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Analysis of Multimodal Data in Project Management: Prospects for Using Machine Learning

P.A. Mikhnenko
Bauman State Technical University, Moscow, Russia

ABSTRACT

The modern project environment is characterized by high complexity, uncertainty, speed and depth of changes that affect the project during its life cycle. However, the project's change management processes do not take into account the need to implement analytical procedures for dynamic processing of multimodal data arrays. The **purpose** of the study is to determine the content of analytical procedures for project management and substantiate the use of machine learning technologies for their effective implementation. The **methodological basis** was project management methods, theory of change, concepts of artificial intelligence and machine learning, as well as analytical approaches. Methods of descriptive modeling of the project management process and expert assessments of the prospects for using machine learning technologies were also used in the work. The information base was made up of scientific materials on the topic under consideration, as well as expert assessments. The **results** of the study allowed us to conclude that for the analysis of multimodal data, natural language processing and intellectual decision support technologies are most in demand, which can serve as the basis for new technological solutions in the field of project management.

Keywords: project management; changes; analytical procedure; multimodal data fusion; machine learning

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INTRODUCTION

During the implementation of projects, profound changes in their internal and external factors often occur, so today one cannot rely on a predetermined project management methodology — new approaches are needed that not only involve changes, but also allow one to benefit from them [1]. Project teams are forced to identify and analyze changes, continuously evaluate processes and feedback, and maintain dialogue with stakeholders.

Project management faces challenges that arise not only from external factors, but also from errors and changes in team performance. Project managers are forced to consider feedback dynamics to effectively manage change [2], and responsibility for change management often leads to disagreements among project participants [3]. Communication plays an important role in the change management process, facilitating interaction between the project team and stakeholders [4].

In modern theory and practice of project management, more and more attention is paid to digital transformation [5]. The introduction of intelligent tools contributes to the digitalization of project management and the creation of competitive advantages for organizations [6]. The use of artificial intelligence (AI) technologies, in particular machine learning, improves the efficiency of project management, increases productivity and reduces the likelihood of errors in decision making [7].

Thus, in a complex and dynamic external environment, project change management (PCM) processes require multimodal data analysis. To solve this problem, AI technologies, in particular machine learning, can be used.

SCIENTIFIC DEVELOPMENT OF THE PROBLEM AND FORMULATION OF THE RESEARCH PROBLEM

Literature review

Since the early 1950s methodology of project management has developed primarily in line with theories and methods of operations research, management decision making, critical path [8], decision graphs [9], program evaluation and analysis [10], work scope management [11], critical chain [12] and other approaches. Today, scientific publications cover a wide range of problems connected with an increase in the efficiency of project management through the use of mathematical and instrumental methods, including those in the context of PCM.

Work [13] presents methods for selecting projects using optimization methods and mathematical programming, as well as management decision support systems to reduce the subjectivity factor. Research on PCM processes confirms the conceptual complexity of this activity, which differs from general project management practices, especially in the context of communications [14]. In this regard, it is worth noting the publication [15], in which project changes are assessed from the point of view of the manager's ability to understand the motivation of participants and take it into account when managing changes. The work [16] describes taxonomies of the causes and effects of project changes, as well as ways to use them in the change management process. The authors of the publication [17] show that the positive effect of high-quality project planning can be reduced by the negative consequences of changing its goals, therefore the success of the project is associated with effective change management.

Work [18] discusses the difference between projects as a "process of change" and projects as the "content of change": the

first approach is that organizational change management is carried out in the form of projects, and the second is that the purpose and content of change is to create project form of management of the organization's activities. The cited authors draw attention to the paradox: organizational changes aimed at introducing a project form of management are often carried out not in the form of a project.

Changes in IT projects are the main source of risk, affecting the time, cost of development and quality of software, which can be increased and successfully completed by effective PCM [19], which consists of identifying and managing multiple sources of uncertainty [20]. The most stringent requirements that drive unique project changes come from clients, end users, and government agencies [21].

Projects with unclear goals or goals that cannot be defined initially (for example, research projects) are managed using an extreme approach in which the team and client are constantly learning and making "discoveries", which allows them to adjust the project boundaries at each stage [1].

Today, an important problem in managing projects in general and their changes in particular is the processing of large volumes of multimodal information and the use of intelligent digital systems for decision making under conditions of uncertainty. Work [22] describes a method of computer support for decision-making and continuous improvement of a company's business processes in the context of PCM. The authors of the article [23] propose a fuzzy production system model for managing IT project tasks using natural language categories for decision making under conditions of uncertainty and change. The use of fuzzy logic allows project managers to work with qualitative categories of variables, which helps improve the quality of decisions.

Most current publications on the research topic focus on the development of systems and procedures using machine learning technologies. It is noteworthy that the first mention of artificial intelligence in relation to project management was in 1987 in an article [24], where it was noted that AI-based software could help managers capture their experience and share it with other project participants.

Modern authors consider the areas of application of visual analytics in flexible IT project management [25], emphasize the importance of situational advisory systems for managing complex technological investment projects [26], explore the use of fuzzy logic and neural networks in intelligent project management information systems [27], discuss the prospects for using artificial neural networks and the cognitive visualization method for managing project portfolios [28], pointing out the possibilities of using machine learning in the management of innovative projects, while noting the limited applicability of this method due to the need to access large amounts of information about previous solutions for model training [29].

Statement of the research problem

As a review of the literature shows, the most promising tasks in project management are increasing the efficiency of control systems and the use of machine learning technologies in project practice.

The object of study in this article is the project management process. The subject is the analysis of multimodal data[1] in the management of PCM.

The research hypothesis is that the analytical procedures performed in the PCM

[1] The term "multimodal" here refers to the use of multiple modes and means of presenting information within a single analytical context. Multimodal data refers to data of different natures and forms of presentation: text, sounds, images, video, data from technical devices, etc.

require solving the problem of fusion and analyzing multimodal data arrays.

Multimodal fusion is a technology for intelligently combining data of different natures, resulting in the synthesis of new information about production, management, economic and other processes and phenomena, as well as increasing the accuracy of analysis and decision-making. For example, to analyze the organizational structure, corporate culture and human resources of a company, the following can be used: texts (job descriptions, staffing, orders and instructions); images (diagrams of organizational structure and business processes, photographs of workplaces); video and audio files (interviews with employees, video minutes of meetings); numerical data (number of employees and wages); information from the media and social networks (employee profiles, comments). Multimodal fusion of such data makes it possible to more accurately and quickly identify errors in job descriptions, analyze the quality of management decisions, draw conclusions about the compliance of employee competencies with job responsibilities, predict structural changes, assess the quality of communications and corporate culture, etc.

To solve these problems, neural networks, big data and machine learning technologies are used.

In accordance with the National Strategy for the Development of Artificial Intelligence in the Russian Federation for the period up to 2030, artificial intelligence is called "a set of technological solutions that allows you to simulate human cognitive functions (including self-learning and searching for solutions without a predetermined algorithm) and when performing specific tasks to obtain results comparable to those of human intellectual activity.[2] "

Technologies based on the use of AI include: computer vision, natural language processing, speech recognition and synthesis, intelligent decision support, advanced artificial intelligence methods.[3]

In the article, machine learning is understood as a scientific and practical discipline and a set of technologies in the field of research and development of algorithms and models capable of synthesizing new knowledge and using it for decision making. The main feature of such algorithms is the ability to learn without explicitly programmed instructions. Machine learning forms the basis of many applications and technologies, such as speech recognition, computer vision, recommendation modeling, natural language processing, etc.[4]

The study is aimed at identifying the content of analytical procedures for processing multimodal data in project management, as well as assessing the potential of machine learning in project change management.

To achieve this goal the following methods were used: 1) analysis of the compliance of modern machine learning technologies with project management processes; 2) descriptive modeling of the PCM process; 3) examination of the prospects for using machine learning technologies in project management.

METHODS

AI technologies comparable to PCM tasks

The authors of the review [30] identify groups of machine learning technologies that can be used in project management (*Table 1*).

[2] National strategy for the development of artificial intelligence for the period until 2030. Decree of the President of the Russian Federation dated October 10, 2019 No. 490 "On the development of artificial intelligence in the Russian Federation". URL: http://www.kremlin.ru/acts/bank/44731

[3] "Order of the Ministry of Economic Development of the Russian Federation dated June 29, 2021 No. 392 "On approval of criteria for determining whether projects belong to projects in the field of artificial intelligence." URL: http://publication.pravo.gov.ru

[4] The article does not discuss aspects of deep learning as one of the features of modern machine learning algorithms.

Table 1

Machine learning methods in project management

Reference	Machine learning method	English term
ANN	Artificial neural networks	Artificial neural networks
HONNS	Neural networks of high order	Neural networks of high order
HNN	Hopfield neural network	Hopfield neural network
FL	Fuzzy logic	Fuzzy logic
DCM	Fuzzy cognitive maps	Fuzzy cognitive maps
GA	Genetic algorithms	Genetic algorithms
FMGA	Fast-messy genetic algorithm	Fast-messy genetic algorithm
SVM	Support vector machine	Support vector machine
BT	Bootstrap technique	Bootstrap technique
GB	Gradient Boosting	Gradient Boosting
RF	Random Forest	Random Forest
KGM	K-grouping means	K-grouping means
FNN	Neuro-fuzzy	Neuro-fuzzy
NNAB	Neural network-adding bootstrap	Neural network-adding bootstrap
NNAR	Neural networks of adaptive reinforcement	Neural networks of adaptive reinforcement
FRBS	Fuzzy Rule-Based Systems	Fuzzy Rule-Based Systems
GFS	Genetic Fuzzy Systems	Genetic Fuzzy Systems
EFSIM	Evolutionary fuzzy support vector machines inference model	Evolutionary fuzzy support vector machines inference model
EFNIM	Evolutionary fuzzy neural inference model	Evolutionary fuzzy neural inference model
EFHNN	Evolutionary diffuse hybrid neuronal network	Evolutionary diffuse hybrid neuronal network

Source: compiled by the author based on [30].

Analysis of the above methods allows us to assume that their use in PCM will create new approaches to data processing and analysis, automation of decision-making processes, forecasting and optimization. However, for the full application of these methods, more in-depth research is required, as well as their adaptation to this subject area. *Table 2* shows machine learning methods that can be used in PCM.

Today, project management uses many technological solutions based on AI. They can be divided into two classes:

1. Virtual assistants to the project manager (intelligent assistants), which help him in performing various tasks and making decisions.

2. AI technologies integrated into project management systems for process automation, data analysis, event forecasting, etc.

Table 2

Machine learning methods in project change management

Project management process	Machine learning method	Machine learning method
Planning	ANN, GA	ANN, GA
Project data analytics, Random Forest, Gradient Boosting	EFNIM, BT, RF, GB	EFNIM, BT, RF, GB
Project risk modeling, mitigation and management	GA, SVM	GA, SVM
Project mitigation and recovery plans	ANN	ANN
Project execution discovery and modeling	GA, EFNIM	GA, EFNIM
Real time predictive analytics	GA, EFHNN	GA, EFHNN
Automated report generation	GA	GA
Stakeholder Management	EFSIM	EFSIM

Source: compiled by the author.

Both classes have potential for development, however, to select and implement a solution, it is necessary to take into account the specifics of the project environment, the needs of the organization and the availability of technology (*Table 3*).

The use of AI technologies in PCM opens up opportunities for increasing the efficiency of management decisions, which requires interdisciplinary research, development of methodologies, and adaptation of AI technologies to the features of PCM.

Table 4 shows the tasks by type of AI technology, which are comparable in purpose and content with the tasks of the PCM.

DESCRIPTIVE MODEL OF THE PCM PROCESS

As already noted, PCM requires the use of multimodal analytics methods based on the extraction, fusion and analysis of data, their sentiments, multimodal deep learning, etc. Data mining is the process of identifying meaningful patterns, hidden relationships, regularities and trends in large data sets that can be used for forecasting, identifying opportunities and making decisions.

Data fusion refers to the process of combining data through matching, deduplication, missing values, aggregation and other techniques to help uncover hidden relationships, recognize trends, create new information and develop more reliable models and forecasts.

The fusion of data from different sources, known as multi-source data fusion, is the combination of information from different sources. Multi-modal data fusion is the combination of data from different modalities (text, images, sound, video, etc.) to obtain a more complete or accurate picture of events. The use of this term is justified when it is necessary to emphasize the importance of merging data of different natures and the use of processing and analysis methods to solve technical problems is required.

Sentiment Analysis is the determination of the emotional tone of a text (positive,

Table 3

AI-based technological solutions in project management

Technological solutions	Area of application in project management
PMOtto.ai	Speech and text recognition and their convertion into commands for information systems. Formation of recommendations for PM
Lili.ai	Optimizing the project budget and increasing the efficiency of the management program
Autodesk Construction IQ	Identification of work with a high probability of delays and other risks of construction projects
Bitrix24	Creating new project tasks, assigning or replacing executors, updating the status of task execution, etc.
Smart Projects	Full cycle support of PM
Aurora	Creation of optimal calendar and network schedules for large and complex projects
Liquid Planner	Automatic adjustment of expected completion dates for project tasks
Infosys Nia Contracts Analysis	Contract management, speeding up contract review and reducing contract risks
PsodaVision	Sync physical and digital Kanban boards using machine vision technology
Cloverleaf	Formation and development of a project team based on a comparison of the personal qualities and skills of the participants
PineStem	Formation of a project team based on existing experience in IT projects
TARA.ai	Formation of options for project implementation within the budget, assistance with the selection of project team members

Source: compiled by the author.

negative, neutral) using natural language processing and machine learning. Used to analyze reviews, social media, news and make informed decisions.

Multimodal Deep Learning is the use of neural networks with multiple input layers, each of which processes different types of data, which makes it possible to analyze and extract semantic relationships and dependencies between different modalities, increasing the quality and accuracy of the analysis. In general, the PCM (*Fig. 1*) includes a number of analytical procedures:

A1 — identification of current factors of the external and internal environment relevant to the goal and scope of the project;

A2 — forecasting changes in project results;

A3 — planning project changes;

A4 — distribution of responsibilities and coordination of actions of project participants during the PCM;

A5 — assessing the operational results of project changes;

A6 — assessment and interpretation of the current results of the project;

A7 — defining and updating the goals and scope of the project.

In this study, an analytical procedure is understood as a set of actions aimed at obtaining new information through the merging and intelligent processing of arrays of heterogeneous data, mainly in real time of project management.

Table 4

AI-Technologies comparable to the tasks of the PCM

AI Technology Category	Technological task	Task code
Computer vision	Identification of objects in complex environments	KZ1
	Pattern recognition based on context and signals from multiple sources (data fusion)	KZ2
	Event analysis using video analytics systems	KZ3
	Monitoring the progress of a production or organizational process using video analytics systems	KZ4
	Analysis of data received from spacecraft	KZ5
Natural Language Processing	Classification and clustering of individual statements, short and long texts	OY1
	Search and classify various types of entities in text, including names of organizations and personal names	OY2
	Extraction of facts from texts and their systematization, including automatic training of ontologies	OY3
	Searching for text documents by analogy or meaning, searching for trends and future guidelines for scientific and technological development, searching for hidden content and meanings	OY4
	Isolating the most important information from the context and synthesizing unique texts	OY5
Speech recognition and synthesis	Creating multitasking conversational assistants	RS1
	Sound and speech recognition in challenging environments	RS2
	Recognition of complex semantic structures and slang in speech for use in systems for searching for hidden content and meaning, including for improving current solutions	RS3
Decision support	Predictive and prescriptive analysis, which allows you to predict the development of the situation based on data analysis and automate decision making in real time	PR1
	Preparation of solutions based on open data sources and unstructured information, including for adaptive dynamic control of complex objects	PR2
	Intelligent simulation modeling of the behavior of market participants for goods, works and services	PR3
	Providing decision support based on long-term data, including for calculating standardization in economic sectors	PR4
	Control of equipment and production systems based on data from measurement systems and historical data on the behavior of systems in various situations	PR5
	Ultra-short-term forecasting, real-time data flow analysis and emergency forecasting	PR6
	Identifying anomalies in production processes and searching for their causes	PR7

Source: compiled by the author.

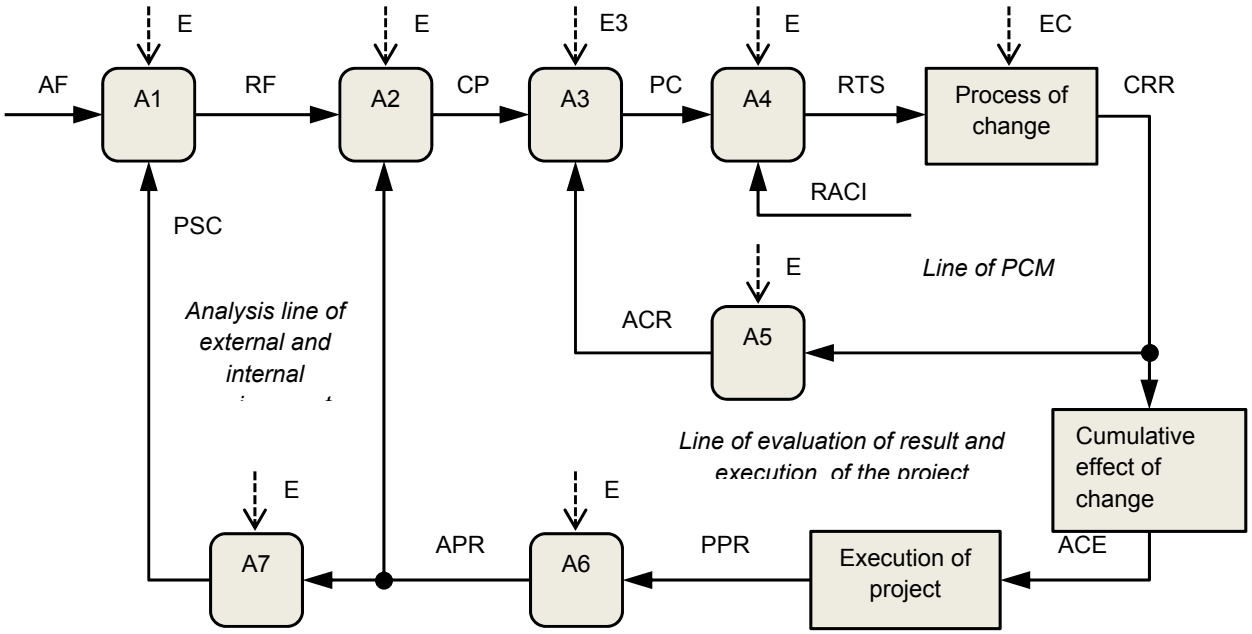

Fig 1. **Analytical procedures for project change management**

Source: compiled by the author.

Note: AF — actual factors of the external and internal environment of the project; RF — relevant factors; CPR — change prediction; PCP — project change plan; RACI matrix; RTS — revised project team structure; CRR — changes-related results; ACR — assessment of changes-related results; ACE — accumulated change effect; PPR project performance results; APR — assessment of project performance results; PSC– project scope; E 1...E 7 — errors; ECP — error of change process.

The set of analytical procedures and processes form three interconnected circuits:

1. Analysis of the external and internal environment of the project.
2. Evaluation of the results of the project.
3. Project change management.

The dynamic nature of the model indicates the continuity of the PCM process, which reflects the most general understanding of the role and content of PCM in project management — it most closely corresponds to the agile project management approaches and extreme project management approaches. At the same time, the model does not contradict the traditional approach based on the Incremental PMLC model of project life cycle management, and within their framework describes the processes of initiating and implementing change requests [1].

The project execution process is influenced by changing external and internal environmental factors (AF). Change data comes from information systems, financial and annual reports, signaling devices, business publications, media reports, social media channels, etc. [31, 32], and their probabilities and strengths of influence are characterized by linguistic and quantitative assessments.

The relevance of external and internal environmental factors (RF) is assessed by a comparison of the array of relevant factors (AF) and information about the current understanding of the goal and scope of the project (PSC). The RF and PSC arrays are represented by data of different modalities and dimensions, which suggests their multimodal fusion and synthesis of new information during the analytical procedure A1.

Forecasting changes in project results (A2) is carried out by a comparison of RF and APR

Table 5

Content of analytical procedures

Analytical procedure	Input array	Possible data source and type	Synthesized information
A1 — identification of current external and internal environmental factors relevant to the goal and scope of the project	AF — current factors of the external and internal environment of the project	Reports of analytical agencies: numerical, texts, images, graphs. Laws and orders of executive authorities. Statistical data: numerical, texts, graphs, videos. News publications and social media: texts, images, graphics, audio, video. Market and competitor analysis results: numerical, text, images, graphs, videos. Information about past projects and experience accumulated by the project team: text, communications	RF — current factors of the external and internal environment, relevant to the goals and scope of the project
	PSC — goals and scope of the project	Technical task. Charter and other project documents: numerical, texts. Interviews with stakeholders. Strategic documents of the company. Past project experience	
A2 — forecasting changes in project results	RF — current factors of the external and internal environment, relevant to the goals and scope of the project	RF — current factors of the external and internal environment, relevant to the goals and scope of the project	CPR — forecast of changes in project results
	APR — assessment of current project implementation results	Project documents: numerical, texts, graphics, communications of participants. Signals from devices and sensors, video recording	
A3 — planning project changes	CPR — forecast of changes in project results	Project documents: numerical, texts, graphics, participant communications	PCP — Dynamic Project Change Plan
	ACR — Assessing the operational results of project changes	Data from information systems: numerical, graphs. Communications of participants. Videos of change management processes	
A4 — distribution of responsibilities and coordination of actions of project participants during the PCM	PCP — Dynamic Project Change Plan	Project documents: numerical, texts, graphics, communications of participants. Project manager decisions: text, communications	RTS — updated structure of responsibility and coordination of project participants
	RACI matrix — the current structure of distribution of responsibilities of project participants	Expert assessments: numerical, text. Opinions of project participants: text, communications, audio, video. Project documents: matrix of responsibilities of project participants, data on the actual composition of the project team. Results of assessing personal competencies and psychological compatibility of project team members	

Table 5 (continued)

Analytical procedure	Input array	Possible data source and type	Synthesized information
A5 — Assessing the operational results of project changes	CRR — operational results of project changes	Project documents: numerical, texts, graphics, communications of participants. Video recordings of change management processes. Expert assessments: numerical, text. Opinions of project participants: text, communications, audio, video. Device and sensor data. Expert assessments: numerical, text	ACR — Assessing the operational results of project changes
A6 — evaluation and interpretation of current project results	PPR — current results of the project implementation	Project documents: numerical, texts, graphics, communications of participants. Video recordings of project management processes. Opinions of project participants: text, communications, audio, video. Device and sensor data. Expert assessments: numerical, text	APR — assessment of current project implementation results
A7 — defining and updating the goals and scope of the project	APR — assessment of current project implementation results	Project documents: numerical, texts, graphics, communications of participants. Opinions of project participants: text, communications, audio, video. Expert assessments: numerical, text	PSC — goals and scope of the project

Source: compiled by the author.

data sets; the second is described by linguistic and quantitative variables that characterize the fact that the next stage of the project has been completed or the product release has acquired new consumer properties. The peculiarity of the analytical procedure A2 is also due to the difference in the content and dimension of the input data arrays and the need to carry out their multimodal fusion and synthesis of new information.

The project change planning process in this study is also represented by the analytical procedure (A3), since it involves the multimodal fusion of heterogeneous CPR and ACR data sets; the second serves as an assessment of the operational results of project changes carried out in the previous cycle of changes, obtained as a result of the implementation of individual operations and activities that do not have a significant impact on the current results.

The process of distributing responsibilities and coordinating the actions of project participants during the PCM ends with the organizational and administrative procedure for making a management decision. However, the need for analysis allows us to classify it as analytical. Procedure A4 involves comparing the content of the dynamic project change plan (PCP) with the current structure of distribution of responsibilities of project participants (RACI matrix), justifying the need to involve relevant mechanisms for coordination and motivation of the latter, as well as updating the structure itself.

The analytical procedure for assessing the operational results of project changes (A5) consists of a multimodal fusion of data obtained from different sources to correctly interpret their compliance with the dynamic change plan.

Table 6

Professional status of experts

Professional status	Number, people
Project manager	6
Project team member	15
Software Developer	8
Middle manager	6
Teacher of specialized disciplines	7

Source: compiled by the author.

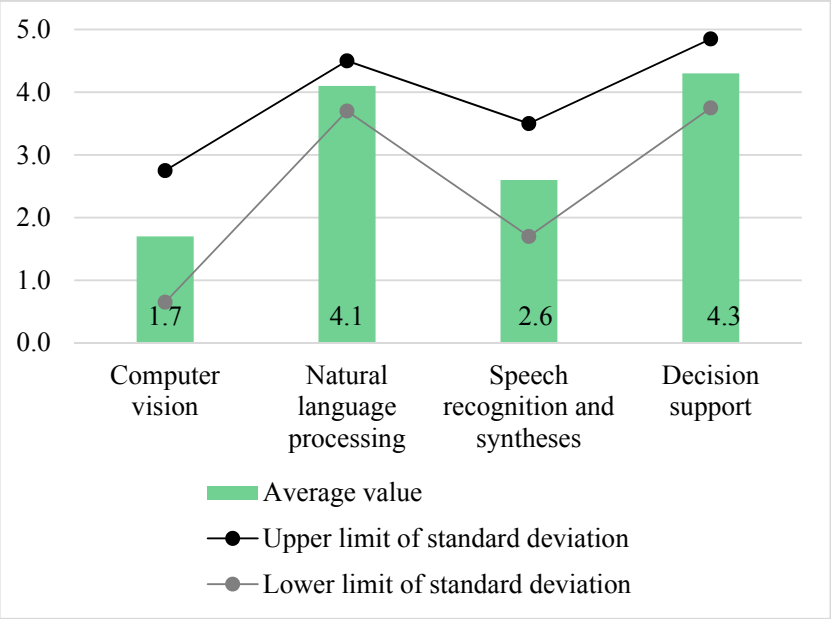

Fig. 2. **Expert assessments of the prospects for the use of AI technologies in the PCM**

Source: compiled by the author.

The cumulative effect in a broad sense refers to the accumulation and receipt of the cumulative result of all project changes (both positive and negative) made to it throughout the life cycle. The cumulation of the results of project changes has a significant impact on its key indicators: cost, schedule, quality, risks and stakeholder satisfaction.

The analytical procedure for assessing and interpreting the current results of a project (A6) is a systematic and structured study of its current state to determine how successfully it is being implemented. In general, A6 includes:

1. Assessing the current results of the project — analyzing data received from project

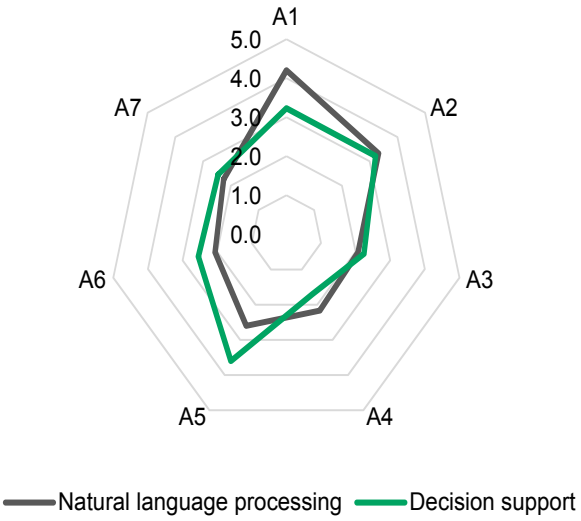

Fig. 3. **Diagrams of the distribution of average estimates of the relevance of the two categories of technologies and analytical procedures of the PCM**

Source: compiled by the author.

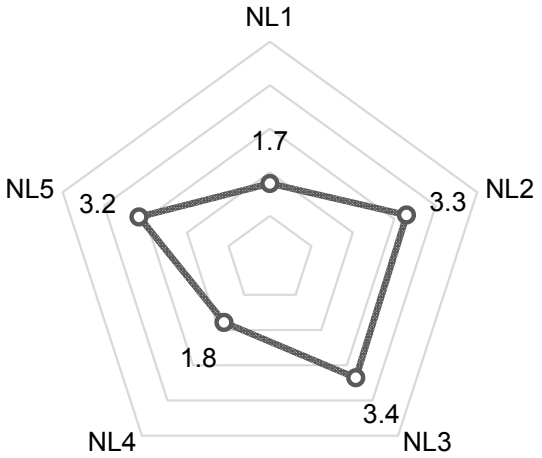

Fig. 4. **Diagram of the distribution of average estimates of the relevance of technological tasks in the category "Natural language processing"**

Source: compiled by the author.

team members and other stakeholders to determine its current status.

2. Identification of problems and risks — identifying those that may affect the implementation of the project.

3. Performance assessment — its measurement and comparison of actual indicators with planned ones.

4. Development of recommendations — identifying ways to improve productivity and generating proposals for improving project management.

5. Control and feedback — establishing mechanisms for monitoring the implementation of the project and providing feedback to improve the process of its implementation.

The importance of the analytical procedure for determining and updating the goals and scope of the project (A7) is due to the need to make adjustments to it in terms of describing the scale, boundaries, purpose, functional specification, hierarchy of work and conditions for its execution as a result of the changes made [1].

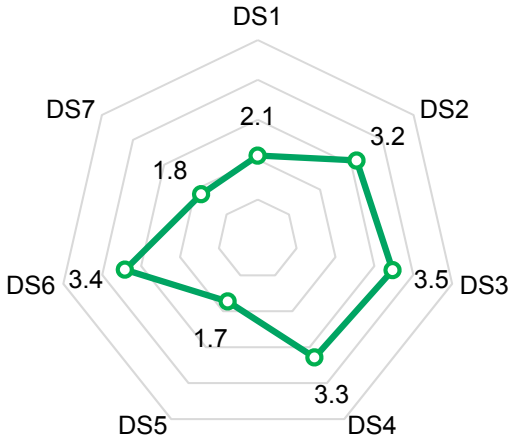

Fig. 5. **Diagram of the distribution of average estimates of the relevance of technological tasks in the category of "Decision support"**

Source: compiled by the author.

In general, the implementation of all the described analytical procedures is accompanied by errors, which are shown in *Fig. 1* are designated by variables E 1...E 7. The ECP variable indicates the presence of potential errors when implementing project changes as outlined in the dynamic plan.

Table 7

Comparison of technological tasks relevant to the problem of PCM with machine learning methods and existing technological solutions in the field of AI

Code	Technological task relevant to the problem of PCM	Machine learning method	Technological solution
NL2	Search and classification of various types of entities in texts, including names of organizations and names of personalities	ANN, GA, EFNIM, EFHNN	PMOtto.ai, PsodaVision
NL3	Extraction of facts from texts and their systematization, including automatic training of ontologies	ANN, EFNIM, BT	PMOtto.ai, TARA.ai
NL5	Isolating the most important information from the context and synthesizing unique texts	ANN, GA, EFNIM, EFHNN	PMOtto.ai, PsodaVision
DM3	Intelligent simulation modeling of the behavior of market participants for goods, works and services	ANN, GA, EFNIM, GA+SVM	PMOtto.ai, Lili.ai
DM4	Providing decision support based on long-term data, including for calculating standardization in economic sectors	ANN, GA, EFHNN, EFSIM	Lili.ai, Liquid Planner, Cloverleaf, PineStem
DM6	Ultra-short-term forecasting, real-time data flow analysis and emergency forecasting	GA, EFHNN	Autodesk Construction IQ, Битрикс24, Liquid Planner, PsodaVision, Cloverleaf

Source: compiled by the author.

Table 5 shows the content of the analytical procedures of the PCM and indicates some possible sources and types of data.

RESULTS

Evaluation of the prospects for using AI technologies in PCM

To assess the potential of use of AI technologies in PCM, two rounds of online experiment were organized, in which 42 experts[5] took part. In the first round, they were asked to evaluate the prospects for the implementation and use of AI technologies in PCM by 2030 on an individual rating scale from 0 to 5, where 0 means that there is no prospect, and 5 means that it is most likely. The professional status of the experts is given in *Table 6*.

As a result of the first round of examination, assessments were obtained that made it possible to substantiate the prospects of using AI technologies in PCM. Score charts indicate heterogeneity across technology categories (*Fig. 2*).

The assessments of the prospects for the use of natural language processing (NL) and decision support (DS) technologies in PCM turned out to be the highest and most consolidated. The maximum variability of opinions with a minimum average was identified when assessing the prospects for using computer vision (CV) technology.

Since, according to the results of the first round, the NL and DS technologies were

[5] 39 experts took part in the second round.

recognized as the most promising, in the second round the experts determined the degree of relevance of technological tasks in these categories to the analytical procedures of the PCM (*Fig. 3*).

The relationship of the diagrams indicates the possibility of a rational combination of AI technologies to improve the efficiency of analytical procedures of the PCM. The use of natural language processing technologies is most promising in relation to the analytical procedure A1, and decision support technologies are relevant to the A5 procedure.

In the "Natural Language Processing" category, the maximum scores were obtained for technological tasks NL2 — search and classification of various types of entities in the text, including names of organizations and names of personalities; NL3 — extraction of facts from texts and their systematization, including automatic learning of ontologies; NL5 — identifying the most important information from the context and synthesizing unique texts (*Fig. 4*).

In the "Decision Support" category, the most highly rated technological tasks were DS3 — intelligent simulation modeling of the behavior of participants in the market for goods, works and services; DS4 — providing decision support based on long-term data, including for calculating standardization in economic sectors; DS 6 — ultra-short-term forecasting, analysis of data flow in real time and forecasting of emergency situations (*Fig. 5*).

Comparison of technological tasks of PCM with AI technologies

Table 7 shows an option for comparing technological problems with machine learning methods and existing AI technological solutions.

It should be noted that this comparison is variable: firstly, solving technological problems is not limited to the use of these machine learning methods; secondly, some of the solutions provided go beyond the technology categories "Natural Language Processing" and "Decision Support" chosen by experts (for example, PsodaVision belongs to the "Computer Vision" category).

Nevertheless, the data in *Table 7* allow us to evaluate the directions for updating existing and developing new technological solutions to improve the efficiency of PCM processes.

DISCUSSION

An important feature of PCM analytical procedures that involve processing dynamic arrays of multimodal information is the need to merge data of different natures and dimensions, which makes it difficult to form conclusions and decisions using traditional methods and analysis tools.

A promising solution to this problem is the use of AI technologies in the field of:

Natural language processing:

- search and classification of various types of entities in texts, including names of organizations and names of personalities;
- extraction of facts from texts and their systematization, including automatic learning of ontologies;
- selection of the most important information from the context and synthesis of unique texts.

2. Decision support:

- intelligent simulation modeling of the behavior of participants in the market for goods, works and services;
- providing support for decision-making based on long-term data, including for calculating standardization in economic sectors;
- ultra-short-term forecasting, real-time data flow analysis and forecasting of emergency situations.

The use of AI in the listed areas may be most in demand, but other problems can also be solved with its participation. The comparison results make it possible to assess the directions of development of the corresponding solutions and their architectures in the interests of implementation in PCM processes. When using data sources, it is necessary to take into account industry specifics, scale and complexity of projects.

It is important to note that this study does not aim to prove the universality of AI technologies and their priority in the field of project management in relation to traditional approaches. The results obtained by the author make it possible to substantiate the possibilities of using AI in the PCM as an additional tool that expands the capabilities of the project team and increases the efficiency of its work.

The main limitations of the method include:

a) the level of detail used in the model and the composition of analytical procedures (however, the model allows for the description of other processes and analytical procedures of the PCM);

b) variability of expert assessments due to the level of competencies of the group.

The use of neural networks and deep machine learning technologies in project management in the future may lead to the formation of unique risks, the consideration of which will require the adoption of managerial, legal and economic decisions and the creation of appropriate institutions.

The most actively predicted risks these days are:

- reduction in demand for labor of analysts, experts, consultants and junior administrative and managerial personnel;
- reducing the responsibility of project team members who perceive the neural network as a "black box" that generates "correct" recommendations;
- formation by a neural network of non-optimal solutions (or optimal according to criteria that do not coincide with the project's performance indicators).

Specific risks of using AI technologies in managing projects and their changes include:

a) inaccuracy in estimating project deadlines when the neural network does not have data on all its parameters (insufficient training data on task durations under different conditions);

b) prioritization errors leading to suboptimal resource allocation (limitations of machine learning methods in understanding complex interdependencies between tasks);

c) underestimation or incorrect assessment of project risks (the inability of modern AI algorithms to simulate rare "tail" events);

d) failure to take into account the "human factor": AI algorithms are not able to take into account all the emotional aspects of the behavior of project team members (the difficulty of formalizing and taking into account emotional and behavioral factors);

e) lack of creativity: AI technologies are not able to offer innovative and creative solutions (specificity of the current level of technology development).

The most obvious economic effects can be meeting project deadlines, as well as reducing resource overruns by optimizing change management procedures.

The directions for the development of the method are a detailed description of the analytical procedures of the PCM and clarification of the requirements for the architecture and purpose of specific technological solutions in the field of AI.

The priority tasks for further research are:

- identification and systematization of data sources on factors of the internal and external environment of projects;

• formation of ontologies of features of project management situations for deep learning of neural networks;

• development of algorithmic and software for hybrid systems for multimodal fusion and processing of heterogeneous data.

Comparison of the descriptive model of the PCM process with the results of an examination of the prospects for using AI technologies in PCM allows us to develop a normative model of PCM, which is also one of the promising directions for the development of this research.

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ABOUT THE AUTHOR

Pavel A. Mikhnenko — Dr. Sci. (Econ.), Associate Professor, Professor of the Department of Business Informatics, Bauman Moscow State Technical University, Moscow, Russia
https://orcid.org/0000-0002-1766-8029
mpa69@yandex.ru

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