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The role of artificial intelligence in developing engineering project management

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ABSTRACT

This study aims to verify the role of artificial intelligence in developing engineering project management. It seeks to determine the feasibility of implementing artificial intelligence to increase productivity, improve safety, reduce costs, and save time within engineering projects. The focus of the study is on two approaches to project management: traditional, which does not involve extensive integration of the latest intelligent systems, and innovative, where artificial intelligence is used for automated decision-making and risk forecasting. The methodological tools include pairwise comparison methods based on the Saati scale, as well as formulas for integral assessment, which compare the total benefits and opportunities with costs and risks. The results indicate that the innovative approach with deep integration of artificial intelligence has a higher overall indicator due to better productivity, more efficient resource allocation, and a more flexible security system, despite the additional initial costs and risks of implementation. In the long term, this approach allows for significant time savings and improved economic performance, which is critically important in the context of global competition and rapid technological change. This study confirms the feasibility of using artificial intelligence and provides an analytical tool for rational decision-making between traditional and innovative approaches to engineering project management.

Contribution/Originality: The study offers valuable insights for project managers, engineers, and stakeholders by proposing a framework for effectively adopting artificial intelligence to optimize project outcomes, reduce costs, and increase efficiency. It also addresses a significant research gap in applying artificial intelligence specifically to the unique challenges of engineering project environments.

1. INTRODUCTION

1.1. The Importance of the Topic

In the modern economy, most economic tasks are solved based on specific projects, meaning goals are defined, and efforts are made to achieve them considering time, resource, and financial constraints. Project planning, combined with regulation and control processes, forms the basis of engineering project management. Global experience

indicates that engineering project management has become a standard practice in various fields [1, 2]. The activity of reproductive processes in the real sector of the economy depends on state policy in the field of macroeconomics but is also determined, to some extent, by microeconomic factors, in particular the presence of specific participants in investment activity with a certain amount of knowledge, experience, and specific tools for implementing and financing real investments, which usually take the form of engineering projects. Global transformations of the second half of the 20th and early 21st centuries have qualitatively changed the world, which, in theoretical terms, was reflected in the new global development paradigm, beginning to dominate all areas of scientific research, primarily in economics. Universal imperatives for the global success of national economies are the intellectualization of all types of social activity, combined with the ability of economic agents to constantly innovate. The effective development of national economies, industries, large corporations, and small and medium-sized businesses under modern conditions is primarily ensured by their ability to develop and implement innovative strategies. At the same time, universities play an integrative role in ensuring society's innovative development, as they concentrate intellectual capital, generate, organize, and implement ideas, develop progressive forms of educational innovation activities with direct, large-scale, and dynamic transmission of new knowledge, and accumulate and constantly update the information resource for development. The use of engineering project management principles allows for effective solutions to organizational development tasks and increases the reliability of successfully achieving set goals [3, 4]. At the same time, the success of engineering project management depends on the motivation of the organization's employees, their understanding and support of the philosophy of the engineering project approach, as well as the effectiveness of building intra-corporate communications.

Small engineering projects include scientific research and experimental design developments at industrial enterprises, including design, technological, organizational, and economic preparation of production, manufacturing of experimental industrial samples of new products, reconstruction, technical re-equipment, and modernization of production. In American practice, such engineering projects include innovations with capital costs of up to 10-15 million dollars and labor costs of up to 40-50 thousand man-hours. Such engineering projects, as a rule, are carried out by the enterprises themselves. The development period of such projects does not exceed one or two years.

Medium engineering projects include work on the design and construction of enterprises, the development and arrangement of small mineral deposits (oil, gas, coal), if their design is based on standard design solutions and construction is carried out using a complete-block method. The essence of this method is that most of the object being built is manufactured not at the construction site but at the facilities of the contractor (manufacturer of structures). Large projects are implemented under targeted national economic programs and contain many multi-projects, united by a common goal, resources used, and a single development and implementation plan-schedule. Such programs can be national, international, regional, sectoral, inter-sectoral, etc. They are formed and coordinated at the macro level, as a rule, with the participation of the state [5, 6].

The need for engineering project management, namely the need to coordinate the use of human and material resources throughout the project life cycle using modern management methods and techniques to achieve an appropriate level of income for project participants and high product quality, is associated with a significant increase in the scale and complexity of engineering projects, requirements for their implementation deadlines, and the quality of work performed. The development of project management began in the 1930s with Soviet scientists creating calendar planning methods using cycloramas. One of the first management methods was developed in the West in the 1950s through grid planning methods. In the 1980s, the first computer programs for optimizing the management process appeared. Today, project management is a globally recognized methodology for solving organizational and technical problems; it is a philosophy of project management. Market conditions are becoming more demanding, and the pace of change is increasing. Project management involves managing a team and engineering project resources using specific methods and techniques to successfully achieve the set goals. An important element is the project environment, as it is crucial to determine the environment in which the project arises, exists, and is completed. The

engineering project environment consists of factors influencing its preparation and implementation, which can be divided into internal and external factors.

1.2. Key Issues on the General Topic of the Article

At the current stage of technological development, technologies based on artificial intelligence have become widespread, fundamentally changing approaches to the organization and implementation of engineering projects. Engineering projects traditionally require the involvement of numerous specialists, careful resource planning, and clear coordination among all participants. However, due to increasing structural complexity, larger data volumes, and the need for rapid responses to market challenges, traditional methods may no longer be sufficiently flexible [7, 8]. We believe that artificial intelligence provides new opportunities for increasing the efficiency of engineering projects, as it enables the automation of routine tasks, more accurate risk prediction, and time savings. In our opinion, the integration of algorithms capable of learning from large data sets helps create conditions for increasing productivity, reducing costs, and ensuring reliable security. Therefore, it should be noted that without the implementation of innovative solutions, particularly technologies based on artificial intelligence, modern engineering projects risk losing momentum in a competitive environment and failing to meet current demands (Figure 1).

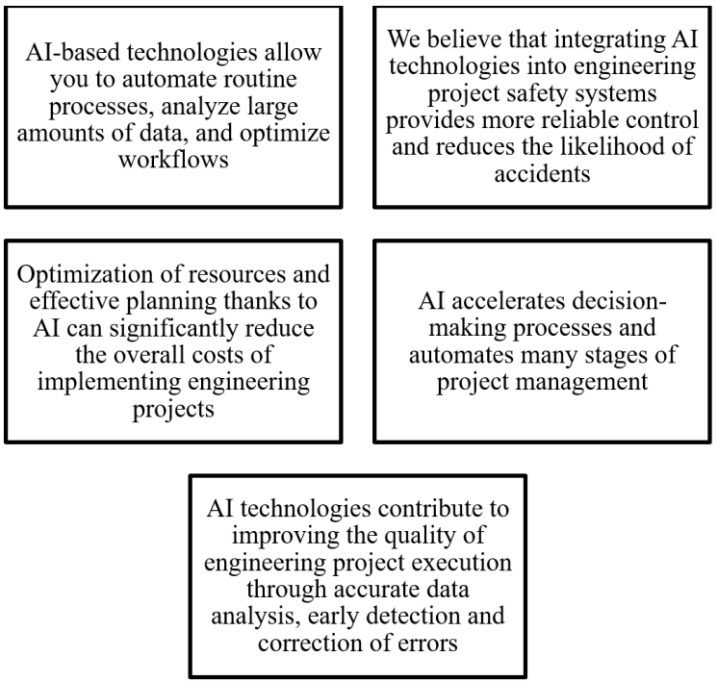

Figure 1. Key principles for updating the topic of the article.

A significant push towards digitalization occurred at the turn of the 20th and 21st centuries, when information systems became available to a wide range of industrial and service companies. If earlier project management in engineering was based on the application of traditional planning and control methodologies, then gradual informatization led to the transition to digital tools [9, 10]. We believe that it was the combination of data on resources, technical characteristics, and operational indicators with algorithmic information processing that allowed managers to gain a broader view of the status of projects in real time. In our opinion, digital platforms that integrate various processes have made it possible to optimize budget planning and task performance control, thereby ushering in the era of productivity improvement. It should be noted that the current stage of digital transformation in the field of engineering projects is reaching a new level, as technologies based on artificial intelligence can analyze large volumes of data much faster and more accurately than any previous solutions.

2. LITERATURE REVIEW

Scientists note Druzhinina, et al. [11], Ginevičius, et al. [12], Shareef and Hussein [13] and Schieg [14] that one of the most obvious positive effects of introducing AI technology into engineering projects is the automation of a significant part of routine processes. For example, algorithms can perform initial analysis of drawings, calculate optimal design parameters, or automatically generate reports on material consumption. This not only speeds up work but also helps increase the productivity of engineering personnel, as human resources are freed up for more creative and analytical tasks [10, 15]. We believe that AI-based automation leads to the fact that engineers can focus on developing and improving conceptual solutions, instead of wasting time on monotonous calculations or checks. In our opinion, this is one of the key factors that accelerates the time to market of a project and helps to achieve a competitive advantage. It should be noted that automation does not eliminate the need for human specialists: on the contrary, highly qualified people remain indispensable for making complex decisions, but their role in the project is shifting towards control, analysis, and optimization.

We agree with the opinion of scientists that engineering project management involves constant monitoring of thousands of parameters, indicators, and intermediate results. Traditional computer systems can undoubtedly process significant amounts of information, but it is artificial intelligence-based technologies that provide the opportunity to find hidden patterns and trends [16-18]. We believe that, thanks to machine learning algorithms and deep neural networks, it has become possible to predict equipment failure, forecast resource usage, and even assess the probability of schedule disruption. In our opinion, such proactivity allows project managers to adjust plans in advance and avoid financial losses that could arise from unforeseen breakdowns or delays. It should be noted that big data analysis contributes to the reduction of the overall cost of the project, as accurate forecasting of material and labor needs reduces unnecessary costs, helps to avoid excessive inventories, and reallocates resources in a timely manner (Table 1).

Table 1. Results of the literature review.

Reference	Results of the literature review
Shanmugam, et al. [19] and Borisova, et al. [3]	AI-driven methodologies to enhance project management efficiency in engineering projects. Utilization of AI technologies in staffing and recruitment processes.
Batarseh, et al. [20] and Tubishat, et al. [6]	State-of-the-art review on engineering machine learning systems from a software engineering perspective.
Sandfreni and Budiardjo [21]and Bilan et al. [8]	Roadmap analysis of AI engineering methods.
Lu, et al. [22] and Syahputri, et al. [23]	Systematic review on the necessity of software engineering methods in AI-based systems. Role of artificial neural networks and machine learning in leveraging spatial information.
Nasrallah, et al. [24] and Ahmad, et al. [25]	Innovative applications of AI and machine learning in mobile robotics. Examination of requirements, practices, and gaps in engineering human-centered AI systems.
Prayuktha, et al. [26] and Kim and Shin [1]	Development of a test for artificial intelligence ethical awareness. Examination of AI's impact on human rights, highlighting both opportunities and risks.
Williams, et al. [5] and Kwon [7]	Study on changes in ethical awareness and education in an AI-driven society. Development and evaluation of AI+ ethics curricula for middle school students.
Cebollada, et al. [27] and Guo, et al. [28]	State-of-the-art review on mobile robotics tasks using AI and visual data. Design and research of AI-based robot image perception systems.
Nasrallah, et al. [24] and Ahmad, et al. [25]	Human-centered AI prioritizes safety in system design.
Alqudah, et al. [2] and Sandfreni and Budiardjo [21]	AI engineering methods optimize resource allocation. AI in management streamlines operations, reducing costs.
Cepeda Zapata, et al. [29] and Orozco, et al. [30]	AI education tools reduce training time. Challenges in adopting AI for medical device software development.

The following table presents a comprehensive review of relevant literature on the role of artificial intelligence (AI) in developing engineering project management. We can see how much research has been conducted on the topic we chose.

3. METHODOLOGY

The essence of the research methodology involves a structure of four elements (Figure 2).

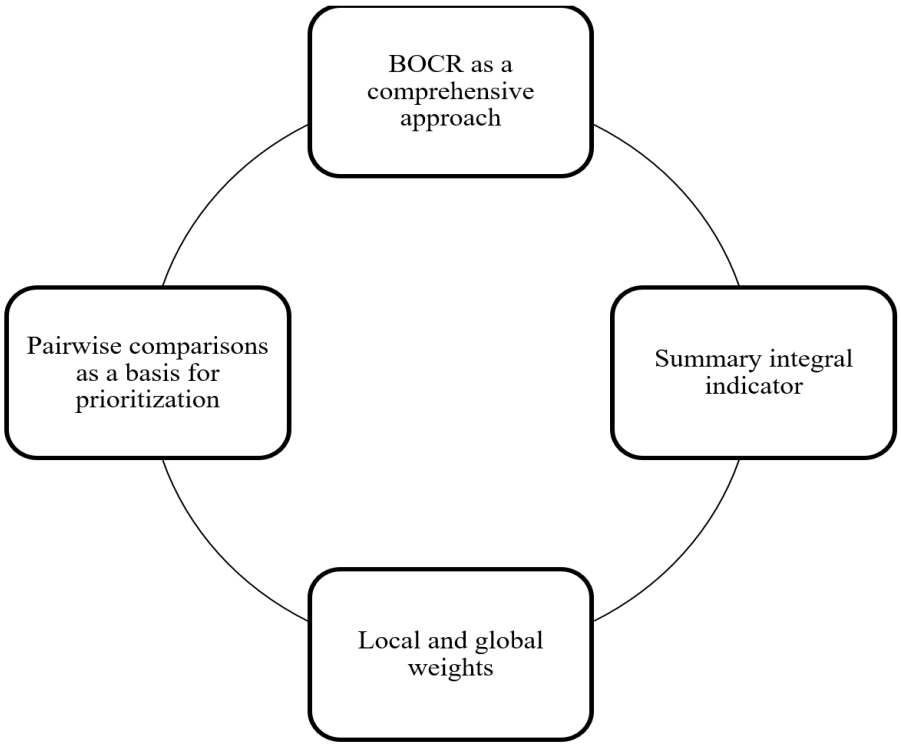

Figure 2. Research methodology structure.

The BOCR method allows you to consider a management problem from the standpoint of benefits, opportunities, costs, and risks simultaneously. This provides a more balanced view than a simple "for-against" analysis, as both positive and negative factors are taken into account. The basis of the method is pairwise comparison, which enables experts or decision-making groups to determine the relative importance of categories and criteria. The scale of 1–9 (according to Saaty) allows for flexible and subtle assessment of how much one alternative or factor outweighs another [11, 17].

The process of calculating weights includes normalization to ensure that the sum of all priorities equals 1. This is important for the correct comparison of heterogeneous criteria. After determining the weights for blocks B, O, C, R, each criterion within the block receives its own local weight. The formula for calculating the final result often uses the ratio between the sum of the weighted benefits and opportunities and the sum of the weighted costs and risks. This division approach helps to identify the extent to which the benefits and opportunities outweigh the costs and risks.

4. RESEARCH RESULTS

4.1. Results of Modeling

The BOCR method (Benefits, Opportunities, Costs, Risks) involves considering four categories when making a management decision [26, 31]. In the context of the development of engineering project management using artificial intelligence, we highlight four key factors.

1. Increased productivity (B/O) - can be considered both a direct advantage and an opportunity.

2. Safety (B/R) - can be an advantage (reducing danger using new technologies), but it also contains risks (the threat of cyberattacks).
3. Cost reduction (B/C) is an advantage (reducing operating costs) but requires initial investments (costs).
4. Time savings (B/O) is mostly an advantage; sometimes it opens up new opportunities for projects.

Approach A (Traditional) - engineering project management without the active involvement of artificial intelligence (classical methodology).

Approach B (Innovative) – project management with deep integration of artificial intelligence (risk prediction, planning automation, intelligent monitoring).

To compare the importance of the four categories (B, O, C, R), we use a scale of 1–9 (where 1 indicates equal importance and 9 indicates that one category is extremely more important than the others). Let us form the corresponding matrix (Table 2).

Table 2. Calculation matrix.

Comparison	Points	Explanation
B vs O	3	Benefits are slightly more important than opportunities.
B vs C	5	Benefits are significantly more important than costs.
B vs R	4	Benefits are significantly more important than risks.
O vs C	3	Opportunities are more important than costs.
O vs R	2	Opportunities are slightly more important than risks.
C vs R	1/9	Costs are slightly less important than risks (Risks are slightly more critical).

Next, we calculate the weights for B, O, C, and R using normalization. We obtained the following values.

w_B=0.40.

w_O=0.25.

w_C=0.20.

w_R=0.15.

Next, a pairwise comparison (or evaluation) of the criteria "Increase in productivity," "Safety," "Reduce cost," and "Save time" is carried out within each BOCR block. Thus, for the Benefits category (B): increase in productivity versus reduce cost versus save time (safety can be considered additionally if it has a positive aspect). An example of paired evaluations is presented in Table 3.

Table 3. Paired evaluations.

Comparison	Points	Explanation
Increase productivity versus reduce costs	2	Productivity is slightly more important than cost savings.
Increase productivity versus save time	3	Productivity is significantly more important than time savings.
Reduce costs versus saving time	1/2	Time savings are slightly more important than cost savings.

1. Using the pairwise comparison algorithm, we calculate the local weights of each criterion within B.
2. For the Opportunities category (O)

- We consider productivity improvement, security, and time saving as potential sources of new opportunities.

3. For the Costs category (C)

- Cost reduction can decrease overall expenses, but the initialization of artificial intelligence (training, equipment) increases costs. Security requires investments in cyber protection.

4. For the Risks category (R)

- Security is often included among risks, particularly cyber-attacks, and a risk can also be the mismatch of artificial intelligence to real needs or the human factor in interaction with new technology.

As a result, each criterion (for example, "Productivity Improvement") is assigned scores in all BOCR blocks (where relevant). The resulting local weights are multiplied by the global weight of the category (for example, w_B, w_O, etc.). For Approach A (Traditional) and Approach B (Innovative), we determine the scores for each criterion, for example:

$$Score_A(B) = 0.60, Score_A(O) = 0.50, Score_A(C) = 0.40, Score_A(R) = 0.70$$
$$Score_B(B) = 0.80, Score_B(O) = 0.85, Score_B(C) = 0.55, Score_B(R) = 0.60$$

Next, we apply the generalization formula (One of the common variants).

$$Final\ Score_i = (w_B \cdot Score_i(B) + w_O \cdot Score_i(O))/(w_C \cdot Score_i(C) + w_R \cdot Score_i(R))$$

Let's substitute conditional numbers for Approach A: Final $Score_A$=1.97.

Let's substitute conditional numbers for Approach Б: Final $Score_B$=2.66.

The higher indicator is in Approach B, which demonstrates the advantage of integrating artificial intelligence. Therefore, Approach B (Innovative) — project management with deep integration of artificial intelligence (risk prediction, planning automation, intelligent monitoring) — is the most optimal.

4.2. Interpretation of Results

A comparison of the BOCR categories revealed a higher weight for the Benefits category, while Risks received the lowest weight, but it is still significant.

Analysis of internal criteria showed that productivity improvement and time savings play a key role in decision-making.

Comparative evaluations of alternatives made it possible to measure each approach according to four blocks (B, O, C, R).

The innovative approach with artificial intelligence received a higher final score due to significant benefits and opportunities, despite certain costs and risks.

The overall conclusion is that the use of artificial intelligence in engineering project management is more appropriate since the potential benefits exceed the costs and risks.

5. DISCUSSIONS

Artificial intelligence is significantly transforming engineering project management in construction contracting companies. The implementation of AI helps to increase efficiency, reduce costs, and improve the quality of project execution. The following are the main areas where AI plays a key role:

1. Project Planning

- Time and Cost Forecasting: Using machine learning algorithms to analyze historical data and predict project duration and budget.
- Schedule Optimization: Automatically create and adjust schedules based on real-world conditions and resources.
- Critical Path Identification: Identify key tasks that affect the overall project execution time.

2. Design and Engineering Solutions

- Automated Design: Generative design to create optimal structures, taking into account given parameters.
- Structural Solution Analysis: Using AI to model and simulate loads, stability, and other engineering indicators.
- Design Personalization: Creating individual solutions according to the specific requirements of the customer.

Discussing the results of the study, several aspects were overlooked, but this has already been investigated by us. For example, the issue of interaction during engineering project management. There are already results indicating [9, 32, 33] that engineering project management requires close interaction between different departments and

specialist profiles: from designers and constructors to suppliers and installation teams. Digitalization has introduced new formats of cooperation, in particular cloud platforms, documentation sharing systems, and product lifecycle management software. We believe that, thanks to modern tools based on artificial intelligence, communication is faster, more transparent, and the level of errors caused by incorrect information exchange is significantly reduced. In our opinion, multi-user design environments with integrated artificial intelligence algorithms can simultaneously analyze changes made to drawings, calculations, and technical tasks to prevent conflicts or duplication of work. It should be noted that such synchronization not only increases productivity but also saves time, as all participants have access to up-to-date data and can respond quickly to any adjustments (Figure 3).

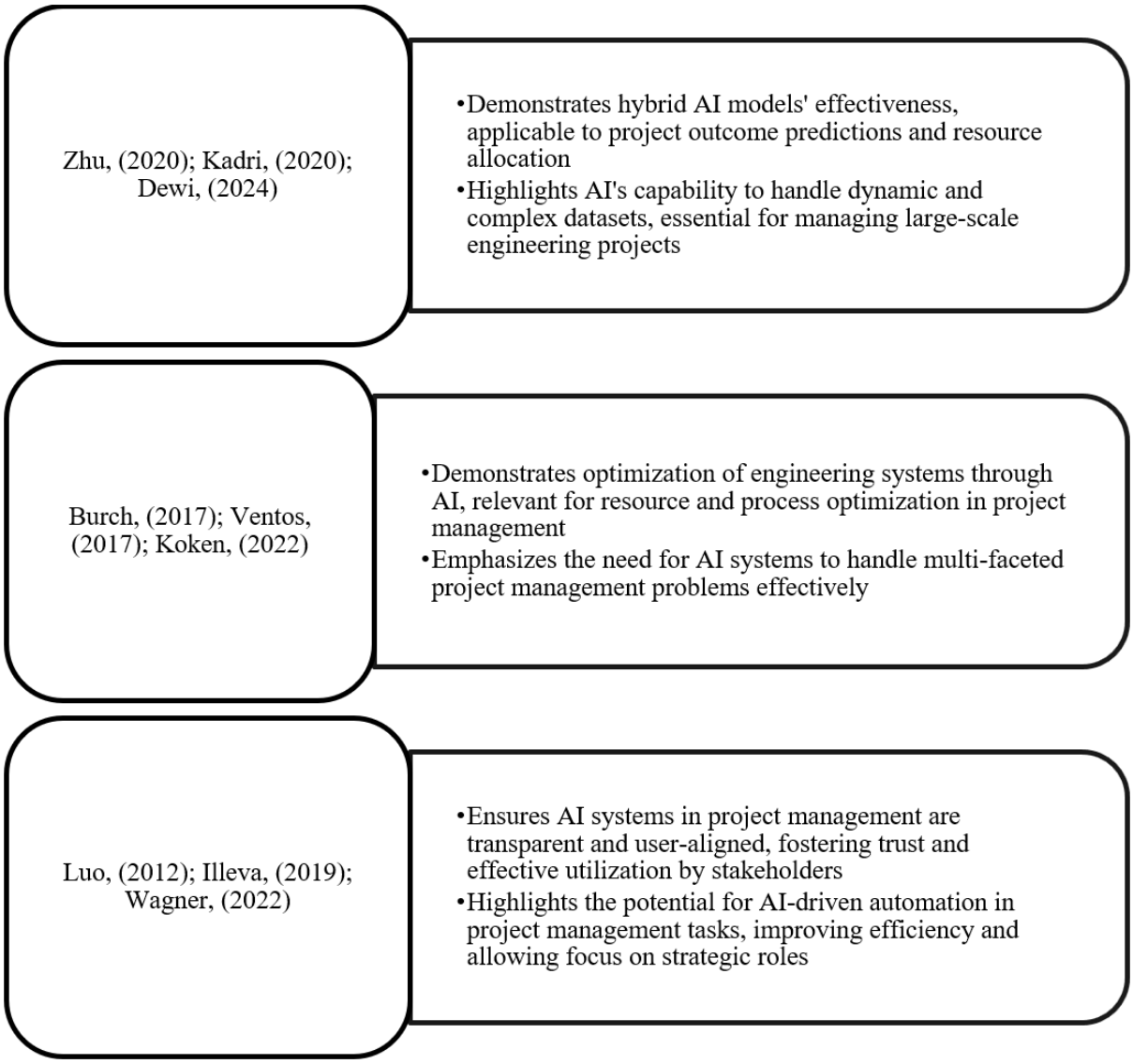

Figure 3. Discussion of the research topic by other scientific and practical works.

Source: Zhu, et al. [34]; Ksantini, et al. [35]; Devi, et al. [9]; Moravčík, et al. [36]; Ventos and Teytaud [37]; Köken [38]; Luo and Zhang [39]; Lukanova and Ilieva [40] and Habiba, et al. [41].

Engineering projects often fall under a number of state and international regulations related to safety, ecology, and standardization [42-44]. The implementation of technology based on artificial intelligence opens up new opportunities but also creates the need to comply with ethical norms and legislative requirements. We believe that the development of algorithms capable of making decisions on resource allocation or risk assessment should occur under strict control and with due regard for human rights and safe working conditions. In our opinion, the further

spread of artificial intelligence in engineering will require the establishment of clear protocols on issues of responsibility, transparency, and data protection. It should be noted that projects operating in high-risk industries such as nuclear power or civil engineering should pay special attention to the issues of algorithm validation and verification. Proper compliance with these norms will help maintain a proper level of security and prevent the emergence of crisis situations associated with the incorrect operation of intelligent systems.

6. CONCLUSIONS

An engineering project is a set of specific actions aimed at achieving defined goals within a given timeframe and with limited resources. It should be noted that a project should not be equated with the concepts of "plan" or "program." A plan is a documentation of a system of goals, tasks, and means that facilitate directed change in a situation under a specified environmental condition. A program is a planned set of economic, social, scientific, and research activities aimed at achieving general goals or implementing a particular development direction. Currently, the role of information technologies in engineering project management is increasing. Thanks to engineering project management information systems (PMIS), management efficiency improves, and the number of unfinished projects decreases because this system allows for managing all factors that significantly impact the project [23, 27]. Thanks to information technologies, communication between participants becomes more stable, making it easier to identify and respond to deviations from the plan. Documentation of all project stages is carried out efficiently, without unnecessary waste of time, and control becomes operational. There are many methods and tools for engineering project management that enable effective project implementation while considering specified limitations. These tools include work schedules (time constraints), estimates, budgets, and project financing plans (related to financial resources), project documentation (based on the technical task), control and supervision of project implementation (covering all types of constraints), and risk insurance (restrictions on various types of access). All of these require information support through the use of appropriate IT [22, 45]. The characteristics of a project, as an object of management, are limited in time, budget, and resources; variability (purposeful transfer of the system from the existing to the desired state, which is described in terms of project goals); complexity; legal and organizational support; and novelty in relation to the enterprise implementing the project. These factors emphasize the prerequisites for using engineering project management information systems. Today, effective project management is impossible without the use of modern software tools, since the size of projects, the frequency of their implementation, and the volume of information are increasing. In engineering project management, theoretical research is needed in the direction of implementing information technologies to automate the effective management of several projects and control the implementation of projects.

1. Challenges and Prospects

A) Challenges

1. High initial costs of implementing AI.
2. The need for staff training and adaptation to new technologies.
3. Ensuring data security and confidentiality.

B) Prospects

1. Further development of AI algorithms for more accurate forecasting and analysis.
2. Integration of AI with other technologies, such as the Internet of Things (IoT) and blockchain.
3. Expanding the application of AI in different stages of the construction project life cycle.

Artificial intelligence, introduced into the field of engineering project management, brings tangible economic results. Thanks to accurate risk forecasting, resource optimization, and reduction of downtime, the total costs of project implementation are significantly reduced [37, 38]. We believe that such savings of time and money allow companies to invest more in the development of innovations or the expansion of activities, which ultimately leads to increased productivity and competitiveness. In our opinion, the use of technology based on artificial intelligence can

accelerate the introduction of new products and services, increase the safety of facilities, and make engineering projects more attractive to investors. It should be noted that the prospects for the development of artificial intelligence in the field of engineering are not limited to current applications: every year, new approaches and methods of analysis, modeling, and communication emerge, gradually forming a technological breakthrough and transforming the traditional management system [24, 28]. Engineering projects often fall under a number of state and international regulations related to safety, ecology, and standardization. The implementation of technology based on artificial intelligence opens up new opportunities, but also creates the need to comply with ethical norms and legislative requirements. We believe that the development of algorithms capable of making decisions on resource allocation or risk assessment should take place under strict control and with due regard for human rights and safe working conditions. In our opinion, the further spread of artificial intelligence in engineering will require the establishment of clear protocols on issues of responsibility, transparency, and data protection. It should be noted that projects operating in high-risk industries for example, nuclear power or civil engineering should pay special attention to the issues of algorithm validation and verification. Proper compliance with these norms will allow maintaining the proper level of security and prevent the emergence of crisis situations associated with incorrect operation of intelligent systems (Figure 4).

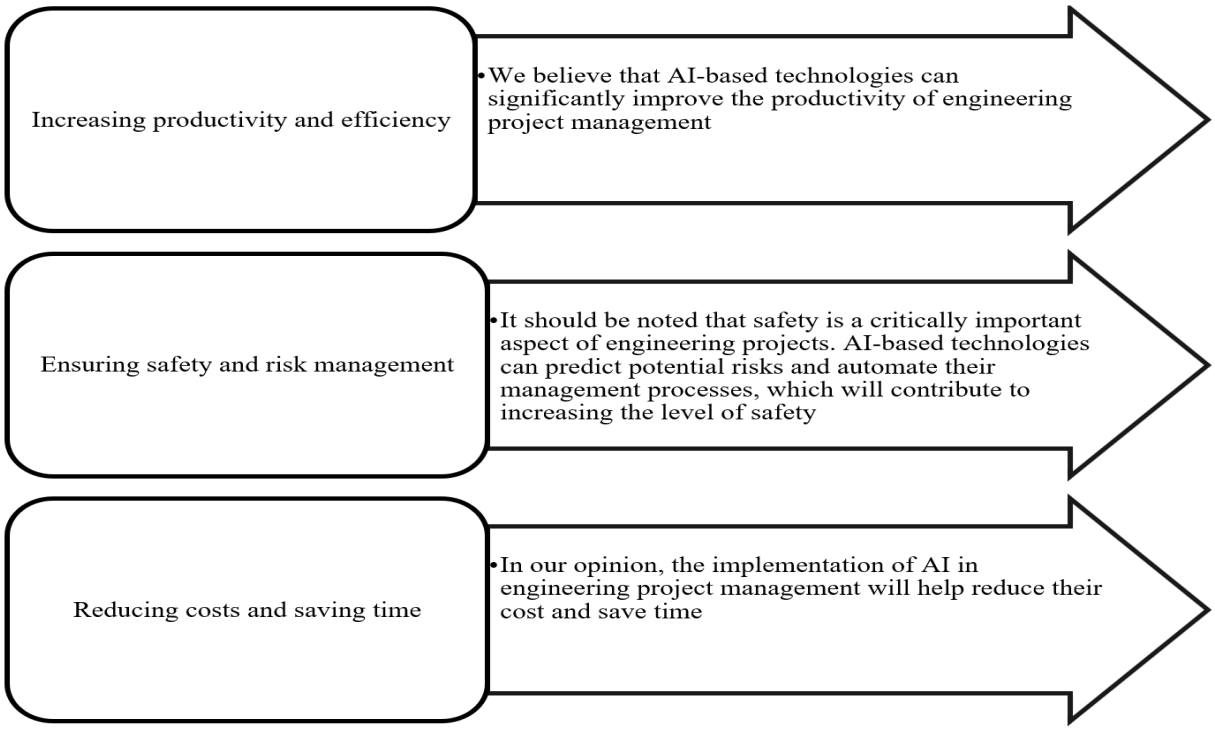

Figure 4. Further perspectives in the research on the role of artificial intelligence in the development of engineering project management.

Thus, digitalization has fundamentally changed the engineering project management system, making it more flexible, more open to innovation, and more effective in terms of resource allocation and risk minimization. We believe that, in modern conditions, without systems built on the basis of artificial intelligence, it is difficult to imagine projects that successfully withstand the pace of market changes and technological challenges. In our opinion, the intelligent integration of artificial intelligence at the planning, design, control, and analysis stages can provide increased productivity, reduced costs, and a high level of safety, which is crucial for industry and society as a whole. It should be noted that the development of machine learning, big data processing, and intelligent systems is not limited to short-term achievements: we are standing on the threshold of an era when artificial intelligence will be able to autonomously design buildings and infrastructure facilities, generate innovative solutions, and manage complex processes with minimal human intervention. That is why engineering projects of the future will become inseparable

from technologies based on artificial intelligence, and companies that begin this transition today will gain significant advantages in the areas of competitiveness, flexibility, and strategic development.

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