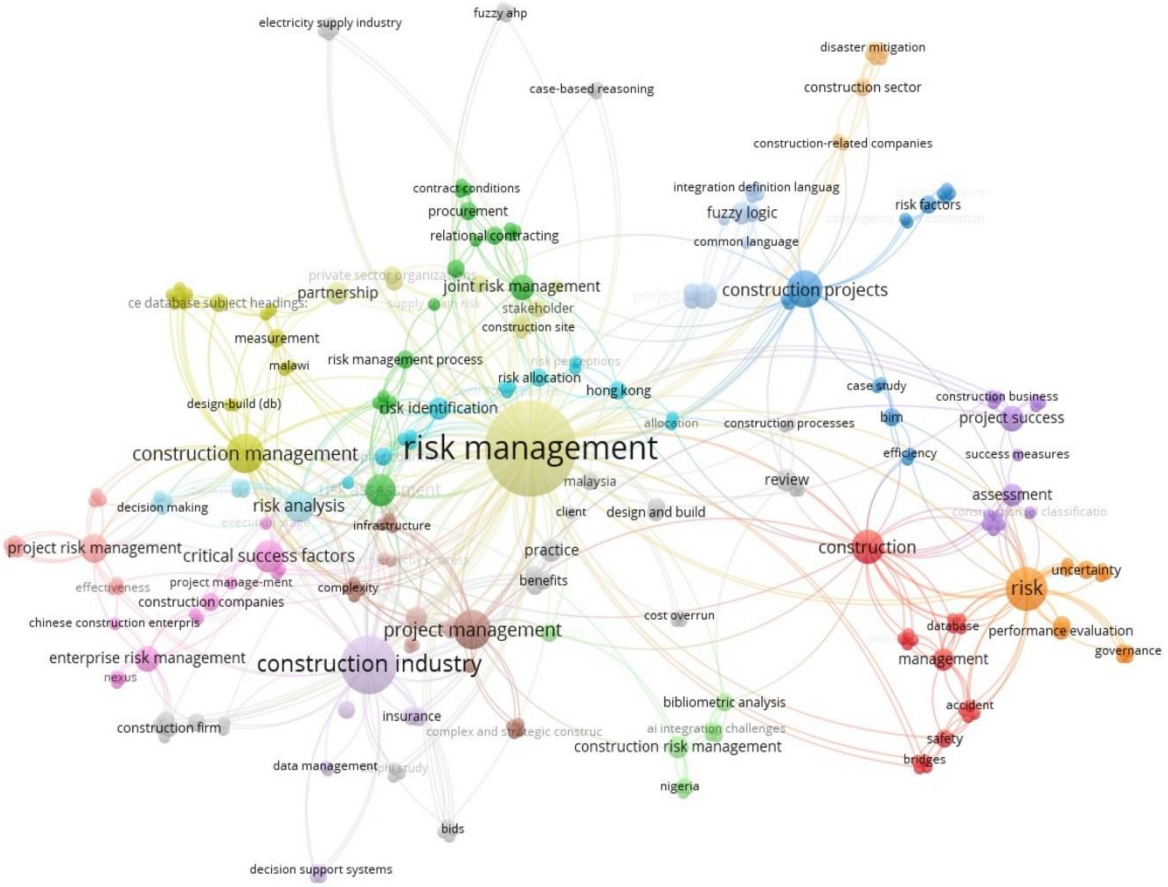

Fig. 1. Analysis of the thematic structure of research in the field of risk management of construction projects based on cluster visualization

Using the text mining feature in VOSviewer, keywords were extracted from titles, annotations, and citation contexts [32]. The central element of the network is the concept of "risk management" indicating the highest frequency of research publications and forms the semantic core of studies. Stable links diverge from this term to four main thematic clusters: "construction industry" (construction industry — the brown cluster), "construction projects" (construction projects — the blue cluster), "critical success factors" (critical success factors — the red cluster) and "risk" (risk — the orange cluster).

The blue cluster is of the greatest methodological importance combining the terms "fuzzy logic", "case-based reasoning" and "BIM-based risk management", which indicates the growing use of mathematical methods and digital technologies for analyzing uncertainties in construction projects. Special attention should be paid to the identified relation between the concepts of "project success" and "risk factors" with a connecting line thickness of 0.78, confirming the significant impact of the quality of risk management on the final results of construction activities.

The red cluster including the terms "governance", "safety" and "cost" reflects the importance of organizational aspects of risk management. It is to be noted that the concept of "decision support systems" forms a bridge between the technical (blue) and the managerial (red) clusters emphasizing the interdisciplinary nature of the recent research.

The analysis enables us to make the following conclusions:

1. The latest research on risk management in construction is characterized by a distinct multidisciplinary approach combining technical, managerial and mathematical ones.

2. There is a steady trend of risk management digitalization, which means active introduction of BIM technologies and decision support systems.

3. Fuzzy logic and case-based reasoning are becoming standard tools for assessing construction risks.

4. The efficiency of risk management directly correlates with the success of construction projects as confirmed by the strength of the identified semantic links.

The results are critical for further development of risk management methodology in construction indicating the need for integrated consideration of technological, organizational and information aspects in developing new management solutions.

Discussion and Conclusion. The bibliometric analysis has displayed the evolution of risk management in construction from traditional methods to digital solutions identifying the relationship between the standards, methods and areas of the recent research.

According to the analysis, despite a considerable progress attained in methodological support, including the international and national standards, there is still a major gap between the theoretical developments and their practical application, which is particularly osberved at the stage of investment justification of projects. The latest approaches to risk management are integrating digital technologies to a growing extent, including BIM, decision support systems, and artificial intelligence methods, which might greatly improve prediction accuracy. However, the process of digital transformation is faced with some major organizational and personnel barriers in terms of the lack of the employees' relevant competencies [24, 25].

The current situation has profound methodological roots. The expert assessment methods being widely used in the industry and absolutely practically valuable are displaying systemic limitations associated with the inevitable subjectivity of expert judgments. This is crucial in the context of the uniqueness of construction projects and the lack of relevant statistical data at the pre-project stage.

In this context, the development of hybrid approaches combining the advantages of expert assessments with the capabilities of machine learning is of particular importance. Such integrated approaches are in great demand while assessing complexly formalized risks characteristic to the initial stages of construction projects, where traditional methods often prove to be insufficiently efficient.

The current geopolitical realities, including restrictions imposed by the sanctions [26] as well as the tightening environmental regulations [30] are acting as additional uncertainty factors that are hardly taken into consideration in the traditional risk management models. These changes call for a major revision of the existing approaches to risk assessment and management in construction.

At the same time, risk management in construction calls for a balance between innovation (digitalization, artificial intelligence) and reliability (standards, expertise). Bridging the gap between theory and practice will be a major condition for sustainable development of the industry amidst turbulence.

References

1. Yu Y, Yazan DM, Junjan V, Iacob ME Circular Economy in the Construction Industry: A Review of Decision Support Tools Based on Information & Communication Technologies. *Journal of Cleaner Production.* 2022;349:131335. https://doi.org/10.1016/J.JCLEPRO.2022.131335

2. Graboviy PG, Bolotin SA, Graboviy PG *Risk Management in Real Estate.* Moscow: Prospekt; 2012. 424 p. (In Russ.)

3. Altman EI, Iwanicz-Drozdowska M, Laitinen EK, Suvas A Financial Distress Prediction in an International Context: A Review and Empirical Analysis of Altman's Z-Score Model. *Journal of International Financial Management & Accounting*. 2017;28:131–71. https://doi.org/10.1111/JIFM.12053

4. Altman EI, Hotchkiss E *Predict and Avoid Bankruptcy, Analyze and Invest in Distressed Debt Third Edition Corporate Financial Distress and Bankruptcy.* Hoboken, NJ: John Wiley & Sons Edition; 2006. 368 p.

5. Bernstein PL *Against the Gods: The Remarkable Story of Risk.* Moscow: Olimp-Bizness; 2008. 400 p.

6. Knight FH *Risk, Uncertainty and Profit.* Moscow: Delo; 2003. 355 p. (In Russ.)

7. Brickham E, Gapenski L. *Financial Management: Theory and Practice.* Saint Petersburg: School of Economics; 1997. (In Russ)

8. Lapidus A, Topchiy D, Kuzmina T, Chapidze O Influence of the Construction Risks on the Cost and Duration of a Project. *Buildings.* 2022;12:484. https://doi.org/10.3390/BUILDINGS12040484/S1

9. Siraj NB, Fayek AR Risk Identification and Common Risks in Construction: Literature Review and Content Analysis. *Journal of Construction Engineering and Management.* 2019;145:03119004. https://doi.org/10.1061/(ASCE)CO.1943-7862.0001685

10. Klinke A, Renn O A New Approach to Risk Evaluation and Management: Risk-Based, Precaution-Based, and Discourse-Based Strategies 1. *Risk Analysis*. 2002;22. https://doi.org/doi:10.1111/1539-6924.00274

11. Keeney RL, Von Winterfeldt D Eliciting Probabilities from Experts in Complex Technical Problems. *IEEE Transaction on Engineering Management.* 1991;38:191–201. https://doi.org/10.1109/17.83752

12. Bedford T, Quigley J, Walls L Expert Elicitation for Reliable System Design. *Statistical Science*. 2006;21:428–50. https://doi.org/10.1214/088342306000000510

13. *Lapidus A, Chapidze O* Analysis of Risk Factors in the Construction Industry. *Russian Engineer.* 2020;2(67):45–48. https://doi.org/10.22227/1997-0935.2021.12.1608-1619 (In Russ.)

14. Ulitko EV, Lapidus AA Stochastic Model of Technical and Economic Efficiency of the Organization of Construction of Housing Facilities. *Building Production.* 2021:2–6. https://doi.org/10.54950/26585340_2021_4_1_2 (In Russ.)

15. Lapidus AA, Chapidze OD Factors and Risks in Residential Construction. *Building Production*. 2020:2–9. https://doi.org/10.54950/26585340_2020_3_2 (In Russ.)

16. Lapidus AA, Vorobyov AS Identification and Analysis of Technical Risks in the Construction of Low-Rise Residential Buildings. *Building Production*. 2021:2–7. https://doi.org/10.54950/26585340_2021_2_2 (In Russ.)

17. Lapidus AA, Makarov AN A Risk-Based Approach to Construction Control Applied by a Developer. *Vestnik MGSU*. 2022:232–41. https://doi.org/10.22227/1997-0935.2022.2.232-241 (In Russ.)

18. De Marco A, Thaheem JM Risk Analysis in Construction Projects: a Practical Selection Methodology. *American Journal of Applied Sciences*. 2013;11(1):74–84. https://doi.org/10.3844/AJASSP.2014.74.84

19. Chan APC, Chan DWM, Yeung JFY Overview of the Application of «Fuzzy Techniques» in Construction Management Research. *Journal of Construction Engineering and Management.* 2009;135:1241–52. https://doi.org/10.1061/(ASCE)CO.1943-7862.0000099

20. Dey PK Decision Support System for Risk Management: A Case Study. *Management Decision*. 2001;39:634–49. https://doi.org/10.1108/00251740110399558/FULL/XML

21. Taroun A Towards a Better Modelling and Assessment of Construction Risk: Insights from a Literature Review. *International Journal of Project Management*. 2014;32:101–15. https://doi.org/10.1016/J.IJPROMAN.2013.03.004

22. Aven T Risk Assessment and Risk Management: Review of Recent Advances on their Foundation. *European Journal of Operation Research.* 2016;253:1–13. https://doi.org/10.1016/J.EJOR.2015.12.023

23. Li CZ, Zhong RY, Xue F, Xu G, Chen K, Huang GG et al. Integrating RFID and BIM Technologies for Mitigating Risks and Improving Schedule Performance of Prefabricated House Construction. *Journal of Cleaner Production.* 2017;165:1048–62. https://doi.org/10.1016/J.JCLEPRO.2017.07.156

24. Zhao X, Feng Y, Pienaar J, O'Brien D Modelling Paths of Risks Associated with BIM Implementation in Architectural, Engineering and Construction Projects. *Architectural Science Review.* 2017;60:472–82. https://doi.org/10.1080/00038628.2017.1373628

25. Deng X, Low SP Exploring Critical Variables That Affect Political Risk Level in International Construction Projects: Case Study from Chinese Contractors. *Journal of Professional Issues in Engineering Education and Practice.* 2013;140:04013002. https://doi.org/10.1061/(ASCE)EI.1943-5541.0000174

26. Chang T, Hwang BG, Deng X, Zhao X Identifying Political Risk Management Strategies in International Construction Projects. *Advances in Civil Engineering*. 2018;2018:1016384. https://doi.org/10.1155/2018/1016384

27. Doloi H, Sawhney A, Iyer KC, Rentala S Analysing Factors Affecting Delays in Indian Construction Projects. *International Journal of Project Management*. 2012;30:479–89. https://doi.org/10.1016/J.IJPROMAN.2011.10.004

28. Ding LY, Zhou C, Deng QX, Luo HB, Ye XW, Ni YQ et al. Real-Time Safety Early Warning System for Cross Passage Construction in Yangtze Riverbed Metro Tunnel Based on the Internet of Things. *Automation in Construction*. 2013;36:25–37. https://doi.org/10.1016/J.AUTCON.2013.08.017

29. Fang Q, Zhang D, Wong LNY Environmental Risk Management for a Cross Interchange Subway Station Construction in China. *Tunnelling and Underground Space Technology*. 2011;26:750–63. https://doi.org/10.1016/J.TUST.2011.05.003

30. Chen W, Zhang G, Jiao Y, Wang H Unascertained Measure-Set Pair Analysis Model of Collapse Risk Evaluation in Mountain Tunnels and Its Engineering Application. *KSCE Journal of Civil Engineering*. 2021;25:451–67. https://doi.org/10.1007/S12205-020-0627-8

31. Van Eck NJ, Waltman L Software Survey: VOSviewer, a Computer Program for Bibliometric Mapping. *Scientometrics*. 2010;84:523–38. https://doi.org/10.1007/S11192-009-0146-3/FIGURES/7

32. Al Qudah SMA, Fuentes-Bargues JL, Ferrer-Gisbert PS Bibliometric Analysis of the Literature on Risk Management in the Construction Sector: Exploring Current and Future Trends. *Ain Shams Engineering Journal*. 2024;15:102843. https://doi.org/10.1016/J.ASEJ.2024.102843

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