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Mathematical model and intelligent system for analyzing the intensity of megaproject changes: the role of temporary change management hubs

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Abstract

Megaprojects represent large-scale investment programs with complex organizational structures, uniting a multitude of stakeholders whose interactions lead to the redistribution of power and the creation of temporary management centers. In conditions of unstable and uncertain external environments, such stakeholder behavior can result in the failure to achieve the set goals of the megaproject. An important scientific task is the development of mathematical models and methods for managing changes in megaprojects caused by the integrative actions of stakeholders under complex external conditions. The present study is aimed at creating a mathematical model and developing an information system for neural network analysis of the intensity of changes in megaprojects. Megaproject management is described using a vector-matrix model of a dynamic system with feedback based on the results of changes. To identify recurring patterns of negative events, the event-oriented analysis method was used. This allows for justifying new approaches to management aimed at reducing uncertainty and enhancing the effectiveness of megaproject implementation. Based on the proposed tools, a retrospective neural network analysis of the intensity of changes in the "Nord Stream 2" megaproject was conducted. Within the study, key groups of stakeholders were identified whose interactions significantly impacted the project's implementation: Group 1 – Gazprom PJSC, European companies and the governments of Russia and Germany supporting the project; Group 2 – the governments of transit countries, the USA, environmental organizations and Baltic region countries opposing the project or expressing concern about its consequences. It was demonstrated that the integration of separate stakeholder groups contributes to the formation of temporary management centers with varying interests, leading to an increase in both positive and negative changes within the project. The outcome of the work was the development of an information system for analyzing the intensity of changes in megaprojects in the form of a prototype, which includes: a mathematical model for managing changes in megaprojects; a neural network analysis methodology based on the use of a large language model for processing textual information and generating quantitative assessments; as well as a software interface for uploading documents, automated data processing, and visualization of results. The primary neural network used was the large language model Qwen 2.5-Plus, which, while not specifically adapted for this task, had its parameters calibrated for analyzing the intensity of changes in megaprojects. The system prototype provides users with the ability to analyze stakeholder interactions, assess the intensity of changes and forecast potential risks based on historical data. A promising direction for further research involves applying the model we developed and neural network analysis methodology for comparative studies of various types of megaprojects.

Keywords: megaproject, "Nord Stream 2", stakeholders, integration activity, uncertainty, intensity of changes, temporary change management center, mathematical model, large language model, neural network analysis, information system

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Introduction

In this study, we define megaprojects as large-scale investments that require significant resource allocation and have long implementation times, with far-reaching implications for the economy, society, and environment [1]. The increasing prevalence of these projects is closely linked to the transformation of the global economic system [2]. Key stakeholders in megaprojects include government agencies, private companies, financial investors, and civil society organizations [3], whose interactions determine the outcomes of these projects. Due to their size and complexity, megaprojects not only affect the livelihoods of millions, but also generate varied and often conflicting expectations among different stakeholders [4, 5].

The key challenges of megaprojects include high costs, budget overruns and schedule delays [6], with the likelihood of cost and time overruns increasing alongside the scale of the project [7]. Frequently, mega-projects fail to achieve their expected outcomes due to uncertainty about economic benefits and complexity in stakeholder behavior [8].

In Russia, megaprojects are seen as tools for socio-economic development and temporary management hubs that help coordinate the actions of various participants [9, 10]. They are also viewed as mechanisms for promoting technological sovereignty based on the concept of technological development until 2030. However, their informational support is still fragmented, making it difficult to compare projects on a unified methodological basis [10].

A distinguishing feature of megaprojects is the ambiguity of goals and the redistribution of stakeholder influence, which leads to the formation of temporary management hubs [11, 12]. Participants interpret project goals through symbolic frameworks that shape perceptions of the project's legitimacy [5]. Reducing uncertainties can be achieved by analyzing relationships between uncertainty types, incorporating stakeholder expectations and fostering dialogue with stakeholders [13].

From an organizational design perspective, megaprojects can be characterized as complex, multilayered networks [14–16]. As adaptive systems, they demonstrate properties of self-organization and emergence, wherein stakeholders dynamically adjust their behaviors through interconnected network interactions [3]. To address tasks within constrained timeframes, various coordination mechanisms establish temporary management hubs [17, 18]. However, a cohesive and universally accepted understanding of their fundamental nature remains elusive [17].

Megaprojects are characterized by flexible boundaries that facilitate the interchangeability of internal and external components, enabling the emergence of diverse configurations throughout their lifecycle [19, 20]. The concept of "organizational capabilities" is employed to describe their organizational design, encompassing a blend of knowledge, skills, resources, and processes for effective stakeholder integration [16, 21, 22]. Informal stakeholders often leverage coordination and adaptation mechanisms, which can lead to their incorporation into temporary management hubs, thereby amplifying their influence [23]. Ultimately, the success of megaprojects hinges on the nature and quality of interactions among stakeholders [24].

The object of this research is megaprojects – large-scale investment programs aimed at addressing socio-economic development challenges which require significant resources and time. The subject is the change management processes of megaprojects, driven by the integration of stakeholders under conditions of external environmental uncertainty.

The goal of the study is to develop a mathematical model for managing changes in megaprojects and an intelligent information system for analyzing the intensity of these changes.

This research addresses a critical business problem associated with the fundamental challenges of megaproject management [6, 8]: budget overruns, delays, incomplete achievement of results and the complexity of stakeholder coordination. These issues arise from the high uncertainty of the external environment, intricate participant interactions and intersubjective factors. We characterize change management in megaprojects as a "wicked problem," defined by the absence of clear-cut solutions, dependence on context and participants and the necessity to consider multiple perspectives.

We identify several limitations in traditional methods of project change analysis. For instance, PERT/CPM fails to account for stakeholder interactions, Earned Value Management (EVM) struggles to adapt to uncertainty, and tools like IBM Rational Focal Point and SAP Portfolio and Project Management lack the capability to analyze temporary management hubs and process large volumes of data.

The main outcome of our research is a prototype of an information system. This system includes a mathematical model for change management in vector-matrix form, a methodology for neural network analysis based on the large language model Qwen 2.5-Plus (Alibaba Cloud) and a software interface for document uploads and automated data processing. The prototype enables the analysis of stakeholder interactions, assessment of the intensity of changes and forecasting of consequences based on historical data.

The research hypothesis is that the integration activity of stakeholders leads to the formation of temporary change management hubs (TCMHs), the dynamics of which determine the intensity and direction of changes in the megaproject, while the success of implementation depends on the ability of key stakeholders to establish sustainable cooperative relationships.

1. Research methods

This study employs a mixed-methods research design combining systematic literature analysis with empirical validation. Our methodological approach addresses three research gaps identified in megaproject management literature: (1) stakeholder coordination inefficiencies, (2) environmental uncertainty prediction, and (3) emergent governance structures (Temporary Collaborative Management Hubs – TCMHs).

The empirical investigation comprised three complementary phases:

First, we conducted primary data collection through semi-structured interviews with 12 senior project managers across the energy infrastructure sector, supplemented by participant observation at three international megaproject conferences (2021–2023). This qualitative approach enabled us to capture practitioner insights on stakeholder dynamics.

Second, we performed document analysis of 47 megaproject artifacts, including progress reports, meeting minutes, and stakeholder agreements. This made possible systematic examination of interaction patterns and TCMH formation processes in real-world contexts.

Third, we developed and validated a neural network analysis framework, benchmarking its performance against traditional content analysis methods using a corpus of 3 200 project documents. The comparative assessment focused on change detection sensitivity and pattern recognition accuracy.

The study progressed through two sequential research stages:

1. The developmental stage involved creating a novel mathematical model for change management, operationalized through a dedicated information system. Our vector-matrix formulation incorporates feedback loops to capture non-linear stakeholder influences.

2. The application stage featured retrospective analysis of the "Nord Stream 2" megaproject, selected as a critical case due to its complex stakeholder ecosystem and well-documented implementation challenges. We processed 1 850 project documents spanning 2018–2022 using our neural network architecture.

Key operational definitions guide our analysis:

- Megaproject stakeholders: Formal and informal actors exerting influence through direct participation or external pressure.
- Management actions: Deliberate interventions altering project trajectories.
- Integration Activity: Proactive coalition-building efforts measured through communication frequency and commitment levels.

Our findings demonstrate that effective integration requires either formal authority delegation or emergent leadership recognition. These integration processes catalyze TCMH formation, creating distinct governance nodes that significantly impact project outcomes.

1.1. Mathematical model for managing changes in a megaproject

Grounded in the methodological frameworks of control theory and organizational change theory, we propose a vector-matrix mathematical model to describe the dynamics of megaproject management. This model represents a dynamic system with negative feedback based on the results of changes (*Fig. 1*).

Changes in the external environment EXT make the vector G of project goals relevant, the comparison of which with the vector of results of the next stage R_C forms a vector of misalignment:

$$D = G - R_C + N.$$

The vector D is a vector of operational tasks for managing project changes. By the intensity of megaproject changes, we mean the extent of transformation of its actual goals and the structure of stakeholder interactions in response to changes in external environmental factors.

The intensity changes matrix $\mathbf{Q}$ $(s \times g)$ is the result of the matrix product:

$$\mathbf{Q} = \mathbf{AP},$$

where $\mathbf{A}$ is a symmetric square matrix $(s \times s)$ representing the degrees of pairwise stakeholder integration:

$$\mathbf{A} = \begin{bmatrix} a_{11} & \cdots & a_{1s} \\ \vdots & \ddots & \vdots \\ a_{s1} & \cdots & a_{ss} \end{bmatrix},$$

$\mathbf{P}$ is the matrix $(s \times g)$ representing the degrees of stakeholder impact on the achievement of the project's actual goals:

$$\mathbf{P} = \begin{bmatrix} p_{11} & \cdots & p_{1g} \\ \vdots & \ddots & \vdots \\ p_{s1} & \cdots & p_{sg} \end{bmatrix}.$$

The matrix $\mathbf{Q}$ indicates the extent to which each stakeholder, while influencing the achievement of project goals, involves other stakeholders in solving tasks.

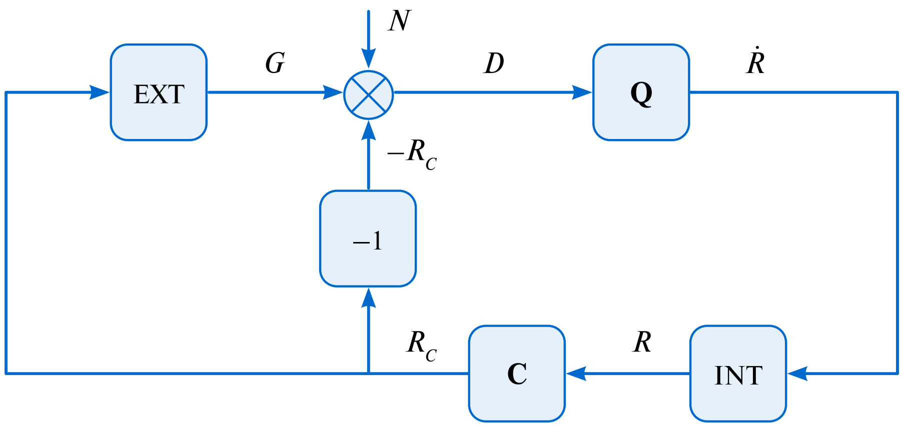


Fig. 1. Diagram of the mathematical model for managing changes in a megaproject[1].
Source: developed by the author.

[1] Here and hereafter, matrices are denoted by bold uppercase letters, with their dimensions indicated in parentheses. Vectors are denoted by italicized uppercase letters (a column vector is implied by the term "vector").

To assess the degree of stakeholder integration in the matrix **A**, we use a scale ranging from 0 to 1. Here, 0 indicates no integration, while 1 represents maximum interaction. The elements on the main diagonal reflect the degree of self-organization of each stakeholder. These values may be less than 1 if the stakeholder represents a group of participants that does not employ forms of maximum coordination.

The forms of stakeholder integration are ranked according to the degree of coordination (*Table 1*).

Analysis of the matrix **A** enables the identification of TCMHs to assess their role in achieving project goals at each stage. In the matrix **P**, the degree of a stakeholder's impact is evaluated on a scale from 0 to 1 (from complete lack of integration to maximum potential). Depending on the stakeholder's role, their potential can be directed either toward supporting or opposing the project goals.

To analyze the intensity of changes, a normalized matrix is formed:

$$\mathbf{Q}_N = \frac{100}{\sum_i \sum_j |q_{ij}|}\mathbf{Q},$$

where q_{ij} are the elements of matrix **Q**.

The normalization of matrix $\mathbf{Q}_N$ ensures that the sum of its elements equals 100%, with each element representing the percentage share of change intensity caused by the impact of a stakeholder, taking into account their interactions with other stakeholders. Multiplying the vector D on the left by matrix **Q** yields an s-dimensional vector $\dot{R}$, which describes the rate of project changes caused by the actions of stakeholders:

$$\dot{R} = \mathbf{Q}D.$$

The element INT (integral) describes the formation of an s-dimensional vector of cumulative change results for the project:

$$R(t) = \int_{t_0}^{t} \dot{R}(t)dt.$$

We introduce a control matrix **C** ($g \times s$), which allows us to compare the cumulative results of the project with its goals:

$$\mathbf{C}(t) = \mu \mathbf{Q}^{\mathrm{T}},$$

where μ is the coefficient of dynamics for eliminating misalignment, and "T" denotes transposition.

Table 1.

Forms of stakeholder integration

Degree of integration	Form of integration	Explanation
0.0–0.2	Independent management	Stakeholders work independently without coordinating decisions or interacting with each other.
0.2–0.4	Coordination (weak integration)	Stakeholders regularly exchange information and coordinate plans but remain responsible for their own tasks.
0.4–0.6	Collaboration (moderate integration)	Stakeholders collaborate to achieve project goals, hold regular meetings, and use shared tools and platforms.
0.6–0.8	Unification (high integration)	Stakeholders work closely together, form working groups and teams, make joint decisions, and develop strategies.
0.8–1.0	Consolidation (maximum integration)	All aspects of the project are fully integrated; stakeholders have a single management and control center, using unified standards and processes.

The result of left multiplication of vector R by matrix $\mathbf{C}$ is a g-dimensional vector $R_C = \mathbf{C}R$, which reflects the cumulative results aligned with the project goals. This vector impacts the project's external environment EXT and is used for comparison with the goal vector G. The matrix $\mathbf{C}$ ensures dimensional consistency among the vectors R_C, G, N and D according to the number of project goals.

An important aspect of modeling is the error vector N, caused by the uncertainty of the external environment and the inaccuracy of stakeholders' result evaluations. The model with negative feedback allows for analyzing the impact of change intensity on the alignment of results with project goals (vector D). In this study, we modeled the vector N as a set of uniformly distributed random variables centered around the variables of vector V, with variance corresponding to the expert assessment of informational uncertainty in the external environment.

The stochastic model enables the optimization of change intensity by minimizing the mathematical expectation and standard deviation of the misalignment vector D. The optimal intensity depends on the rate of changes in the external environment and the level of informational uncertainty. An increase in the pace of external environmental changes requires higher management intensity to enhance adaptability; however, a rise in uncertainty reduces the need for stakeholder integration [25]. Artificially intensifying stakeholder integration may divert the project's progress from the plan, increasing the variance of misalignments and reducing the predictability of outcomes. Nevertheless, insufficient change intensity under conditions of a dynamic external environment leads to a deviation of the project's trajectory's mathematical expectation from the planned path.

In this model, the dynamics of goal changes as a function of the dynamics of external environmental factors were modeled by the expression

$$g = \alpha_1 + \alpha_2 \sin(2\pi\alpha_3 t),$$

where g is an element of vector G;

α_1 is the offset coefficient along the ordinate axis, taking conditional values of 1, 2, 3, and 4 according to the number of goals for each stage;

α_2 is the amplitude of change;

α_3 is the frequency coefficient of changes, whose value equals the expert assessment of the degree of external environment dynamics under which the goal was set;

t is the time instant – the step for generating change results during one project stage.

The process of forming TCMHs is described as follows:

1. The process begins when the integration threshold is reached:

$$a_{ij} > \alpha,$$

where a_{ij} is an element of the integration matrix $\mathbf{A}$ – the degree of interaction between stakeholders i and j;

α is the threshold value (assumed to be 0.5).

2. A group of stakeholders is classified as a TCMHs if the following condition is met:

$$\sum_{j=1}^{s} a_{ij} > \beta \text{ for all } i \in \text{TCMHs},$$

where β is the minimum total degree of integration for TCMHs participants (assumed to be 2).

3. The impact strength of a TCMHs:

$$p_{\text{TCMHs}} = \sum\nolimits_{i,j \in \text{TCMHs}} a_{ij} \cdot p_{ij} .$$

The dynamics of TCMHs development are described by changes in key parameters over time:

1. The change in integration is described by the equation:

$$\frac{da_{ij}(t)}{dt} = f\left(a_{ij}(t), p_i(t), p_j(t), n(t)\right),$$

where f is a function that takes into account the current degree of integration, the impact potential of stakeholders, and the level of informational uncertainty.

2. Adaptation to external conditions:

$$g_i(t+1) = g_i(t) + \gamma \cdot c_{ij}(t) \cdot \left(g_i(t) - r_i(t)\right),$$

where γ is the adaptation rate coefficient.

3. The disintegration of a TCMHs occurs when $a_{ij}(t) < \delta$ or there is a significant increase in informational uncertainty $n(t) > \varepsilon$, where δ and ε are the threshold values for integration and uncertainty, respectively.

4. New TCMHs are formed if:

$$a_{ij}(t) > \alpha \text{ and } \sum_{j=1}^{s} a_{ij} > \beta.$$

Methods for analyzing the evolution of TCMHs:

1. Stakeholder clustering:

$$\text{Claster } k = \left\{ i \mid a_{ij} > \alpha_k \; \forall j \in \text{claster } k \right\}.$$

2. Identification of key parameters of the interaction network:

a) stakeholder centrality[2]:

$$c_i = \sum_{j=1}^{s} a_{ij},$$

b) clustering coefficient:

$$\phi_i = \frac{\sum_{j,k} a_{ij} \cdot a_{ik} \cdot a_{jk}}{\sum_{j,k} a_{ij} \cdot a_{ik}}.$$

3. Evaluation of the TCMHs life cycle:

a) average degree of integration:

$$\overline{a}_k(t) = \frac{1}{|k|} \sum_{i,j \in k} a_{ij}(t).$$

b) total impact:

$$p_k(t) = \sum_{i \in k} p_i(t).$$

Using the mathematical model for managing megaproject changes in the information system should address the following key questions:

1. What is the degree of stakeholder integration at each stage? What factors impact changes in the level of integration?
2. What TCMHs are formed during the project implementation? What is their role and nature of interaction?
3. What is the overall intensity of changes? How do positive and negative changes compare?
4. How do the speed of changes and informational uncertainty affect project management?
5. What is the level of misalignment between goals and results? What factors impact its dynamics?
6. How will changes in stakeholder activity impact future outcomes? What scenarios are possible?
7. What level of change intensity is optimal? How can the impact of uncertainty be minimized?
8. How does the model respond to estimation errors and changes in input data?

Thus, the mathematical model we developed differs from traditional models in the following key aspects:

1. Stakeholder consideration: The concept of “stakeholder integration activity” has been introduced, enabling the description of TCMHs formation mechanisms; the integration matrix **A** quantitatively evaluates the interaction among stakeholder groups [12, 18].
2. Detailed feedback mechanism: A negative feedback mechanism based on change results is used, providing an accurate description of goal adjustments based on actual outcomes [3, 4].
3. Intensity assessment: Intensity is determined

[2] “Stakeholder centrality” is a quantitative measure of their importance, impact, or role within the interaction network.

through the matrix product of **A** and **P**; accounting for the signs of the elements in matrix **Q** ensures a comprehensive analysis of changes [3, 21, 23].

4. Uncertainty consideration: The error vector N models informational uncertainty, allowing the system's behavior to be studied under varying levels of comple-xity [13].

5. New variable interpretation: The vector D is considered as an operational management task; the control matrix **C** aligns cumulative results with goals, which is crucial for long-term projects.

6. Megaproject specificity: Goal dynamics are modeled using a periodic function, reflecting the extended implementation timelines; integration accounts for the complex relationships among participants [19, 23].

7. Change optimization: The interrelationship between the rate of external environment change, informational uncertainty, and change intensity is considered, enabling project management adaptation to evolving conditions [25].

8. Practical applicability: The model was developed with real-world megaprojects in mind, such as the "Nord Stream 2" project.

These features ensure an accurate description of change management processes in megaprojects and the practical applicability of the model.

1.2. Intelligent information system and methodology for retrospective neural network analysis of megaproject change intensity

We conducted a retrospective neural network analysis to systematize information about the megaproject and obtain numerical estimates for calculating the intensity of changes and the role of TCMHs. By "retrospective," we refer to the analysis of a completed project, while "neural network-based" highlights our use of a large language model – an artificial transformer-type neural network built on machine learning technology.

We based our methodology on the use of the large language model Qwen 2.5-Plus (freely licensed) and implemented it through the Qwen Cloud API. We developed the software interface in Python 3.10. The main characteristics of the system are outlined in *appendix 1*, and the data processing algorithm along with the evaluation generation process is described in *appendix 2.*

The input data included documents containing information about stakeholders, goals, budgets, timelines and other aspects of the megaproject. We sourced this information from publicly available project charters, feasibility studies, scientific articles, official websites of organizations, statistical reports and industry reviews.

We formulated the user query to the model to obtain information about project stages, stakeholders, project goals, and numerical estimates of matrices and vectors. To enhance reliability, we utilized prompt engineering templates (*appendix 3*).

The adequacy of the generated content depends on the choice of a model capable of processing both textual and numerical data, the quality of the input data, the effectiveness of the query constructed using prompt engineering principles, and the analytical and statistical processing of the output data.

To improve the quality of the results, we applied a procedure of sequential statistical processing of numerical estimates. Within a single session, we processed batches of documents step by step, expanding the project's informational base. After loading each new document, we generated intermediate estimates while taking previous steps into account. This approach allowed us to bypass interface limitations related to the volume of uploaded files and improve the accuracy of estimates through sequential statistical processing, including the calculation of arithmetic means and standard deviations of the results. The number of steps was determined by the available volume of documents and the need to achieve convergence of mean values and stabilization of deviations.

2. Results of the retrospective intelligent analysis of changes in the "Nord Stream 2" megaproject

In this study, we analyzed 63 documents (2011–2024) to form the information base. These documents include media publications (RBK, TASS, Financial Times, etc.), scientific articles (eLIBRARY, Scopus, Web of Science) and data from official websites (PJSC "Gazprom", "Nord Stream 2", etc.). To refine numerical estimates, we processed the documents in eight steps by merging files.

Table 2 presents the list of key project stakeholders generated based on the results of the neural network analysis of textual data.

General goal of the "Nord Stream 2" project is to diversify gas supply routes, eliminate transit risks, meet the growing demand for energy resources in European countries and strengthen the continent's energy security. The project is exclusively commercial in nature[3].

Table 3 provides a list of the key goals of the project by stages, along with expert assessments of the dynamics of change (V) and informational uncertainty (N) in the external environment, which impact the setting of these goals.

In *appendix 4*, the stakeholder integration matrices by project stages are presented, constructed using the methodology of neural network analysis. The analysis

Table 2.

Key stakeholders of the "Nord Stream 2" project

Code	Stakeholder	Explanation
S1	PJSC Gazprom	The initiator and main beneficiary of the project, aiming to increase gas exports and reduce transit risks. The model considers the role and activities of Nord Stream 2 AG, whose sole shareholder is PJSC Gazprom.
S2	European energy ompanies	Investors and partners in the project interested in stable gas supplies and profits from participation: Uniper SE (Germany), Wintershall Dea GmbH (Germany), OMV AG (Austria), Engie SA (France), Royal Dutch Shell (Netherlands).
S3	Government of Russia	Supports the project to ensure revenues from gas exports and accelerate socio-economic development in Russia.
S4	Government of Germany	Initially supported the project as economically beneficial but later changed its position under pressure from the USA.
S5	Governments of transit countries	Opponents of the project, concerned about losing transit revenues and increased Russian impact.
S6	Government of the USA	An active opponent of the project, viewing it as a threat to Europe's energy security and a tool for Russian impact. It imposed sanctions on companies involved in the construction.
S7	Environmental organizations	Opposed the project, expressing concerns about its impact on the Baltic Sea environment.
S8	Governments of the Baltic region countries	Have mixed attitudes toward the project: some segments of the population support it due to potential economic benefits, while others are concerned about environmental risks and geopolitical consequences.
S9	Gas consumers in Europe	Interested in stable and affordable gas supplies but also concerned about the opinions of some politicians regarding possible dependence on Russia.

[3] Formulated based on: RIA "News" (official website), Lavrov stated the goal of the "Nord Stream 2" project, 28.08.2018 (updated 03.03.2020) [online resource]. URL: https://ria.ru/20180828/1527333450.html?ysclid=m3ic7exqtj972069035. Accessed on 15.11.2024.

Table 3.

Key objectives by project stages with assessments of dynamics of change (*V*) and information uncertainty (*N*) of the external environment[4]

Project stage	Key objectives	*V*	*N*	Comment
Stage 1. Concept and Planning (2011–2015)	G1.1. Planning to double gas supplies to Europe compared to the "Nord Stream" project.	0.22 (0.05)	0.31 (0.04)	Gas consumption growth in Europe was relatively predictable, though subject to fluctuations.
	G1.2. Developing the concept of reducing dependence on transit countries.	0.73 (0.06)	0.64 (0.06)	Political instability in transit countries created supply risks. High dynamics and uncertainty.
	G1.3. Developing the concept of European energy security.	0.50 (0.03)	0.44 (0.05)	The concept of European energy security was discussed, but its specific content and relation to "Nord Stream 2" were ambiguous.
	G1.4. Planning to attract European investments and partners.	0.43 (0.10)	0.53 (0.05)	European companies showed interest in the project, but the stance of individual countries and the EU as a whole remained unclear.
Stage 2. Preparation and Start of Construction (2015–2018)	G2.1. Obtaining necessary permits and approvals.	0.60 (0.09)	0.72 (0.04)	The process of obtaining permits and approvals across different jurisdictions was complex, lengthy, and highly uncertain.
	G2.2. Signing contracts with contractors and suppliers.	0.27 (0.11)	0.19 (0.12)	Signing contracts with contractors was a relatively standard procedure, albeit with certain risks.
	G2.3. Financing the project.	0.52 (0.08)	0.60 (0.07)	Attracting financing depended on political factors and sanction risks, creating uncertainty.
	G2.4. Starting the construction of the offshore pipeline section.	0.33 (0.10)	0.35 (0.07)	Technical challenges of constructing the offshore section were predictable and manageable.
Stage 3. Active Construction Phase and Increased Sanctions Pressure (2018–2021)	G3.1. Completing the pipeline despite U.S. sanctions.	0.90 (0.04)	0.81 (0.07)	U.S. sanctions pressure constantly increased, creating high dynamics and uncertainty for project completion.
	G3.2. Minimizing the impact of sanctions on project timelines and costs.	0.80 (0.11)	0.72 (0.10)	Finding ways to minimize the impact of sanctions was a challenging task with high uncertainty.
	G3.3. Certification and launch of the pipeline.	0.70 (0.05)	0.83 (0.09)	Certification and project launch faced political pressure and regulatory obstacles, creating high uncertainty.
	G3.4. Maintaining dialogue with European partners and regulators.	0.81 (0.08)	0.92 (0.07)	Political dialogue amid sanctions and changing geopolitical conditions was extremely difficult and unpredictable.
Stage 4. Project Suspension and Geopolitical Consequences (2022–present)	G4.1. Preserving the infrastructure of the "Nord Stream 2" project.	0.20 (0.09)	0.72 (0.06)	Preserving the infrastructure is technically possible, but the future of the project remains uncertain.
	G4.2. Assessing damages and exploring potential uses of the pipeline.	0.13 (0.06)	0.90 (0.05)	Potential uses of the pipeline under geopolitical instability are highly uncertain.
	G4.3. Minimizing financial losses.	0.52 (0.10)	0.81 (0.08)	Assessing and minimizing financial losses is complicated due to uncertainty about the project's future.
	G4.4. Analysis and lessons learned.	0.12 (0.07)	0.20 (0.05)	Analysis and lessons learned are internal processes, relatively independent of external factors.

[4] The mean value and the 95% confidence interval (Student's t-distribution) of the assessments from six experts are shown.

of their structure revealed two TCMHs (Temporary Change Management Hubs):

- TCMH-1: S1–S4 (Gazprom, European companies, Russia, Germany) – a stable integration during the first three stages and disintegration at the fourth stage;
- TCMH-2: S5–S8 (transit countries, the USA, environmental organizations, Baltic region countries) – an increase in integration across the stages of the project.

Examples of TCMH evolution:

TCMH-1 (S1–S4):

- Formation: High initial integration (a_{ij} > 0.8) and shared goals for project implementation.
- Development: Stable existence during the first three stages due to the support of key stakeholders.
- Dissolution: Significant decrease in integration at the fourth stage due to changes in the political climate (a_{ij} < 0.4).

TCMH-2 (S5–S8):

- Formation: Gradual increase in integration (a_{ij} > 0.4 by the third stage) in response to growing opposition to the project.
- Development: Strengthening of cooperation among project opponents (a_{ij} > 0.7 by the fourth stage).
- Current state: Maintaining a high level of integration even after the project's suspension.

The graphs of the integration dynamics of these TCMHs across the project stages form the "integration scissors" (*Fig. 2*).

Examples of the most illustrative dynamics of integration at various stages of the project include the following pairs of stakeholders (*Fig. 3*):

- S1/S4: Gazprom, Germany – a decline and a sharp drop at the final stage;
- S3/S4: Russia, Germany – a decline and a sharp drop at the final stage;
- S4/S6: Germany, USA – a decline during the first three stages and a sharp increase in "mutual understanding" at the final stage;
- S5/S6: Transit countries, USA – steady growth;
- S1/S9: Gazprom, Consumers – a noticeable decline.

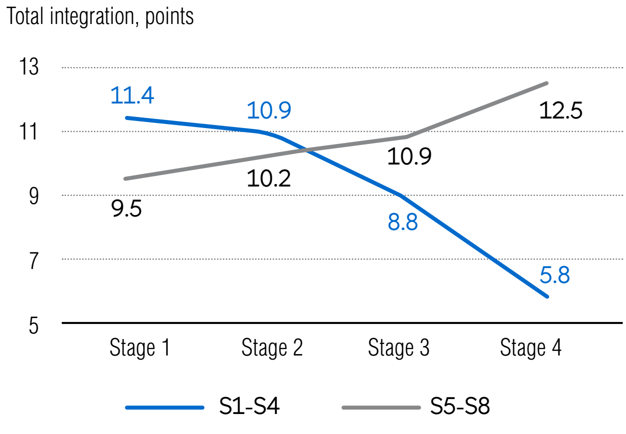


Fig. 2. "Integration scissors" of two groups of stakeholders, points.

In *appendix 5*, we present matrices explaining the stakeholders' impact on project objectives at different stages, derived using neural network analysis. Negative values denote adverse impacts that hinder the achievement of these objectives.

Figure 4 illustrates the relationship between the levels of integration, total impact, and negative influence of stakeholders across project stages (in points).

The decline in integration was accompanied by a decrease in the absolute value of stakeholders' influence. Negative influence became most pronounced during the second and third stages of the project.

Appendix 6 presents matrices of the intensity of project changes across stages. Negative values correspond to the intensity of adverse changes. *Figure 5* illustrates the total absolute values of overall change intensity (in points) and the percentage of negative change intensity across project stages.

The most intense changes occurred during the first two stages of the project, with a minimum of negative changes observed in the first stage. By the third stage, nearly 46% of all changes were directed toward opposing the project.

Figure 6 illustrates the dynamics of the generation of both total and negative changes as described by the aforementioned TCMHs.

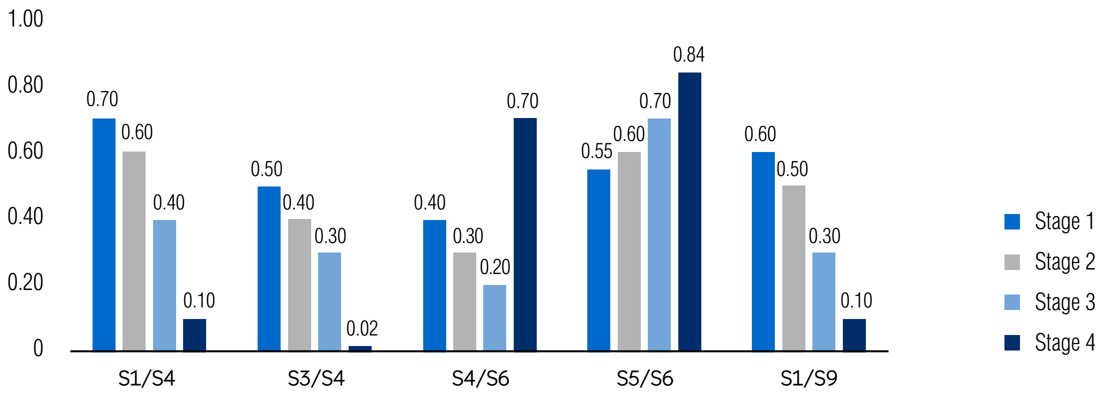


Fig. 3. Examples of integration dynamics for selected pairs of stakeholders across project stages.

At the first stage, TCMH-1 generated approximately 75% of positive changes, whereas at the third stage, TCMH-2 triggered over 46% of changes, nearly all of which were aimed at opposing the project.

Classification of TCMH types based on the analysis of the "Nord Stream 2" project data:

A. Stable TCMHs are characterized by a high degree of integration ($a_{ij} > 0.8$) and resilience to changes in the external environment (e.g., TCMH-1).

B. Dynamic TCMHs exhibit a moderate degree of integration ($0.4 < a_{ij} < 0.8$) and respond quickly to changes in external conditions (e.g., TCMH-2).

C. Transitory TCMHs emerge temporarily to address specific tasks and dissolve shortly after their completion ($a_{ij} < 0.4$) (e.g., temporary working groups for obtaining permits).

Figure 7 illustrates the graphs of the dynamics of cumulative results of R_C, constructed based on matrices **A** and **P**. The x-axis reflects the conditional duration of the stage, divided for clarity into 20 segments. The y-axes indicate the goal numbers. The direction of the shift of the R_C curve relative to the horizontal axis illustrates the degree of goal achievement and the deviation from planned values.

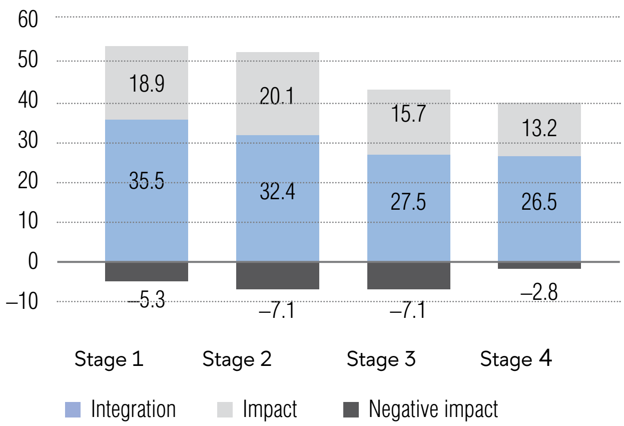


Fig. 4. Integration, total impact, and negative influence across project stages, in points.

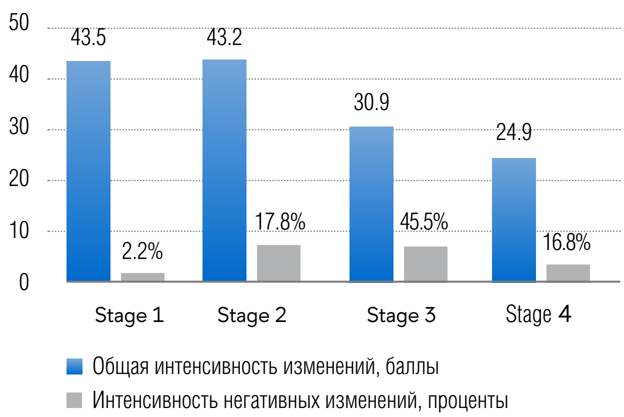


Fig. 5. Intensity of changes and percentage of negative changes.

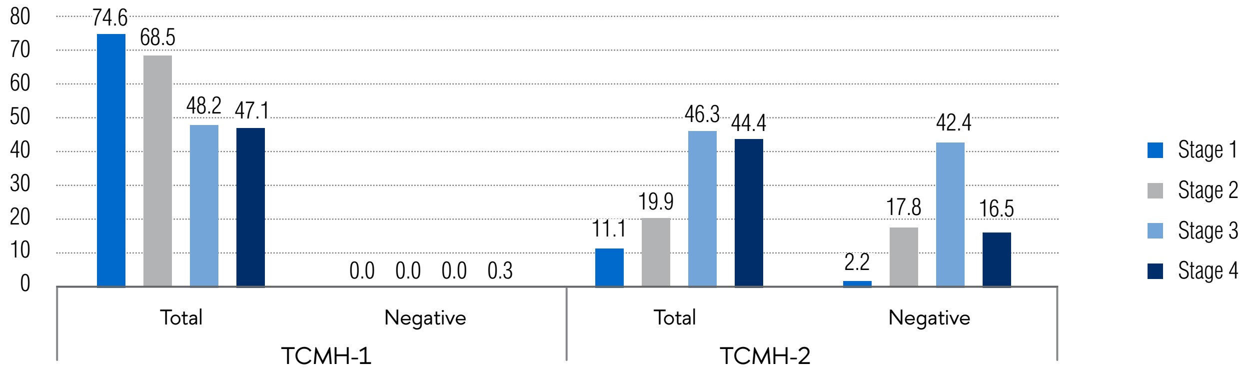


Fig. 6. Dynamics of change generation by two TCMHs, in percentages.

According to the simulation results, the goals of the first two stages (conceptual planning and construction preparation) were achieved thanks to TCMH-1, despite the negative influence of TCMH-2. Experimental modeling[5] demonstrated that an increase in the integration of TCMH-2 during the first stage would not have altered the outcomes. However, the maximum negative impact of TCMH-2 would have reduced the dynamics of goal achievement, particularly affecting the following objectives: reducing dependence on transit countries (G1.2), establishing European energy security (G1.3), concluding contracts (G2.2), securing financing (G2.3), and initiating construction (G2.4).

The implementation of the goals for the active construction phase encountered increasing sanction pressure: the construction pace (G3.1) and dialogue with regulators (G3.4) fell below the planned levels. The goals of minimizing the impact of sanctions (G3.2) and certifying the pipeline (G3.3) were not achieved due to the influence of TCMH-2. Experimental modeling demonstrated that maximum integration of TCMH-1 would have facilitated the achievement of goals G3.2 and G3.3, whereas an intensification of the negative impact from TCMH-2 would have resulted in the complete failure of the objectives for this stage.

Evaluating the geopolitical consequences requires time, with the analysis and lessons learned (G4.4) identified as the primary focus of the current stage. The simulation results indicate that achieving full integration of TCMH-1 is essential for successfully accomplishing all objectives at this stage. Furthermore, reducing the intensity of changes during the third and fourth stages diminishes the impact of informational "noise" but leads to greater deviations from the desired target outcomes [25].

3. Discussion and conclusion

The results of the retrospective analysis of changes in the "Nord Stream 2" megaproject are consistent with expert assessments and existing literature, confirming the suitability of the analytical framework we developed. These findings also support the hypothesis that the integrative activities of stakeholders lead to the formation of temporary change management hubs (TCMHs), which significantly influence the intensity of project changes. The dynamics of TCMH integration influence both the intensity and direction of changes. Additionally, the success of megaproject implementation hinges on stakeholders' ability to establish sustainable cooperative relationships.

[5] By experimental modeling, we refer to the "hypothetical" modification of certain values in matrices **A** and **P** to identify the nature of the impact that such scenarios would have on the cumulative results of R_C.

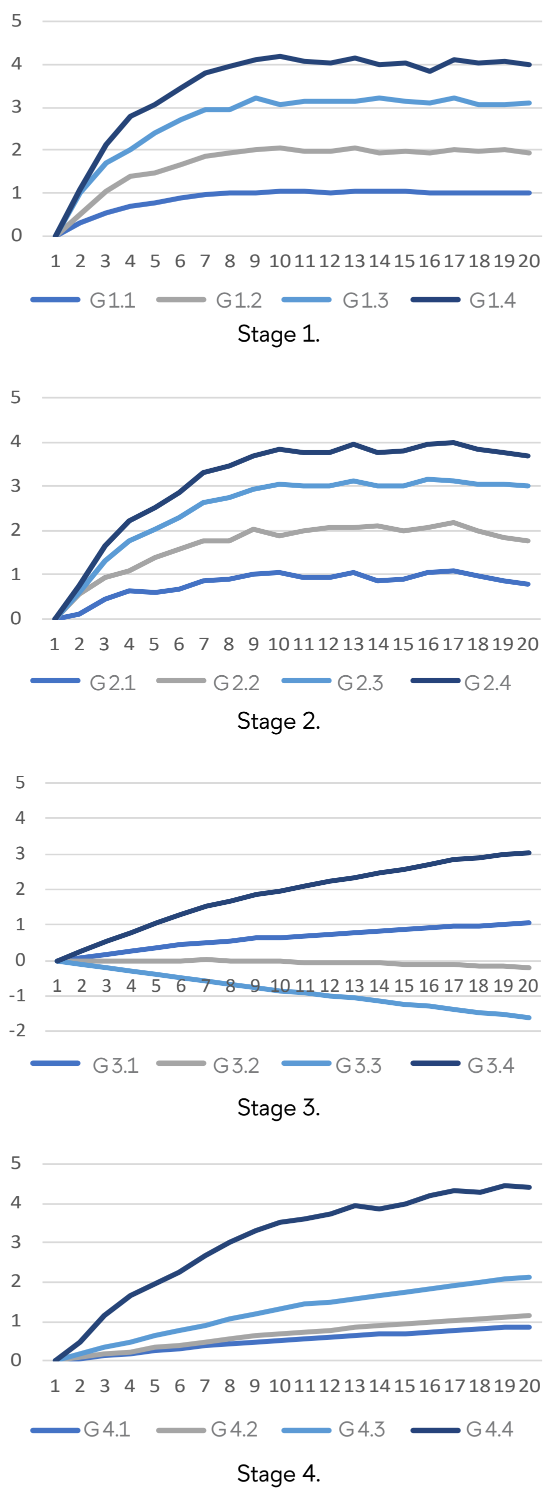


Fig. 7. Dynamics of the cumulative results of project content changes by stages.

The proposed mathematical model and neural network analysis methodology make it possible to assess change intensity and the impact of stakeholder integration activities on megaproject implementation. These insights could prove useful for project managers and participants, government authorities and researchers in the field of large-scale project management.

This research has identified the limitations of rational decision-making methods in managing megaproject changes:

1. The mathematical model demonstrates high sensitivity to input parameters, a characteristic typical of "wicked" problems.

2. The analysis of the "Nord Stream 2" megaproject revealed the significant influence of intersubjective factors on the dynamics of changes.

3. TCMHs were predominantly formed through informal mechanisms of coordination and adaptation.

The intelligent information system (IIS) we developed was compared with existing systems such as SAP Portfolio and Project Management (SAP), Total Organizational Risk Engine (TORE), Microsoft Power BI with Azure Machine Learning (MPBI) and IBM Watson Discovery (IBM). A comparative analysis was conducted by a panel of five experts using a scale ranging from 0 to 5.

The criteria for comparison included: document processing time (C1), data volume (C2), consideration of external environmental uncertainty (C3), analysis of temporary change management hubs (C4), evaluation of change intensity (C5), adaptability to new data (C6), interface usability (C7) and the need for customization (C8). *Figure 8* shows the distribution of expert scores across information systems and criteria.

According to expert evaluation, the information system we developed outperforms other systems in addressing the tasks under consideration.

The mathematical model, information system and neural network analysis methodology developed in this study can be utilized for both retrospective analysis of completed projects and management of ongoing projects. The key approaches include:

1. Forecasting and optimization of TCMHs dynamics:

Neural network data analysis predicts the formation and transformation of temporary change management hubs (TCMHs), identifying potential conflicts and suggesting preventive measures. Managing the intensity of changes through stakeholder integration levels and accounting for external factors helps avoid both excessive and insufficient activity.

2. Evaluation of management effectiveness and strategy adjustment:

Regular updates of integration and influence matrices enable the assessment of TCMH performance, adjustment of management strategies and adaptation of project goals based on current data and forecasts.

3. Scenario modeling and decision support:

Modifying parameters (integration, uncertainty, external environment) within scenario modeling assists in evaluating the consequences of decisions and selecting the optimal strategy. Integrating analytical data into decision support systems provides an objective foundation for effective management.

4. Risk monitoring and uncertainty management:

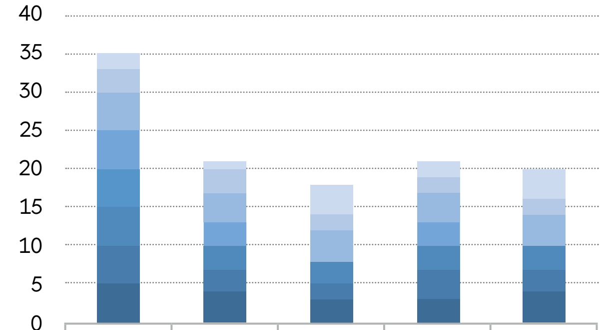
Analysis of key parameters (matrices **A**, **P**, **Q**, and vector D) allows for timely identification of risks and prevention of their escalation. Assessing informational uncertainty and external environmental impacts minimizes risks and enhances project adaptability.

5. Coalition building and stakeholder engagement:

Analyzing opportunities for enhancing integration among key participants facilitates the formation of effective coalitions and strengthens dialogue with stakeholders to achieve shared goals.

Thus, the proposed approaches provide comprehensive change management, enhancing the adaptability and effectiveness of projects.

A promising direction for further research is the application of the neural network analysis methodology to compare megaprojects of different types. This will help identify patterns in TCMH dynamics, taking into account industry-specific characteristics, scale, cultural context and other factors. Based on the data extracted by the neural network from a large document corpus, conclusions can be drawn regarding the success and failure factors of megaprojects. Additionally, universal recommendations for change management can be developed. ■



	IIS	SAP	TORE	MPBI	IBM
C8	2	1	4	2	4
C7	3	3	2	2	2
C6	5	4	4	4	4
C5	5	3	0	3	0
C4	5	0	0	0	0
C3	5	3	3	3	3
C2	5	3	2	4	3
C1	5	4	3	3	4

Fig. 8. Expert scores by criteria.

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Appendix 1.

Key characteristics of the information system developed here

Category	Characteristics
System Architecture	Client-server architecture with cloud deployment. Web interface for interaction with end users. API gateway for integration with external systems.
API Configuration	Access methods: POST requests for sending prompts and receiving responses. Request limits: restrictions on queries per second (QPS) for system stability. Input and output data format: JSON.
Document Upload and Processing Module	Support for DOCX, PDF, TXT, CSV formats. Automatic conversion to UTF-8. Extraction of key metadata.
Data Analysis Module	Implementation of the mathematical model for change management. Application of a neural network model for generating numerical assessments. Sequential statistical processing of results.

Category	Characteristics
Results Visualization Module	Plotting the dynamics of stakeholder integration. Generating reports in HTML format.
Technical Specifications	Platform: Python 3.10. Libraries: Pandas, NumPy, Matplotlib, Seaborn, NLTK. API Qwen Cloud.
Document Upload	Support for DOCX, PDF, TXT, CSV formats. Automatic conversion to UTF-8. Extraction of key metadata.
Information Processing	Text preprocessing using the NLTK library. Forming requests to the Qwen Cloud API. Statistical processing of results using Pandas.
Functional Capabilities	Uploading and analyzing documents related to megaprojects. Generating integration matrices A, influence matrices P, and intensity matrices Q. Calculating the discrepancy vector D and control matrix C. Building predictive scenarios for event development. Evaluating the effectiveness of active TCMHs.
User Interface	Ability to select the project stage for analysis. Customization of analysis parameters (threshold values for integration, influence). Exporting results to Excel for further analysis.
System Workflow	Document upload by the user via the web interface. Text preprocessing and extraction of relevant information. Forming requests to the neural network model according to the mathematical model. Statistical processing of obtained results. Visualization and presentation of results.
Security	Data protection through AES-256 encryption. Two-factor authentication for system access. Role-based access control model.
Performance	Processing a single document up to 1 MB in size within 1-2 minutes. Analyzing a batch of 10 documents within 10-15 minutes. Maximum data volume processed in one session: 100 MB.
Scalability	Capability for horizontal scaling via Docker containers. Automatic scaling of computational resources based on load.
System Requirements	Minimum: Intel Core i5 processor, 8 GB RAM, 100 GB free disk space. Recommended: Intel Core i7 processor, 16 GB RAM, 200 GB free disk space, NVIDIA RTX 2060 GPU.
System Training	Use of a pre-trained neural network model. Capability for retraining on new data. Mechanisms for parameter calibration for specific projects.
Ergonomics	Intuitive interface. Query templates for typical tasks. Ability to save analysis settings.

Appendix 2.

Algorithm for processing textual data and generating numerical scores

Category	Components
Input Data Preparation	Conversion of documents into UTF-8 format. Extraction of metadata: creation date, authors, source. Standardization of terminology using an equivalence dictionary.
Prompt Design	Creation of a structured query template based on the variables of the mathematical model. Inclusion of checkpoints to verify the logical sequence of inferences. Use of a formalized language for describing project management processes (based on PMI PMBOK Guide).
Token Limit Constraints	Splitting documents into semantic blocks, each containing up to 32,768 tokens. Sequential loading of blocks with context preservation. Application of a sliding window to ensure information overlap between blocks.
Model Parameters	Temperature: 0.1 (increased determinism of responses). Top-p: 0.9 (ensuring diversity while maintaining quality). Max output tokens: 8,192 (comprehensive analysis of context). Repetition penalty: 1.1 (reduction of repetitiveness).
Statistical Processing of Results	Iterative refinement of numerical estimates through arithmetic mean and standard deviation calculations. A minimum of 8 document-loading iterations to ensure convergence of average values.

Appendix 3.

Prompt engineering templates

Prompt template	Comment	Code example
Chain-of-Thought Prompting	Breaking down complex tasks into a sequence of logically connected steps	1. “Step 1. Identify all stakeholder pairs with high integration.” 2. “Step 2. Analyze the nature of their interaction.” 3. “Step 3. Evaluate the impact on achieving project goals.”
Few-Shot Learning	Providing several examples of correct answers before the main query	1. “Example 1. For the pair S1 and S4 at stage 1, the degree of integration is 0.70.” 2. “Example 2. For the pair S5 and S6 at stage 3, the degree of integration is 0.60.” 3. “Now perform a similar analysis for the pair S2 and S3.”
Calibration Prompting	Including control questions with known answers to adjust probabilities	1. “What is the probability that S1 will have high integration with S4? (Correct answer: 0.70)”
Decomposition Prompting	Breaking down complex tasks into subtasks	1. “First, determine the integration between all stakeholder pairs.” 2. “Then calculate the overall intensity of changes.”

Output Parsing	Structuring responses in JSON format for ease of further processing	json
		1. {
		2. “integration_scores”: {
		3. “S1_S4”: 0.70,
		4. “S5_S6”: 0.60
		5. },
		6. “change_intensity”: 0.85
		7. }

Contextual Instructions	Including the context of result usage in the query	1. “The assessment is needed to build an integration matrix for further mathematical analysis.”
Step-by-Step Feedback	Sequential refinement of model responses with feedback	1. “First version of the answer — ...” 2. “Now improve the answer, taking into account ...”

Appendix 4.

Stakeholder integration matrices by project stages

Stage 1.

	S1	S2	S3	S4	S5	S6	S7	S8	S9
S1	1.00	0.85	0.90	0.70	0.10	0.20	0.20	0.30	0.60
S2	0.85	0.70	0.38	0.60	0.18	0.30	0.33	0.40	0.70
S3	0.90	0.38	1.00	0.50	0.10	0.11	0.10	0.20	0.39
S4	0.70	0.60	0.50	0.80	0.30	0.40	0.30	0.50	0.60
S5	0.10	0.18	0.10	0.30	0.60	0.55	0.40	0.30	0.22
S6	0.20	0.30	0.11	0.40	0.55	0.80	0.60	0.40	0.36
S7	0.20	0.33	0.10	0.30	0.40	0.60	0.70	0.51	0.30
S8	0.30	0.40	0.20	0.50	0.30	0.40	0.51	0.60	0.40
S9	0.60	0.70	0.39	0.60	0.22	0.36	0.30	0.40	0.70

Stage 2.

	S1	S2	S3	S4	S5	S6	S7	S8	S9
S1	1.00	0.94	0.90	0.60	0.10	0.10	0.12	0.20	0.50
S2	0.94	0.80	0.33	0.50	0.10	0.24	0.20	0.30	0.60
S3	0.90	0.33	1.00	0.40	0.13	0.10	0.08	0.20	0.30
S4	0.60	0.50	0.40	0.75	0.20	0.30	0.20	0.40	0.50
S5	0.10	0.10	0.12	0.20	0.70	0.60	0.50	0.29	0.20
S6	0.10	0.24	0.10	0.30	0.60	0.90	0.70	0.40	0.18
S7	0.12	0.20	0.08	0.20	0.50	0.70	0.84	0.60	0.20
S8	0.20	0.30	0.20	0.40	0.29	0.40	0.60	0.70	0.32
S9	0.50	0.60	0.30	0.50	0.20	0.18	0.20	0.32	0.70

Stage 3.

	S1	S2	S3	S4	S5	S6	S7	S8	S9
S1	0.98	0.73	0.90	0.40	0.10	0.05	0.05	0.10	0.30
S2	0.73	0.60	0.20	0.30	0.08	0.10	0.10	0.20	0.40
S3	0.90	0.20	1.00	0.30	0.10	0.03	0.00	0.13	0.22
S4	0.40	0.30	0.30	0.60	0.20	0.20	0.10	0.30	0.40
S5	0.10	0.08	0.10	0.20	0.80	0.70	0.60	0.29	0.20
S6	0.05	0.10	0.03	0.20	0.70	1.00	0.80	0.40	0.20
S7	0.05	0.10	0.00	0.10	0.60	0.80	0.90	0.50	0.18
S8	0.10	0.20	0.13	0.30	0.29	0.40	0.50	0.70	0.30
S9	0.30	0.40	0.22	0.40	0.20	0.20	0.18	0.30	0.60

Этап 4.

	S1	S2	S3	S4	S5	S6	S7	S8	S9
S1	0.95	0.18	0.90	0.10	0.00	0.05	0.00	0.10	0.10
S2	0.18	0.30	0.10	0.10	0.00	0.10	0.10	0.10	0.20
S3	0.90	0.10	1.00	0.02	0.00	0.03	0.00	0.00	0.08
S4	0.10	0.10	0.02	0.70	0.30	0.70	0.40	0.40	0.44
S5	0.00	0.00	0.00	0.30	0.90	0.84	0.72	0.40	0.30
S6	0.05	0.10	0.04	0.70	0.84	1.00	0.70	0.52	0.40
S7	0.00	0.10	0.00	0.40	0.72	0.70	0.80	0.60	0.30
S8	0.10	0.10	0.00	0.40	0.40	0.52	0.60	0.80	0.40
S9	0.10	0.20	0.08	0.44	0.30	0.40	0.30	0.40	0.70

Appendix 5.

Matrices of the stakeholders' impact on project objectives by project stages

Stage 1.

	G1.1	G1.2	G1.3	G1.4
S1	1.00	0.80	0.88	0.80
S2	0.70	0.40	0.50	0.90
S3	0.90	0.72	0.80	0.50
S4	0.60	0.30	0.40	0.70
S5	-0.72	-0.90	-0.48	-0.40
S6	-0.40	-0.30	-0.40	-0.63
S7	-0.29	-0.22	-0.30	-0.30
S8	0.20	0.10	0.23	0.30
S9	0.50	0.28	0.40	0.60

Stage 2.

	G2.1	G2.2	G2.3	G2.4
S1	0.90	0.92	0.80	0.90
S2	0.68	0.80	0.92	0.70
S3	0.80	0.60	0.70	0.60
S4	0.48	0.40	0.27	0.40
S5	-0.80	-0.62	-0.50	-0.68
S6	-0.63	-0.70	-0.80	-0.60
S7	-0.50	-0.40	-0.30	-0.54
S8	0.20	0.28	0.20	0.18
S9	0.30	0.40	0.27	0.30

Stage 3.

	G1.1	G1.2	G1.3	G1.4
S1	0.98	0.59	0.40	0.50
S2	0.60	0.40	0.26	0.40
S3	0.82	0.53	0.30	0.20
S4	0.54	0.20	0.40	0.60
S5	-0.50	-0.72	-0.80	-0.54
S6	-0.58	-0.83	-0.90	-0.40
S7	-0.30	-0.37	-0.50	-0.32
S8	0.10	0.08	0.20	0.30
S9	0.18	0.20	0.30	0.40

Stage 4.

	G4.1	G4.2	G4.3	G4.4
S1	0.50	0.42	0.72	0.30
S2	0.20	0.30	0.58	0.40
S3	0.60	0.50	0.82	0.20
S4	0.10	0.20	0.30	0.60
S5	-0.20	-0.33	-0.40	0.11
S6	-0.30	-0.40	-0.54	0.70
S7	-0.10	-0.20	-0.30	0.42
S8	0.08	0.20	0.18	0.50
S9	0.20	0.30	0.40	0.63

Appendix 6.

Matrices of the intensity of project changes by project stages

Stage 1.

	G1.1	G1.2	G1.3	G1.4
S1	2.98	2.00	2.43	2.73
S2	2.13	1.33	1.71	2.10
S3	2.46	1.73	2.06	2.07
S4	1.99	1.16	1.60	1.96
S5	-0.10	-0.39	-0.09	0.02
S6	0.12	-0.25	0.05	0.20
S7	0.22	-0.11	0.14	0.30
S8	0.86	0.36	0.67	0.95
S9	1.84	1.08	1.46	1.86

Stage 2.

	G2.1	G2.2	G2.3	G2.4
S1	2.53	2.53	2.47	2.33
S2	1.80	1.92	1.77	1.72
S3	1.95	1.85	1.78	1.74
S4	1.34	1.39	1.24	1.23
S5	-0.72	-0.57	-0.56	-0.68
S6	-0.79	-0.63	-0.65	-0.76
S7	-0.68	-0.49	-0.50	-0.67
S8	0.19	0.33	0.27	0.13
S9	1.24	1.36	1.25	1.17

Stage 3.

	G1.1	G1.2	G1.3	G1.4
S1	2.32	1.36	0.97	1.26
S2	1.37	0.76	0.58	0.93
S3	1.97	1.16	0.82	0.97
S4	1.00	0.39	0.36	0.77
S5	-0.59	-1.13	-1.28	-0.52
S6	-0.85	-1.43	-1.59	-0.64
S7	-0.79	-1.26	-1.41	-0.59
S8	0.08	-0.34	-0.36	0.19
S9	0.80	0.30	0.26	0.68

Stage 4.

	G4.1	G4.2	G4.3	G4.4
S1	1.07	0.95	1.59	0.75
S2	0.23	0.26	0.43	0.54
S3	1.08	0.92	1.55	0.59
S4	-0.04	-0.03	-0.01	1.66
S5	-0.38	-0.55	-0.75	1.56
S6	-0.28	-0.38	-0.50	2.08
S7	-0.27	-0.36	-0.50	1.67
S8	-0.04	-0.03	-0.07	1.62
S9	0.14	0.20	0.31	1.47

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