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# A CONCEPTUAL MODEL FOR MONITORING PORTFOLIO MANAGEMENT IN PROJECT OFFICES BASED ON BLOCKCHAIN

**The subject** of this study is the processes of ensuring transparency, accountability, and data integrity in project portfolio management systems based on distributed ledger technologies. **The objective** of this work is to develop a conceptual model, the Blockchain Portfolio Governance Model (BPGM), to enhance the transparency, integrity, and manageability of strategic portfolio management processes. **Objectives:** to develop a multi-level model architecture that combines traditional management cycles with cryptographic event logging mechanisms; to formalize management decisions as distributed ledger objects using asymmetric cryptography; to propose a comprehensive management quality assessment metric that accounts for both technical integrity and procedural discipline; to validate the model through simulation modeling of business processes. **Research methods:** systems analysis, methods of mathematical and simulation modeling in the Bizagi Modeler environment, asymmetric encryption, and hashing algorithms to ensure data integrity in distributed networks. **Results.** This paper proposes and justifies the architecture of the Blockchain Portfolio Governance Model, comprising five levels: governance, data aggregation, decision formalization, cryptographic integrity, and audit. A mathematical framework for event logging has been developed, where each decision is signed using the ECDSA digital signature algorithm. A new comprehensive metric has been introduced – the Portfolio Governance Compliance Index – which enables the detection of "shadow" management actions by comparing the number of requests initiated in external systems with the number of validated transactions on the blockchain. A series of simulation experiments demonstrated that implementing Proof-of-Authority consensus algorithms in a corporate network introduces negligible time delays (less than 1% of the total cycle), while the majority of the process time is spent on expert analysis. **Conclusions:** The application of the BPGM model enables transforming subjective portfolio management into a transparent, algorithmic process. The proposed solution ensures the creation of a «single source of truth» for all stakeholders, significantly simplifies audit procedures, and enhances the organization's institutional reliability without compromising its operational efficiency.

**Keywords:** blockchain; project portfolio management (PPM); management transparency; distributed ledger technology (DLT); business process simulation; portfolio management compliance index (PGCI); data accountability.

## Introduction

The rapid increase in the complexity of project activities, the accelerating pace of change in the business environment, and the need for more transparent strategic decision-making are driving the search for new approaches to project portfolio management. Under these conditions, traditional management mechanisms do not always ensure a sufficient level of traceability, consistency, and auditability of management decisions, especially when it comes to multi-level approvals, shifting priorities, and resource reallocation. This creates a need for models that simultaneously combine process formalization, data integrity control, and the ability to quantitatively analyze management effectiveness.

The results of the Project Management Institute (PMI) study "Step Up: Redefining the Path to Project Success with M.O.R.E.: Ready to unlock transformative value for your teams, your organization, and beyond?" in 2025 confirm that project success depends to a large extent on the availability of systematic monitoring, regular reassessment of results, and alignment of projects with the organization's strategic goals. This justifies the need to establish transparent mechanisms for monitoring the execution of project portfolios, which ensure the timely identification of deviations, support management decision-making processes, and enhance trust among stakeholders. According to the results of a PMI study, implementing such approaches can increase the project success rate based on stakeholders' perception of value (NPSS) from the current average of 47% to 94% [1].

Traditional centralized management systems, including ERP solutions and specialized project management tools, provide advanced planning and monitoring capabilities; however, they remain vulnerable to data manipulation and do not guarantee the immutability of decisions made. This is particularly critical at the portfolio management level, where strategic decisions regarding budget reallocation, changes in priorities, and timelines are often made without formalized validation mechanisms or a transparent audit trail. As a result, conflicts arise among stakeholders, trust in management outcomes declines,

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and reconstructing an objective picture of the decisions made becomes practically impossible.

In this context, blockchain technology becomes particularly relevant as a tool for ensuring the immutability, transparency, and traceability of management events. Unlike traditional approaches, a distributed ledger ensures that every recorded decision cannot be altered or deleted without the knowledge of system participants, creating fundamentally new opportunities for auditing and verifying the integrity of portfolio management. The corporate sector's growing interest in permissioned blockchain platforms, particularly Hyperledger Fabric, indicates organizations' readiness to implement such solutions in real-world management practice [2]. This creates a need for models that combine the formalization of management decisions with cryptographic mechanisms for recording them, data integrity control, and the ability to quantitatively analyze management effectiveness.

**Literature Review and Problem Definition**

As the complexity of distributed project environments grows, ensuring transparency, accountability, and trust in project and project portfolio management becomes a critically important task. Traditional centralized management systems, including ERP solutions and tools such as Microsoft Project and Jira, provide advanced planning and monitoring capabilities; however, they remain vulnerable to data manipulation, do not ensure non-repudiation, and do not guarantee a single source of truth. These limitations are particularly evident at the project portfolio level, where strategic decisions regarding budget reallocation, schedule changes, and priority adjustments are often made without formalized validation mechanisms or a transparent audit trail, leading to conflicts among stakeholders and reducing management effectiveness.

Blockchain technology is viewed as a promising tool for addressing these issues due to its properties of immutability, decentralization, and traceability. At the same time, recent research highlights an important conceptual distinction between the governance of blockchain systems and governance through blockchain, with the latter area remaining under-explored in the context of project portfolio management.

An analysis of empirical case studies [3, 4] shows that existing research primarily covers the operational level of individual projects: management of information, supply chains, and contractual obligations dominates. The PMBOK Guide's [4, 5] classification by knowledge areas confirms this trend – the highest representation is observed for communications and stakeholder management, while functions critical to portfolio management (integration, risks, scope of work) are minimally represented. The strategic level of portfolio management is virtually absent in these studies, indicating that blockchain's potential for ensuring the integrity of decisions at the portfolio level remains untapped.

An analysis of 95 scientific publications from 2015–2022 [4] noted a lack of research dedicated to project portfolio management (PPM) via blockchain. A systematic review [6] confirms that current approaches focus primarily on the technical aspects of blockchain platform operation, while issues of stakeholder accountability, the distribution of decision-making rights, and organizational management remain overlooked. A similar pattern is observed in the construction industry, where a study [7] covers a wide range of areas – from smart contracts and BIM to supply chain management and energy efficiency – but is also limited to the level of individual projects and does not extend to portfolio management. The absence of research on project portfolio governance in several independent reviews indicates that this is effectively an unexplored niche, which this study aims to address.

Individual empirical studies [8–10] confirm that blockchain integration improves data quality and traceability at the individual project level, but do not propose mechanisms for scaling these benefits to the portfolio level. Works [11–13], dedicated to smart contracts in infrastructure projects, demonstrate the effectiveness of automation at the operational level but create "islands of automation" not linked by a unified logic of portfolio decisions. The BPGM architecture proposed in this paper solves this problem through data aggregation and governance levels that ensure systematic control and synchronization across portfolio projects.

In the domestic literature [14], blockchain in project management is considered primarily in the context of Ukraine's reconstruction using maturity models (PMMM, OPM3, CMMI), but without formalized mechanisms for verifying management decisions through an immutable digital ledger. The BPGM model can serve as such a mechanism, complementing existing approaches to maturity assessment.

Thus, most current research focuses on the application of blockchain at the level of individual projects or the technical aspects of blockchain platforms, while formalized portfolio management, ensuring the integrity of management decisions, and their quantitative assessment remain unexplored. In parallel, the field of AI-based project management is developing [15, 16], confirming the general trend toward the adoption of digital technologies in project management, particularly in turbulent environments. At the same time, AI- and blockchain-based approaches are complementary: while AI provides adaptability and forecasting, blockchain ensures the immutability and auditability of management decisions.

In this regard, this paper, as a logical continuation of the authors' previous research [1, 17–20], proposes a blockchain-based project portfolio management model (BPGM) aimed at formalizing management events, ensuring their immutability, and developing quantitative metrics for assessing portfolio integrity.

The proposed model is particularly relevant in the context of Ukraine's large-scale reconstruction, where, as of early 2026, over 8,000 reconstruction projects have been registered in the DREAM system. Reconstruction projects are implemented according to the "build back better" principle with the integration of sustainable development goals, which requires a multidimensional assessment of the results of both individual projects and their portfolios [21, 22]. At the same time, donors and international partners emphasize the need for a verifiable audit trail for every management decision.

Regarding research at the portfolio management level, the PMI standard defines portfolio management as a discipline that ensures project investments align with the organization's strategic goals and involves a clear distribution of authority and responsibility for decision-making [23]. At the same time, a study of seven decades of PPM evolution [24] indicates that despite a significant accumulation of methodological knowledge, practical tools for transparency and accountability at the portfolio management level remain underdeveloped – most of the proposed methods have proven insufficient or impractical in real organizational conditions. The authors [25] distinguish between portfolio management as an operational practice and portfolio governance as a strategic, continuous oversight process, emphasizing that studies explicitly focused on portfolio governance remain rare. This distinction is fundamental to this work: the BPGM model addresses specifically the governance level – the formalization and verification of strategic decisions – rather than the operational management of individual projects, which distinguishes it from most existing approaches.

## Formulation of the research objective

The objective of this research is to develop a conceptual Blockchain Portfolio Governance Model (BPGM) to enhance the transparency, integrity, and manageability of strategic portfolio management processes.

To achieve this goal, the following research tasks must be addressed:

1. Develop a multi-level model architecture that combines traditional management cycles with cryptographic mechanisms for recording events.
2. Formalize management decisions as objects in a distributed ledger using asymmetric cryptography.
3. Propose a comprehensive management quality assessment metric that accounts for both technical integrity and procedural discipline.
4. Validate the model through simulation modeling of business processes.

Thus, the study aims to combine process modeling, simulation analysis, and blockchain mechanisms to create a tool that supports transparent, controlled, and auditable portfolio management.

## Materials and methods

BPGM is a conceptual multi-level project portfolio management model in which strategic decisions affecting the budget, timelines, priorities, and resource allocation are formalized as events, cryptographically recorded in a distributed ledger, and made available for independent verification and audit.

The key idea behind BPGM is the transformation of subjective management agreements into verifiable digital facts: every decision made at the governance level undergoes formalization, cryptographic protection, and immutable recording in the ledger. This provides a single source of truth for all portfolio stakeholders and prevents retroactive changes to recorded events.

A set of methods was used to develop and validate the model. System analysis methods were applied to decompose the portfolio management process at the decision-making level and to define functional requirements for each level of the BPGM architecture. BPMN modeling was used to formalize and visualize the management process – from the initiation of a change request to the audit verification of the result – taking into account the interaction between the Portfolio Manager, PMO, steering committee, and blockchain components. The ECDSA and SHA-256 cryptographic algorithms

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form the basis of the mechanism for digitally signing management events and constructing a hash chain, ensuring the immutability of records and the ability to independently verify their integrity. The Proof-of-Authority (PoA) consensus algorithm was chosen as the basis for the permissioned blockchain network, as it provides the necessary throughput and organizational accountability with a limited set of authorized validators – members of the steering committee or independent auditors. Simulation modeling was performed in the Bizagi Modeler environment – a specialized tool for simulating business processes built in BPMN notation.

It should be noted that the model is not intended to replace traditional portfolio management systems, but rather to enhance their trust, traceability, and accountability through a blockchain infrastructure with permissioned access.

The goal of BPGM is to ensure:

– the immutability of strategic decisions within the portfolio;

– transparency of changes to budgets, timelines, and priorities;

– control over the reallocation of resources between projects;

– the ability to conduct independent audits of decisions;

– a reduction in information asymmetry among stakeholders;

– increased institutional trust in portfolio management.

In this context, "management in project offices" refers to a set of governance processes implemented by the PMO at the portfolio level: coordination of interdependent project initiatives with a shared resource pool, standardization and validation of decision-making procedures (changes to budget, timelines, priorities), monitoring of alignment with the organization’s strategic goals, and ensuring stakeholder accountability to sponsors and the steering committee. The class of tasks for which the BPGM model is designed involves situations where multiple projects are executed simultaneously amid competition for resources, where every management decision potentially impacts the entire portfolio and requires permanent documentation for future audit. It is precisely under such conditions that the absence of a single verified source of management events most often leads to systemic failures: duplication of decisions, data inconsistencies among stakeholders, and the inability to reconstruct the chronology of strategic changes.

## Results

BPGM comprises five levels that ensure an end-to-end process from data collection to audit:

*1. Governance Layer*

This layer is responsible for the governance context of decision-making. It is here that strategic actions are formulated regarding budget changes; schedule changes; priority changes; resource reallocation; and the approval or rejection of portfolio initiatives. This layer includes the portfolio manager; the governance committee; the PMO; sponsors; and financial and operational stakeholders.

*2. Data Aggregation Layer*

To minimize the risk of manipulation during the change initiation phase, this layer provides automated integration with traditional project management information systems (Microsoft Project, Jira) and corporate ERP solutions. Instead of manual entry, which does not guarantee objectivity, the model’s multi-level architecture allows for the extraction of up-to-date metrics regarding budgets, resources, and the current status of tasks via API. This aggregated data serves as an objective foundation for the operation of the Decision Formalization Layer.

*3. Decision Formalization Layer*

Any management decision is translated into a formalized event record:

$$E = \{PID, Type, \Delta Cost, \Delta Time, DecissionBody, Timestamp, Signature\},$$

where $PID$ is the project identifier; $Type$ is the decision type; $\Delta Cost$ is the budget change; $\Delta Time$ is the schedule change; $DecisionBody$ is the body or entity that made the decision; $Timestamp$ is the time of recording; $Signature$ is the digital signature.

This layer ensures the standardization of management events and establishes a unified logic for all portfolio decisions.

*4. Cryptographic Integrity Layer*

At this layer, the event is converted into a cryptographically secured record:

$$h = H(E),$$

where $H$ is a hash function, such as SHA-256.

The technological foundation for recording these entries is a multi-tier smart contract architecture deployed in a permissioned environment (specifically, using frameworks such as Hyperledger Fabric or private Ethereum networks). To ensure the necessary throughput and organizational accountability of transactions, the Proof-of-Authority (PoA) consensus algorithm is used. In this configuration, the right to validate blocks is granted exclusively to authorized nodes (e.g., members of the steering committee or independent auditors), which guarantees the irreversibility of management actions.

The choice of a permissioned blockchain (specifically Hyperledger Fabric) for the BPGM model is justified by the specifics of corporate project portfolio management (PPM), where the priority is on confidentiality, access control, and efficiency, rather than full decentralization.

A permissioned blockchain restricts access to authorized participants only (PMO, Portfolio Manager, committee), ensuring role-based permissions and identity verification, unlike permissionless blockchains (Bitcoin/Ethereum), where anyone can validate. This is critical for PPM, where decisions contain confidential information about budgets and strategies, preventing leaks via a public ledger.

The subsequent chain of events unfolds as follows:

$$B_n = E\{_n, h_n, h_{n-1}\},$$

where each new entry contains the event itself; its hash; and the hash of the previous entry.

This creates a sequential chain of events that makes it impossible to secretly alter decisions that have already been recorded.

*5. Audit Layer*

The audit layer ensures data integrity and consistency between the document and the registry entry:

$$V(D,h) = \begin{cases} true, & \text{if } H(D) = h \\ false, & \text{otherwise,} \end{cases}$$

where $D$ is a document or dataset; $h$ is a previously recorded hash.

This mechanism allows an independent auditor to verify whether the document has been altered since it was recorded.

Let the project portfolio be defined as:

$$P = \{P_1, P_2, \ldots, P_n\},$$

where $P_i$ is an individual project within the portfolio.

Then the set of all portfolio events is:

$$E = \bigcup_{i=1}^{n} E_i,$$

where $E_i$ is the set of project events.

This means that the portfolio is viewed as a collection of related events, rather than merely as a set of projects.

The system is considered consistent if the following holds for every record:

$$h_n = H(E_n \| h_{n-1}),$$

where || means data concatenation.

Then the integrity of the entire system is defined as:

$$IntegrityIndex = \begin{cases} 1, & \text{if all event sare valid} \\ 0, & \text{otherwise.} \end{cases}$$

In practice, this means that any disruption in the sequence of events is immediately detected during verification.

A new metric is proposed to assess the quality and reliability of the portfolio registry:

$$PEII = \frac{ValidEvents}{TotalEvents},$$

where $ValidEvents$ is the number of events that remained unchanged and passed verification; $TotalEvents$ is the total number of recorded strategic events.

The proposed scale for interpreting $PEII$ values is presented in Table 1.

**Table 1.** *Interpretation of $PEII$ values*

| $PEII$ **values** | **Interpretation** |
|---|---|
| 0,90–1,00 | High level of compliance |
| 0,70–0,89 | Acceptable level |
| < 0,70 | Critical level – audit required |

To improve responsiveness to business-critical decisions, a weighted version of the index is proposed:

$$PEII_w = \frac{\sum_{e \in ValidEvents} w_e}{\sum_{e \in TotalEvents} w_e} \times 100\%,$$

where $w_e$ is the event weight (e.g., 3 for BudgetChange, 2 for ScheduleChange, 1 for other types).

To assess the quality and transparency of portfolio management within the BPGM model, a comprehensive metric is introduced – the Portfolio Governance Compliance Index $(PGCI)$. The $PGCI$ allows for a quantitative assessment of an organization's management discipline:

$$PGCI = \frac{N_{val}}{N_{init}} \times PEII,$$

where $N_{val}$ is the number of management transactions that have been successfully validated by consensus algorithms and recorded on the blockchain; $N_{init}$ is the

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total number of initiated requests for changes to the portfolio (including those that were rejected or deleted outside the system).

This approach allows for the identification not only of technical data integrity errors but also of "gray areas" in governance – cases where decisions are made or changed in circumvention of formalized BPGM procedures. A $PGCI$ value close to 1 indicates high process maturity and full transparency in portfolio management.

The implementation of the $PGCI$ integrated indicator allows for a distinction between the concepts of data integrity and governance compliance. While $PEII$ focuses on the immutability of existing records, the $PGCI$ $N_{val}/N_{init}$ identifies "off-system" management actions that have not been formalized in the distributed ledger. Thus, the $PGCI$ serves as a tool for detecting "shadow" project portfolio management.

To demonstrate the advantages of using the $PGCI$ over traditional technical integrity metrics, let's consider two contrasting scenarios for the operation of a portfolio management system. These scenarios allow us to distinguish between the technical robustness of a distributed ledger and actual management discipline within an organization.

**Scenario A:** *High technological reliability with low managerial discipline*

In this case, the organization uses a perfectly configured blockchain infrastructure that ensures absolute data immutability $(PEII = 1.0)$. However, at the operational management level, protocols are being ignored: managers enter only 50% of the decisions actually made into the ledger, leaving the rest of the changes in the "shadow" zone (outside the BPGM).

Under these conditions, $PGCI = 0.5 \times 1.0 = 0.5$. A low index value signals management risks: despite the system's technical perfection, it does not fulfill the function of transparent control, since a significant portion of processes remains informal.

**Scenario B:** *High management discipline despite technical compromises*

In this scenario, the organization's management demonstrates a strong commitment to established procedures, recording every decision made on the blockchain $(N_{val}/N_{init} = 1.0)$. However, due to insufficient decentralization (for example, a low number of active nodes in the private network), a technical error or a targeted attack occurred, resulting in the corruption of 20% of historical records.

In this case, $PGCI = 1.0 \times 0.8 = 0.8$. Here, the index indicates a breach of technical trust. Although the organizational culture is strong, the registry data can no longer be considered an absolutely reliable source for auditing.

A comparative analysis confirms that the $PGCI$ is an effective tool for diagnosing the "health" of a governance system. It allows stakeholders to clearly identify the nature of the problems: whether they lie in the realm of human error and regulatory violations (Scenario A) or in the realm of technical infrastructure vulnerabilities (Scenario B). This enables the adoption of targeted corrective actions to improve the overall transparency of portfolio management.

Thus, the model can be presented as a sequence of layers: Governance Layer → Data Aggregation Layer → Decision Formalization Layer → Cryptographic Integrity Layer → Permissioned Blockchain Ledger → Audit Layer.

That is, a management decision arises in the portfolio environment, the decision is formalized as an event, the event is hashed and included in the chain of records, the record is stored in a permissioned blockchain, and an independent auditor performs an integrity check.

Thus, we propose the concept of portfolio management as a system of cryptographically verified events, formalize the mechanism for translating strategic decisions into events suitable for immutable storage, and introduce the $PEII$ and $PGCI$ metrics, which allow for the quantitative assessment of the level of integrity and trust in the portfolio registry.

BPMN modeling was used to formalize and visualize the process of management decisions in a portfolio context. The modeling results are presented in Figure 1.

The process encompasses the interaction between management, financial, control, and blockchain components. This structure corresponds to the logic of BPMN swimlanes, where each lane represents a separate responsibility or process participant.

The Portfolio Manager initiates a change request: budget, timeline, priority, or resource allocation. The reason for the change, the expected impact on the portfolio, and the justification for the committee are described. The request is forwarded to the PMO or committee for preliminary analysis. This stage creates an event source, which will subsequently serve as the basis for formalization and verification.

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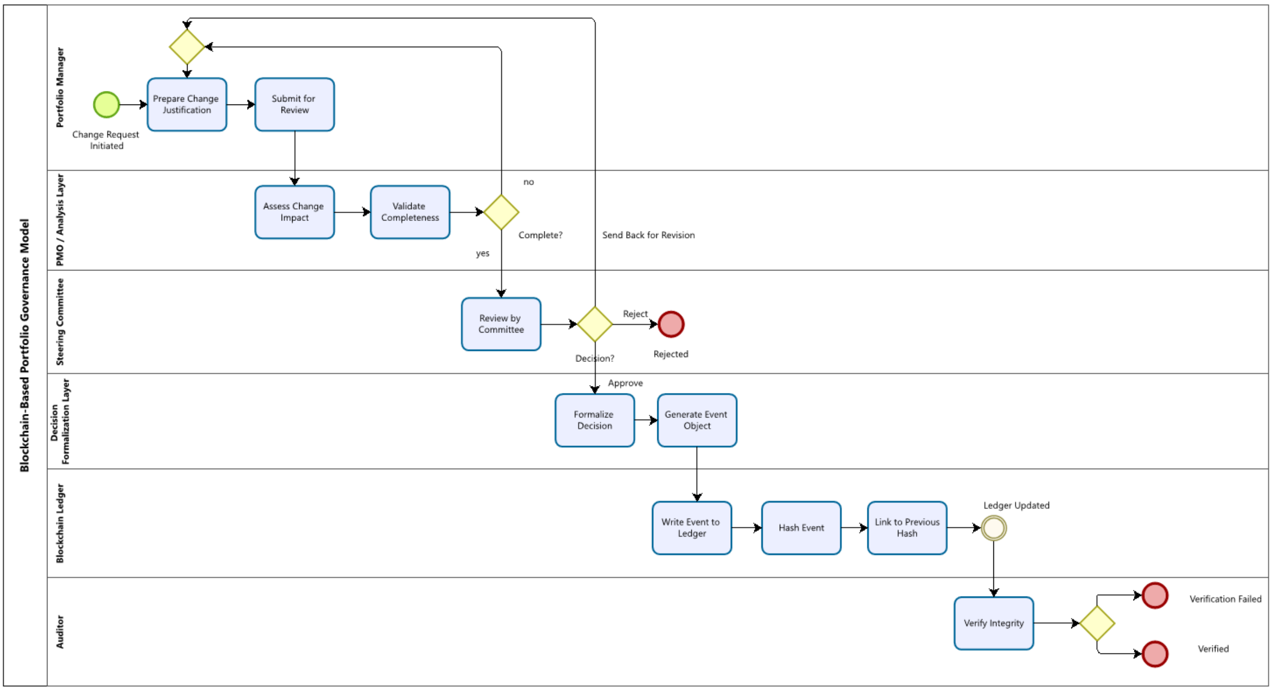


**Fig. 1.** BPMN-based process model of strategic change handling in the Blockchain-Based Portfolio Governance Model (BPGM)

The PMO analyzes the proposal's impact on the budget, timelines, risks, interdependencies between projects, and portfolio KPIs. It is verified whether there is sufficient data for review: the presence of calculations, signatures, financial estimates, and explanations. If the data is insufficient, the process is returned to the Portfolio Manager for revision. If the package is complete, it is forwarded to the committee for review.

Next, the committee reviews the request in terms of strategic feasibility, priority, and resource constraints. At this stage, three options are possible: Approve, Reject, Send Back for Revision. The corresponding gateway is key to the model, as this is where the management decision is formed, which then becomes an event at the blockchain level.

After the decision is approved, a structured record is generated:

– project ID;
– decision type;
– budget change;
– timeline change;
– decision-making body;
– timestamp;
– digital signature.

The event is transformed into a formal object for subsequent recording in the registry. It is here that the management decision is transformed into a blockchain-ready event. The formalized event is recorded in a permissioned blockchain. The event's hash is calculated. The event is appended to the chain of previous records. Once the record is saved, the process proceeds to integrity verification. This ensures the immutability of strategic decisions and a transparent audit trail. The auditor verifies whether the recorded hash matches the current document or event. If everything is correct, the event is deemed valid. If not, a discrepancy is recorded. The audit result concludes the process. This stage links the blockchain mechanism with management accountability, which is one of the model's key advantages.

In the first stage, the BPMN model was modeled using only time parameters and branching probabilities, without explicit resource constraints. This approach allowed us to estimate the process duration, rework cycles, gateway behavior, and the resulting Portfolio Event Integrity Index $\left(PEII\right)$ under various decision-making scenarios.

Tasks performed by humans were modeled using triangular distributions defined by minimum, most likely, and maximum durations, while technical blockchain operations were assigned a fixed duration due to their low variability (Table 2). The time parameters for the blockchain are conservative (intentionally inflated for simulation purposes), since in real Private Ethereum or

Hyperledger networks, this time typically does not exceed a few seconds (this demonstrates that even in the "worst-case" scenario, the blockchain network does not "slow down" business). Gateway routing was determined using branching probabilities for the outcomes of confirmation, revision, rejection, and integrity.

The initial modeling parameters were derived based on the process logic, expert estimates of the duration of individual operations, and assumptions regarding the probabilities of transition between stages. The time characteristics reflect the approximate duration of management actions within the model, while the probabilistic parameters were used to formalize possible process development scenarios at control points. This approach is appropriate in the absence of a complete set of empirical data, as it allows for the reproduction of realistic system behavior, the assessment of its sensitivity to changing conditions, and the comparability of results across scenarios.

The characteristics of the scenarios are presented below.

1. Optimistic. The process proceeds with almost no returns:
- approve: 70%.
- revision: 20%.
- reject: 10%.
- integrity pass: 99%.

2. Base case. The most realistic:
- approve: 60%.
- revision: 25%.
- reject: 15%.
- integrity pass: 98%.

3. Constrained. More revisions and delays:
- approve: 45%.
- revision: 35%.
- reject: 20%.
- integrity pass: 95%.

**Table 2.** *Time characteristics of the process*

| Task | Distribution | Min | Mode | Max |
|---|---|---|---|---|
| Prepare Change Justification | Triangular | 1 | 2 | 4 |
| Submit for Review | Fixed | 0,1 | 0,1 | 0,1 |
| Assess Change Impact | Triangular | 1 | 3 | 5 |
| Validate Completeness | Triangular | 0,5 | 1 | 2 |
| Review by Committee | Triangular | 2 | 4 | 7 |
| Resubmit Change Request | Fixed | 0,1 | 0,1 | 0,1 |
| Formalize Decision | Triangular | 0,5 | 1 | 2 |
| Generate Event Object | Fixed | 0,05 | 0,05 | 0,05 |
| Write Event to Ledger | Fixed | 0,05 | 0,05 | 0,05 |
| Hash Event | Fixed | 0,01 | 0,01 | 0,01 |
| Link to Previous Hash | Fixed | 0,01 | 0,01 | 0,01 |
| Verify Integrity | Triangular | 0,1 | 0,3 | 0,6 |

The simulation was performed using Bizagi Modeler. The simulation results for the base case scenario are shown in Figure 2.

The simulation results for the base case scenario showed that out of 451 initiated requests, 441 were completed within the model, and the average process duration was 17.32 days. The most time was spent on preparing the justification for changes, impact assessment, and committee review, while the stages of recording the decision in the ledger were completed without delays, confirming their operational ease.

The simulation also showed that some requests are filtered out during the completeness check or rejected after review, reflecting the presence of control points in the process. At the same time, 351 completed cycles passed integrity verification, and only 6 cases ended unsuccessfully, indicating the high reliability of the data recording and verification mechanism in this scenario.

Simulation modeling confirmed that the proposed model ensures controlled movement of the request through all stages of portfolio approval, with the main time losses concentrated on management analysis rather than on blockchain operations. This means that blockchain integration does not complicate the process but enhances its transparency and control over the integrity of management decisions.

Within the scope of the study, the BPGM model was developed and formalized as a comprehensive architecture for supporting portfolio governance based on a combination of process logic and blockchain recording mechanisms. The model reflects the sequence of management actions from the initiation of a change request to its verification, approval, or rejection, and also provides for the immutable recording of critical events in a distributed ledger. This structure ensures the traceability of a decision at all stages of its processing and creates a basis for subsequent auditing.

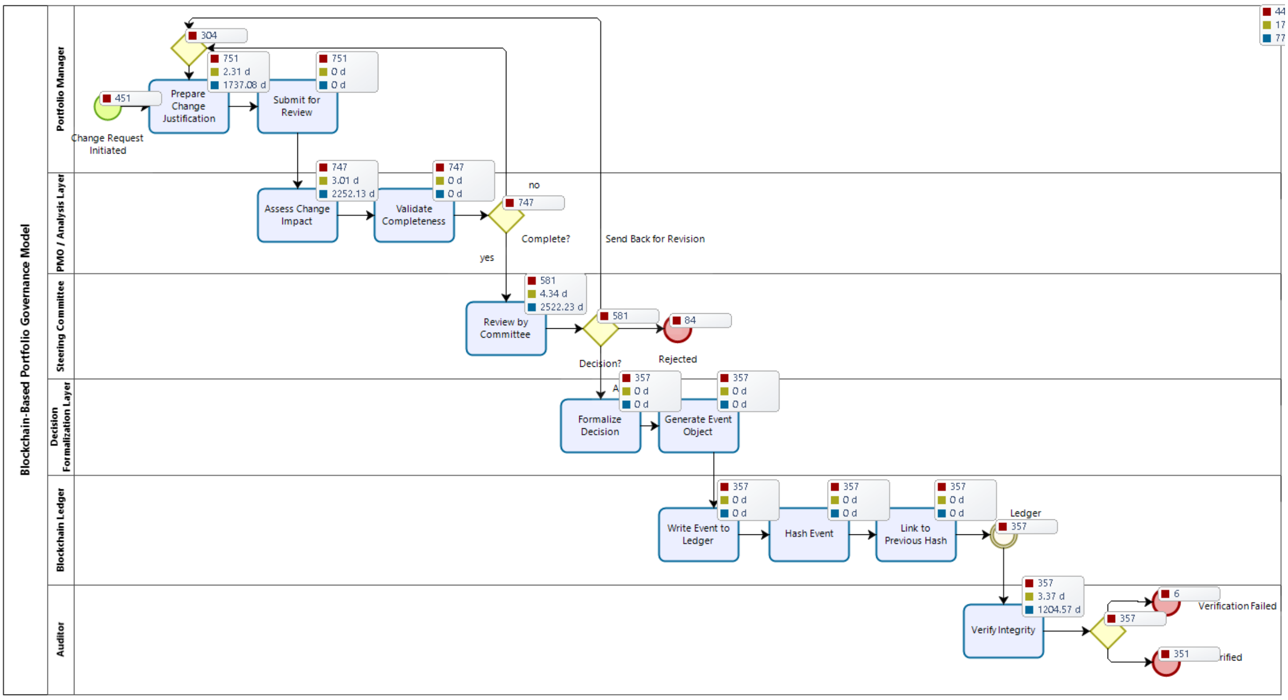


**Fig. 2.** Modeling results (Base case scenario)

One of the key outcomes is that the BPGM model allows for the separation of the actual managerial logic of decision-making from the technical aspects of verifying and documenting those decisions. As a result, every significant action within the process becomes a controllable event that can be verified based on temporal, procedural, and informational criteria. This increases the transparency of portfolio management and reduces the risks of loss, distortion, or duplication of critical data.

Simulation modeling of the BPGM BPMN process was performed for three scenarios: optimistic, base case, and constrained. In all scenarios, the time characteristics of tasks, the probabilities of transitions through gates, and the total duration of the portfolio decision process from request initiation to verification completion were analyzed. The shortest lead time was obtained in the optimistic scenario, while the constrained scenario was characterized by the longest duration due to a higher proportion of re-approvals and revisions.

In the base case scenario, the Review by Committee and Revise Request stages contributed the most to the total process time, indicating their role as the main time bottlenecks. The Decision gate provided the main branching point of the process, with the majority of trajectories ending in approval, while a smaller portion proceeded to revision or rejection. The blockchain-recording stages – Write Event to Ledger, Hash Event, and Link to Previous Hash – had virtually no impact on the total duration due to their technical nature and low variability in execution time.

The *PEII* metric remained high in all scenarios, indicating that the integrity and controllability of portfolio events were maintained within the model's scenarios. The greatest decrease in *PEII* was observed in the constrained scenario, where the proportion of repeat cycles increased and the probability of a request being returned for revision rose.

## Discussion of Results

BPGM is a conceptual model that combines portfolio management, event formalization, and blockchain integrity mechanisms. Its key advantage lies in the fact that strategic decisions cease to be merely managerial agreements and are transformed into verified digital facts.

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This creates a foundation for transparent, controllable, and audit-ready management of project portfolios.

The model can be applied to the management of IT portfolios; construction and infrastructure programs; government digital transformation portfolios; cross-organizational projects; and audits of large programs where the traceability of decisions is critical. Its practical value lies in creating a single source of truth for strategic portfolio decisions.

Scaling the model depending on the complexity of the tasks being solved can be approached in several ways.

1. *Number of projects in the portfolio*

An increase in the number of projects increases the volume of transactions at the blockchain level, but thanks to PoA consensus, this load scales linearly and does not affect latency (confirmed by simulation – <1% of a cycle). However, the load on the governance level increases: more projects mean more cross-project dependencies, which requires expanding the pool of validators and refining the coordination protocols.

2. *Number of hierarchy levels and participants*

For simple portfolios (one PMO, two to three stakeholders), a minimal validator configuration is sufficient. For complex portfolios – corporate or government – multi-level approvals emerge (PMO → sponsor → regulator), and BPGM adapts by adding validator nodes without changing the architecture. This is a structural advantage of a permissioned blockchain.

3. *Frequency and diversity of management decisions*

The higher the rate of change and frequency of decisions (typical for IT portfolios in an Agile environment), the greater the value of a consistent audit trail – and the higher the sensitivity of *PGCI* to deviations. For slow-moving portfolios (infrastructure programs), the model remains valid, but the threshold values for *PGCI* and *PEII* may require calibration for a specific domain.

4. *Degree of project interdependence*

With weak interdependence, BPGM operates as a parallel set of independent decision chains. With strong interdependence, a data aggregation level is activated that tracks cross-project events. The complexity of the task here determines which part of the architecture is involved, but does not break the model.

The results indicate that the value of the BPGM model lies not only in the use of blockchain as a technological component, but primarily in building a managed portfolio governance model where the decision-making process becomes transparent and verifiable. Unlike traditional approaches, in which management actions are often scattered among different participants and information systems, BPGM forms a single logical control loop. This allows for increased confidence in decision-making outcomes and ensures better portfolio manageability.

From a methodological standpoint, BPGM should be viewed as a platform for the further development of digital portfolio management. Its architecture creates the conditions for integration with analytical tools, decision support systems, and portfolio performance monitoring mechanisms. In this context, the model has practical value as a foundation for building more robust, transparent, and formalized management processes.

The results confirm that the proposed BPGM model is sensitive to changes in the logic of approval and the quality of the initial submission of changes. In practical terms, this means that even with a stable blockchain infrastructure, the overall effectiveness of governance is determined primarily by the organization of the process, rather than the technical layer of data storage. Simulation modeling confirmed that the implementation of blockchain tools does not create new technological bottlenecks. The main delay remains in the cognitive sphere – the time required for stakeholders to analyze the governance situation.

Thus, blockchain in a governance model should not replace the management process, but rather enhance its transparency and auditability. At the same time, the simulation itself shows that technical integrity does not compensate for poor-quality management input if requests are frequently returned for revision.

The implementation of BPGM in the real economy is accompanied by a number of limitations that must be taken into account:

1. *The Oracle Problem:* blockchain guarantees the technical immutability of data after it is recorded in the ledger, but it cannot automatically verify the accuracy of information at the stage of its initial entry. If a project manager intentionally enters false data about task status into the aggregation system, the BPGM model will cryptographically record this fact but will not detect the misinformation without additional external audit mechanisms.

2. *Complexity of integration with existing systems:* The effectiveness of the Data Aggregation Layer directly depends on the availability of open APIs in corporate software (ERP, CRM). In organizations with outdated IT infrastructure, automating data collection may be

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technically challenging, requiring a temporary transition to semi-automated input methods.

3. *Cost-effectiveness and scalability:* Although simulation modeling confirmed low time costs, deploying and maintaining a private blockchain network (validation nodes) requires additional expenses for infrastructure and energy consumption. For small businesses with a limited number of projects, the administrative costs of maintaining the BPGM may outweigh the benefits of transparency.

4. *Digital Asset Management (Key Management):* The model relies on asymmetric cryptography, which requires stakeholders to possess a high level of digital literacy in handling private keys. The loss or compromise of a key could lead to a blockage in the approval process or legal disputes regarding the authenticity of signatures.

The identified limitations outline avenues for future research, particularly regarding the development of algorithms for automatic verification of input data using artificial intelligence and the optimization of key storage mechanisms in the corporate sector.

## Conclusions

This article proposes and justifies the BPGM model as a tool for enhancing the transparency, traceability, and integrity of portfolio management. Its architecture combines the process logic of management decisions with mechanisms for immutable event logging, creating a reliable foundation for controlling critical stages of portfolio management.

It is shown that the BPGM model allows formalizing the flow of a management request through all key stages – from initiation to result verification – and thereby reduces the risks of data loss, distortion, or inconsistency. This is particularly important for environments where decisions are strategic in nature and require a high level of accountability.

The results obtained confirm the feasibility of further developing the BPGM as a foundation for the digitalization of portfolio management processes. In future research, it is advisable to expand the model by integrating analytical monitoring tools, performance evaluation mechanisms, and support for adaptive portfolio management.

## Conflict of interest

The authors declare that they have no conflict of interest, including financial, personal, authorial, or any other nature, that could influence the research or the results published in this article.

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## Data availability

The manuscript has no associated data.

## Use of artificial intelligence

The authors confirm that they did not use artificial intelligence technologies to write this paper.

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# КОНЦЕПТУАЛЬНА МОДЕЛЬ МОНІТОРИНГУ ПОРТФЕЛЬНОГО УПРАВЛІННЯ В ПРОЄКТНИХ ОФІСАХ НА ОСНОВІ БЛОКЧЕЙНУ

**Предметом вивчення** є процеси забезпечення прозорості, підзвітності та цілісності даних у системах управління портфелями проєктів на основі технологій розподіленого реєстру. **Мета дослідження** – розроблення концептуальної моделі Blockchain Portfolio Governance Model (BPGM) для підвищення прозорості, цілісності та керованості процесів стратегічного портфельного управління. **Завдання:** розробити багаторівневу архітектуру моделі, що поєднує традиційні управлінські цикли з криптографічними механізмами фіксації подій; формалізувати управлінські рішення як об’єкти розподіленого реєстру з використанням асиметричної криптографії; запропонувати комплексний показник оцінки якості управління, що містить як технічну цілісність, так і процедурну дисципліну; здійснити валідацію моделі способом імітаційного моделювання бізнес-процесів. **Методи дослідження:** системний аналіз, методи математичного та імітаційного моделювання в середовищі Bizagi Modeler, алгоритми асиметричного шифрування й гешування для забезпечення цілісності даних у розподілених мережах. **Результати.** У роботі запропоновано й обґрунтовано архітектуру моделі Blockchain Portfolio Governance Model, яка передбачає п’ять рівнів: управління, агрегацію даних, формалізацію рішень, криптографічну цілісність і аудит. Розроблено математичний апарат фіксації подій, де кожне рішення засвідчується за допомогою алгоритму цифрового підпису ECDSA. Упроваджено новий інтегральний показник – індекс відповідності портфельного управління (Portfolio Governance Compliance Index), що дає змогу виявляти "тіньові" управлінські дії за допомогою порівняння кількості ініційованих запитів у зовнішніх системах із кількістю валідованих транзакцій у блокчейні. Проведено серію імітаційних експериментів, які довели, що впровадження алгоритмів консенсусу Proof-of-Authority в корпоративну мережу додає незначні часові затримки (менше 1% від загального циклу), тоді як основний час процесу припадає на експертний аналіз. **Висновки.** Застосування моделі BPGM допомагає трансформувати суб’єктивне управління портфелем у прозорий алгоритмічний процес. Запропоноване рішення забезпечує створення "єдиного джерела істини" для всіх стейкхолдерів, значно спрощує процедури аудиту й підвищує інституційну надійність організації без зниження її операційної ефективності.

**Ключові слова:** блокчейн; управління портфелями проєктів (PPM); прозорість управління; розподілений реєстр (DLT); імітаційне моделювання бізнес-процесів; індекс відповідності портфельного управління (PGCI); підзвітність даних.

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