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A Conceptual Framework for AI- and Blockchain-Enabled Research Project Evaluation Systems

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Abstract

The evaluation of research and development (R&D) project proposals plays a critical role in shaping national scientific and technological priorities. However, existing expert review systems are often characterized by fragmented digital workflows, limited traceability of decisions, and a strong reliance on manual coordination, which reduces transparency and auditability. This paper proposes a conceptual and methodological framework for a national research project evaluation system that integrates artificial intelligence and blockchain technologies as complementary decision-support and data integrity mechanisms. The framework formalizes the complete evaluation lifecycle, including applicant authorization, formal compliance verification, originality and plagiarism analysis, expert selection and assessment, analytical consolidation of reviews, and fixation of final decisions. Artificial intelligence modules are introduced to support thematic classification, compliance checking, expert matching, and analytical processing of expert evaluations, while blockchain technology is incorporated as an immutable integrity layer for recording critical evaluation events and ensuring data provenance. The proposed approach focuses on architectural design, governance principles, and process modeling rather than system implementation or empirical validation. The framework is intended to serve as a reference model for the design and future development of transparent, accountable, and scalable research project evaluation platforms at national and institutional levels.

Keywords: research project evaluation; artificial intelligence; blockchain technology; expert review systems; decision support platform; transparency; digital expertise; research funding governance

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1. Introduction

The evaluation of research and development (R&D) project proposals is a fundamental element of modern research governance, as funding decisions directly influence scientific priorities, technological advancement, and long-term socio-economic development. National and institutional funding systems predominantly rely on expert-based peer review as the primary mechanism for evaluating research proposals with respect to scientific novelty, methodological soundness, feasibility, and expected impact. Prior research provides a comprehensive conceptual analysis of peer review, describing its historical evolution, core functions, and role in research governance, thereby establishing expert evaluation as a foundational element of funding decision-making processes [1]. Subsequent studies further

examine peer review specifically in the context of research funding, analyzing procedural models, evaluation criteria, and policy implications across funding agencies, which reinforces the central role of expert-based assessment in competitive grant allocation [2]. At the same time, critical analyses of peer review highlight the presence of cognitive, social, and institutional biases that may influence expert judgments, motivating the need for enhanced transparency, consistency, and methodological support within evaluation systems [3]. While peer review remains the dominant evaluation paradigm, it increasingly faces challenges related to transparency, administrative complexity, traceability of decisions, and consistency across large-scale competitive funding calls. These challenges become particularly pronounced in national evaluation systems that process a high volume of heterogeneous proposals under strict regulatory and time constraints.

Digitalization has been widely adopted to support individual stages of the evaluation workflow, such as online submission systems, plagiarism detection tools, and expert databases [4,5]. However, existing platforms are often fragmented and focus on isolated tasks rather than the full lifecycle of project expertise. As a result, critical stages—including formal compliance verification, expert assignment, review consolidation, and protocol generation—remain weakly integrated and largely dependent on manual operations. This fragmentation complicates auditing procedures and creates opportunities for post hoc-modifications of documents or evaluation results, which undermines trust in funding outcomes [6].

Artificial intelligence (AI) has recently attracted significant attention as a means of enhancing expert evaluation processes by supporting analytical and coordination tasks traditionally performed manually. Prior studies demonstrate the potential of AI-based methods for automated document analysis and thematic proposal classification, enabling scalable processing of large volumes of submissions and reducing subjectivity in early-stage screening [7]. Other works show that machine learning-based recommendation and matching techniques can be effectively applied to reviewer selection by modeling semantic similarity between proposal content and expert profiles, thereby improving the alignment of expertise and evaluation quality [8]. More recent research further illustrates how AI-driven decision-support systems can assist in aggregating expert assessments, identifying inconsistencies or anomalies across reviews, and providing structured analytical insights to support final decision-making without replacing human judgment [9]. Proponents argue that AI can reduce workload, improve consistency, and support evidence-based decision making. At the same time, critics highlight risks related to algorithmic bias, lack of explainability, and excessive automation that may interfere with expert judgment [10]. Consequently, there is no consensus on the appropriate role of AI in research evaluation systems, and hybrid approaches combining human expertise with machine-supported analytics are increasingly advocated.

In parallel, blockchain technology has been proposed as a mechanism for improving transparency and trust in governance processes through immutable, time-stamped records and decentralized verification [11,12]. In the context of research management, blockchain-based solutions have been explored for data provenance, intellectual property protection, and secure record keeping [13]. Nevertheless, most existing studies focus on conceptual frameworks or isolated use cases, and practical integration of blockchain into end-to-end research project evaluation workflows remains limited. In particular, the potential of blockchain to prevent hidden modifications of expert assignments, reviews, and final protocols has not been sufficiently operationalized.

In this context, the present study proposes a conceptual and methodological framework for a national research project evaluation system that integrates artificial intelligence and blockchain technologies as complementary components. The paper aims to formalize

the research project evaluation lifecycle, identify stages suitable for intelligent analytical support and integrity control, and propose a reference system architecture aligned with existing regulatory and governance requirements. Artificial intelligence is considered as a decision-support mechanism assisting classification, compliance verification, expert selection, and analytical consolidation of expert assessments, while blockchain is introduced as an immutable data provenance layer ensuring traceability and auditability of critical evaluation events. The proposed framework is intended to serve as a foundation for future system development, pilot implementation, and empirical validation in national and institutional research funding environments.

Despite the widespread adoption of digital research evaluation platforms across different countries, existing systems primarily focus on procedural automation and administrative support. Key challenges related to process transparency, traceability of expert decisions, reproducibility of evaluation outcomes, and scalability under increasing competition volumes remain insufficiently addressed. These limitations motivate the development of an integrated framework that combines analytical support with mechanisms for integrity assurance, forming the basis for the approach proposed in this study.

2. Background

Across major international research funding systems, project evaluation is based on structured, multi-criteria expert review frameworks designed to ensure scientific quality, feasibility, and societal relevance [14]. Although specific terminology and governance mechanisms differ, leading organizations demonstrate a high level of convergence in evaluation logic, procedural stages, and core assessment dimensions.

In the European Union, the Horizon Europe framework applies a comprehensive evaluation model structured around three principal criteria: Excellence, Impact, and Quality and Efficiency of Implementation [15]. Evaluation is conducted by independent, accredited external experts and typically combines individual assessments with collective discussions aimed at consolidating scores and comments into a consensus-based outcome. The process includes eligibility verification, expert scoring, threshold checks, and the formation of a ranked list of proposals. Particular emphasis is placed on interdisciplinary approaches, collaboration with industry and stakeholders, and clearly articulated pathways to scientific, technological, and socioeconomic impact [16].

In the United States, federal research funding agencies such as the National Science Foundation (NSF) and the National Institutes of Health (NIH) employ rigorous peer-review systems that balance scientific contribution with broader societal value [17]. The NSF framework is structured around the criteria of Intellectual Merit and Broader Impacts, assessing both the scientific significance of the proposed research and its contributions to education, inclusion, public benefit, and dissemination. Reviews are supported by qualitative justification and inform program-level funding decisions [18,19]. The NIH applies a criterion-based evaluation model encompassing Significance, Investigator(s), Innovation, Approach, and Environment, typically using numeric scoring to produce an overall impact score that supports institute-level decisions under budgetary and portfolio constraints [20].

In the United Kingdom, research proposal evaluation under UK Research and Innovation is guided by principles of transparency, equal opportunity, and scientific validity [21]. Assessment criteria generally include Vision, Approach, Applicant and Team, and Resources and Management, and the process combines independent expert reviews with panel moderation to ensure consistency of judgment. This structure emphasizes both the ambition of the research objectives and the credibility of the proposed delivery plan, including resource allocation, management strategy, and responsible research conduct [22].

Comparable evaluation models are implemented in other advanced research systems. In Australia, the Australian Research Council (ARC) applies criteria that balance excellence in research with expected benefits beyond academia, supported by external expert assessment and, where appropriate, panel deliberation [23]. In Japan, the Japan Society for the Promotion of Science evaluates proposals based on scientific significance, originality, feasibility, investigator capability, and budget appropriateness, combining compliance checks, conflict-of-interest control, and independent expert reviews with consolidated decision-making [24]. In France, the Agence Nationale de la Recherche employs a system that integrates individual assessments with panel-level discussion, focusing on scientific excellence, feasibility, impact, and project management [25]. In Germany, the Deutsche Forschungsgemeinschaft applies criteria such as originality, scientific significance, methodological rigor, research environment, and applicant qualification, typically relying on multiple independent reviews followed by expert consolidation into a final funding recommendation [26].

Beyond national funding agencies, international organizations such as the Organisation for Economic Co-operation and Development (OECD) emphasize a broader evaluative perspective. The OECD's Development Assistance Committee (DAC) Evaluation Criteria extend assessment beyond scientific quality to include relevance, coherence, effectiveness, efficiency, impact, and sustainability, providing a cross-cutting reference model for evaluating value for money, long-term effects, and the durability of outcomes after funding concludes [27].

While these international frameworks establish robust conceptual foundations for research project evaluation, their practical implementation often relies on heterogeneous digital tools and fragmented workflows. Limited end-to-end traceability, manual coordination across evaluation stages, and insufficient protection against post hocmodification of records remain persistent challenges across otherwise mature evaluation systems [28]. These common limitations motivate the development of integrated digital platforms capable of supporting diverse evaluation models while ensuring transparency, consistency, and auditability—objectives directly addressed by the approach proposed in this study.

National Center for State Scientific and Technical Expertise (ISNCTE) represents a centralized national digital platform supporting research and R&D project evaluation in Kazakhstan, integrating formal compliance checks, plagiarism detection, expert review, and advisory council decision-making [29].

Table 1 highlights a strong convergence across major international research evaluation systems in terms of core assessment dimensions and workflow structure, despite differences in scoring scales and governance models. Nearly all systems rely on multi-criteria expert assessment combining scientific excellence or significance with feasibility and expected impact, while decision-making is typically finalized through panel consolidation or program-level authority.

Table 1. Comparison of Major International Research Project Evaluation Systems.

No.	Evaluation System	Country	Latest Update	Scoring Scale	Key Criteria	Evaluation Workflow
1	Horizon Europe (European Commission)	EU	2025	5-point	Excellence; Impact; Implementation	Eligibility → external experts → panel consensus → thresholds → ranking
2	European Research Council (ERC)	EU	2024	—	Excellence (Project & PI)	Step 1 screening → Step 2 interview/panel → final panel decision

Table 1. *Cont.*

No.	Evaluation System	Country	Latest Update	Scoring Scale	Key Criteria	Evaluation Workflow
3	National Science Foundation (NSF)	USA	2024	Qualitative	Intellectual Merit; Broader Impacts	External reviews → qualitative ratings → program officer → NSF decision
4	UK Research and Innovation (UKRI)	UK	2025	—	Vision; Approach; Applicant & Team; Resources & Management	Reviews + scoring → panel moderation → final panel decision
5	OECD DAC Evaluation Criteria	International	2023	—	Relevance; Coherence; Effectiveness; Efficiency; Impact; Sustainability	Evidence synthesis → criterion-based judgment → evaluation report
6	National Institutes of Health (NIH)	USA	2015	1–9 (1 best)	Significance; Investigator(s); Innovation; Approach; Environment	Study section review → criterion scores → overall impact score → institute decision
7	Research Council of Finland (Academy of Finland)	Finland	2024	6-point	Quality; Impact/Novelty; Feasibility; Applicant Competence	External review → scoring → panel alignment → final decision
8	Agence Nationale de la Recherche (ANR)	France	2025	0–5/0–10	Excellence; Feasibility; Impact; Management	Compliance/COI → 2–3 reviews → panel discussion → ranking → decision
9	Deutsche Forschungsgemeinschaft (DFG)	Germany	2024	0–5	Originality; Significance; Rigor; Environment; Qualification	2–3 reviews → synthesis → panel/meeting → ranking → decision
10	Japan Society for the Promotion of Science (JSPS)	Japan	2023	0–5	Significance; Originality; Feasibility; Capability; Budget	Compliance/COI → 2–3 reviews → consolidation/panel → decision
11	Australian Research Council (ARC)	Australia	2025	0–4	Excellence in Research; Impact	Eligibility/COI → external review → (panel) → decision + feedback
12	ISNCTE (Information System of the National Center for Scientific and Technical Expertise)	Kazakhstan	2024	Mixed (qualitative + numeric)	Scientific quality; Relevance; Feasibility; Impact; Budget justification	Submission → formal compliance → plagiarism check → expert assignment → expert review → consolidation → advisory council decision

3. Materials and Methods

This section presents the methodological approach used to enhance an existing national research project evaluation platform in Kazakhstan using artificial intelligence and blockchain technologies. The methods focus on process modeling and system-level integration while preserving the established evaluation workflow. The study adopts a conceptual and design-oriented research methodology. Rather than conducting empirical performance evaluation, the methodological focus is placed on process modeling, system decomposition,

and architectural synthesis. The research method combines analysis of existing national evaluation workflows, abstraction of functional and governance requirements, and systematic integration of artificial intelligence and blockchain technologies into a unified evaluation lifecycle. This approach aligns with design science methodologies commonly applied in information systems research, where the primary contribution lies in the construction and formalization of reference architectures rather than in experimental validation.

3.1. Baseline Research Project Evaluation Workflow in Kazakhstan

Is.ncste.kz is the information system of the National Center for State Scientific and Technical Expertise JSC, designed for the electronic management of state scientific and technical expert reviews of projects. This platform is used to submit applications for grant and program-targeted funding of scientific and technical projects and programs [29]. The system serves as a single window for all stages of the expert review process: from application registration and obtaining an individual registration number to the publication of expert review results and the work of the appeals committee.

The Figure 1 illustrates the baseline workflow of scientific and scientific-technical project evaluation implemented in the national digital platform.

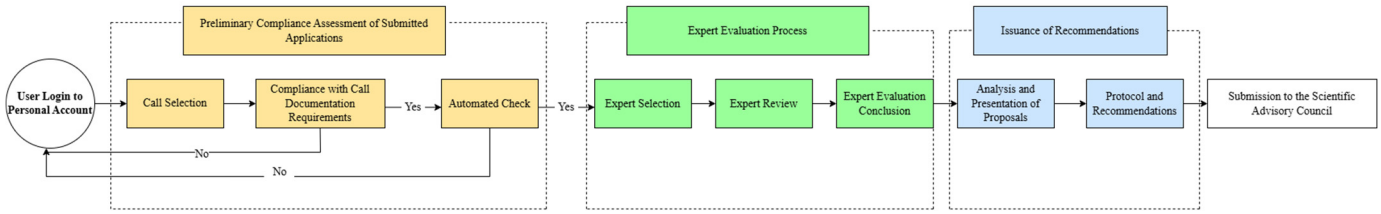


Figure 1. Baseline Workflow of Scientific and Scientific-Technical Project Evaluation.

The baseline research project evaluation workflow considered in this study corresponds to the national practice implemented through the information system is.ncste.kz, operated by the National Center for State Scientific and Technical Expertise of the Republic of Kazakhstan. The platform is used for the electronic administration of state scientific and scientific-technical expertise of research projects and programs and serves as a centralized digital environment supporting all stages of competitive funding procedures.

The workflow begins with user registration and authentication in the system, followed by electronic submission of a project proposal for a selected funding call. Applicants complete a structured electronic application form, upload all required documents, specify the project team, and submit the application through the platform. Each submitted application is signed using a national electronic digital signature and, in the case of institutional submissions, additionally approved by the head of the applicant organization. Upon successful submission, the system assigns the project a unique individual registration number, which is used throughout the entire evaluation lifecycle.

After submission, all applications undergo a primary technical examination conducted by the competition organizer. At this stage, proposals are checked for completeness, correctness of data entry, compliance with formal requirements, and adherence to the thematic scope of the call. Based on the results of this verification, applications may be admitted to further evaluation, returned to applicants for revision, or rejected. The system records the status of each application and notifies applicants through their personal accounts and electronic notifications.

Applications that pass the technical examination are forwarded to the main stage of scientific and technical expertise. Independent experts, including domestic and international specialists, are assigned to review the proposals. Experts access all project materials through their personal accounts in the system and provide evaluations by completing stan-

dardized electronic expert review forms. These forms typically include scoring according to established criteria and qualitative written conclusions. The platform collects expert assessments, calculates the resulting evaluation indicators, and stores all expert reports within the system.

Following expert review, consolidated evaluation materials are prepared and submitted for consideration by the National Scientific Council. Council members receive access to project information, expert scores, and supporting documentation. Based on these materials, final decisions on project support or rejection are made. The results of the council's deliberations are published in the system, and applicants receive official notifications through their personal accounts, including excerpts from the relevant decision protocols.

The workflow also includes a formal appeal mechanism. Applicants who disagree with evaluation outcomes may submit an appeal through the system within the prescribed timeframe. Appeals are reviewed by an authorized appeals commission, and the resulting decisions are recorded and communicated to applicants via the same digital platform.

For projects that receive funding, the platform supports subsequent monitoring and reporting activities. Grant recipients submit periodic and final reports through standardized electronic forms, which are reviewed and approved by authorized coordinators. In this way, the system maintains a continuous digital record of each project, from initial application submission to completion and archival of final results.

3.2. Analytical Methodology

The methodological approach of this study is based on process modeling and system-level analysis of the existing evaluation workflow. Business processes were analyzed using descriptive workflow decomposition, focusing on data flows, decision points, user roles, and document lifecycle stages as documented in official platform guidelines and process descriptions.

The baseline workflow was decomposed into functional blocks:

1. Application submission and registration;
2. Formal compliance verification;
3. Originality and plagiarism checking;
4. Expert assignment and evaluation;
5. Aggregation of results and protocol formation;
6. Decision approval and publication.

This decomposition served as the reference model for identifying stages suitable for technological enhancement. This methodological decomposition provides a reproducible analytical basis for comparing the baseline evaluation workflow with the enhanced AI- and blockchain-supported framework presented in the subsequent sections.

3.3. Artificial Intelligence Modules

Artificial intelligence is incorporated into the national research project evaluation platform as a set of modular decision-support components designed to assist data processing, analytical assessment, and workflow coordination. The AI modules operate as auxiliary services integrated into the existing evaluation process and do not replace human experts or formal decision-making bodies. All AI-generated outputs are treated as advisory information subject to expert or administrative validation.

The thematic classification module is implemented as a multi-label hierarchical classification system for scientific texts. Input data include textual sections of project proposals, such as abstracts, descriptions of objectives, methods, and expected results. Text extraction from uploaded DOCX and PDF files is followed by normalization procedures, including automatic language detection, lemmatization, and removal of non-informative elements.

Two levels of text vectorization are employed. At the base level, TF–IDF representations are used to ensure interpretability and robustness for limited data volumes. At the semantic level, dense vector representations generated by transformer-based language models of the Sentence-Transformers family are applied. For multilingual and interdisciplinary proposals, multilingual models adapted through additional training on historical project applications and expert conclusions are used.

Classification is performed using One-vs-Rest schemes based on linear classifiers as well as neural classification heads trained over embeddings in PyTorch 2.8.0. Semantic similarity between textual objects is computed using cosine similarity, which is consistently applied across classification, expert matching, and originality analysis tasks.

The application classification module performs automated thematic categorization of submitted project proposals. It analyzes textual content, structural features, and semantic relationships within application materials to assign projects to predefined scientific domains and funding call categories. Classification is formulated as a multi-label task and may incorporate hierarchical domain structures, in which broader research areas are identified prior to assignment to more specific subdomains. The module produces structured metadata, including confidence indicators for each assigned category, which are used in subsequent processing stages and stored within the platform's internal data structures. Cases in which confidence values do not exceed predefined thresholds are flagged for administrative confirmation.

The formal compliance verification module supports automated checking of application completeness and conformity with formal requirements. This module evaluates the presence of mandatory documents, correctness of form completion, compliance with submission deadlines, and adherence to formatting constraints. Formal requirements are represented as structured and versioned rule sets to ensure reproducibility of compliance checks across funding cycles. In addition to rule-based validation, semantic similarity indicators may be applied to assess alignment between proposal content and funding call descriptions. The module outputs structured compliance indicators that assist administrators in early-stage screening of submissions.

The plagiarism and originality detection module applies semantic text analysis methods to identify potential textual overlap and paraphrased content across submitted proposals and reference sources. Initial candidate retrieval is performed using fast lexical similarity techniques to identify potentially related documents, followed by semantic reassessment using dense vector representations and similarity measures. Different sensitivity thresholds are applied across proposal sections, such as literature review and statements of scientific novelty, in order to reduce false positives. The module generates similarity indicators and annotated text fragments for further expert or administrative review, without producing automatic rejection decisions.

Model training and adaptation are based on historical datasets of prior project applications and expert evaluations, enabling domain-specific learning aligned with national research funding practices. The use of multilingual and multi-label representations allows the system to process interdisciplinary proposals, which may simultaneously belong to several scientific domains.

Classification quality is monitored using macro-F1 and micro-F1 metrics, while confidence scores produced by the models are calibrated using temperature scaling techniques. In cases where model confidence does not reach predefined thresholds, classification results are forwarded for confirmation by responsible administrators.

Results produced by plagiarism and originality analysis modules are interpreted strictly as risk indicators and do not lead to automatic rejection of applications. To reduce false positives, different similarity thresholds are applied to different sections of a proposal,

and lists of typical scientific formulations are used to filter standard expressions. Final interpretation of similarity results remains under expert control.

The expert selection support module assists in forming expert pools for project evaluation. It analyzes expert profiles, including declared areas of expertise, publication records, prior evaluation experience, and conflict-of-interest indicators. Expert profiles and project proposals are represented using comparable semantic embeddings, enabling similarity-based matching. Final suitability scores may incorporate additional constraints, such as workload balancing and conflict-of-interest penalties. Based on these attributes, the module produces ranked lists of candidate experts suitable for specific project topics, supporting transparent and consistent expert assignment.

During the evaluation phase, the analytical consolidation module processes expert evaluation reports and scores. It aggregates quantitative indicators, analyzes consistency across expert assessments, and identifies potential divergences or anomalies in evaluations. The module generates structured analytical summaries that support decision-making at later stages without modifying original expert judgments.

All artificial intelligence modules are integrated through standardized interfaces and interact with the platform's data repositories and knowledge base. The modular design enables independent updating or extension of individual components while preserving compatibility with the existing evaluation workflow and regulatory framework. Model outputs are accompanied by confidence indicators and explanatory signals to support transparency, auditability, and informed human oversight throughout the evaluation process.

To address risks related to algorithmic bias, the proposed framework relies on human-in-the-loop control and procedural transparency. Artificial intelligence modules do not make final decisions and operate exclusively as analytical support tools. All critical outputs, including classification results, compliance indicators, and originality assessments, are subject to expert or administrative validation.

Bias risks are further mitigated through the use of blind evaluation mechanisms, in which identifying information about applicants and organizations is concealed during early evaluation stages. Analytical artifacts generated by AI modules are preserved together with metadata on models, parameters, and input data hashes, enabling retrospective audit and reproducibility of analytical outcomes.

3.4. Blockchain Integration Strategy

Blockchain technology is incorporated into the national research project evaluation platform as a distributed data integrity and traceability layer. The blockchain component is designed to complement the existing centralized architecture by providing immutable records of critical evaluation events without altering established procedural logic or decision-making authority. All blockchain operations function as supporting mechanisms and do not replace administrative or expert responsibilities.

The proposed framework assumes the use of a permissioned blockchain architecture, in which participating nodes belong to authorized institutions involved in the research project evaluation process, such as funding agencies, expert organizations, and supervisory bodies. This architectural choice enables the application of energy-efficient consensus mechanisms suitable for controlled environments and ensures higher scalability and lower operational overhead compared to public blockchain networks. At the conceptual stage presented in this study, the framework does not bind the system to a specific consensus algorithm, focusing instead on governance-oriented requirements, interoperability, and procedural integrity.

The integration strategy focuses on event-based recording of key stages in the evaluation workflow. Specifically, blockchain records are generated for results of automated

and formal compliance checks, expert assignment actions, submission of expert evaluation reports, and approval of final evaluation protocols and recommendations. Each blockchain entry contains a cryptographic hash of the corresponding data object, a timestamp, and a reference to the evaluation stage, enabling verification of data integrity without exposing sensitive content.

To ensure scalability and compliance with data protection requirements, the system adopts an off-chain/on-chain separation model. Detailed evaluation data, documents, and personal information are stored within the platform's secure databases, while the blockchain stores only cryptographic hashes and metadata required for integrity verification. This approach allows auditability and non-repudiation while maintaining confidentiality and regulatory compliance.

Outputs generated by artificial intelligence modules are recorded as analytical results within the platform's internal data repositories, while their cryptographic hashes and associated metadata are registered in the blockchain layer as part of the event record. This approach ensures integrity and traceability of AI-supported recommendations without storing model outputs directly on-chain. When AI models are updated, newly generated results are recorded as separate events with new hashes, while previously fixed analytical outcomes remain unchanged. This mechanism preserves reproducibility and auditability across model updates and prevents retroactive alteration of prior evaluation results.

Smart contracts are employed conceptually to formalize procedural constraints and sequencing rules within the evaluation workflow. These contracts define permissible transitions between evaluation stages and ensure that specific actions, such as approval of final protocols, can be executed only after completion of required preceding steps. Smart contracts do not introduce autonomous decision-making and are limited to enforcing predefined procedural conditions.

Within the proposed framework, smart contracts are used exclusively to formalize procedural constraints and workflow sequencing rules, rather than to perform autonomous or content-based decision making. Their primary function is to ensure that predefined evaluation stages are completed in the correct order and that critical actions—such as expert assignment, submission of expert reports, and approval of final evaluation protocols—are executed only after fulfillment of required conditions. This design preserves the primacy of human expert judgment while providing machine-verifiable enforcement of regulatory and procedural rules.

The blockchain layer is integrated with the platform through standardized interfaces, enabling interoperability with artificial intelligence modules, analytical services, and document management subsystems. This modular integration allows the blockchain component to operate independently of specific evaluation algorithms while preserving consistency with the overall system architecture.

To address scalability, data protection, and cost considerations, the framework adopts an off-chain/on-chain separation model. Full project documents, expert reports, and analytical data are stored in conventional secure databases, while the blockchain layer records only cryptographic hashes and minimal metadata associated with key evaluation events. This approach significantly reduces blockchain storage requirements and transaction load, enabling efficient operation even for large-scale funding calls, while maintaining auditability, integrity verification, and non-repudiation.

4. Proposed Framework and System Architecture

This section presents the results of enhancing the national research project evaluation platform through the integration of artificial intelligence and blockchain technologies. The results are structured around three complementary dimensions: AI-assisted workflow

support, blockchain-enabled integrity and traceability, and system-level architectural integration. Together, these results demonstrate how the proposed technologies extend the baseline evaluation process while preserving its regulatory structure and expert-driven decision-making logic.

4.1. AI-Assisted Evaluation Workflow

This section builds upon the baseline evaluation workflow described in Section 3 and focuses exclusively on the analytical support functions introduced by artificial intelligence, without repeating the underlying procedural stages.

The integration of artificial intelligence algorithms into the evaluation process of scientific and scientific-technical projects forms a multi-layer intelligent infrastructure that significantly enhances the efficiency, objectivity, and overall speed of the evaluation system. AI components are embedded across all key stages, from preliminary document analysis to the generation of final evaluation protocols, enabling automation of routine operations, intelligent support for experts, and in-depth analytical processing of large volumes of evaluation data. This architecture contributes to the development of a self-improving evaluation environment in which decisions are supported by objective criteria and the quality of expert assessment is continuously enhanced through learning from accumulated data.

The concept of a self-improving evaluation environment refers to controlled model updates based on accumulated analytical artifacts, rather than autonomous or real-time learning during active evaluation processes. When models are updated, new analytical artifacts are generated and recorded, while previously fixed results remain unchanged.

This mechanism enables managed model drift control and long-term reproducibility of analytical conclusions, ensuring that improvements in analytical performance do not compromise the integrity of prior evaluation results.

As shown in Figure 2, artificial intelligence is integrated into the research project evaluation workflow as a multi-layer analytical support mechanism spanning all major process stages. AI modules are used to support thematic classification, formal compliance verification, plagiarism detection, and expert selection by automating routine analytical tasks and generating structured recommendations for early-stage processing, while preserving human oversight. Figure 2 illustrates the baseline evaluation workflow shown in Figure 1, augmented with artificial intelligence modules that provide analytical support without altering the original procedural structure.

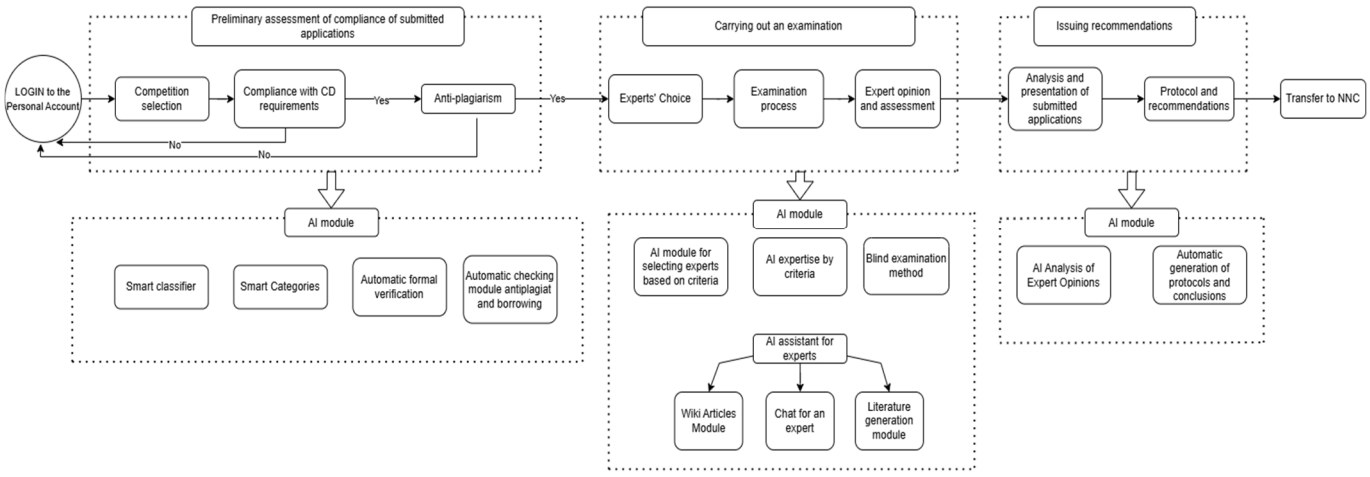


Figure 2. AI-Assisted Evaluation Workflow for Scientific and Scientific-Technical Projects.

At the initial stages of the baseline workflow (Section 3), AI modules provide automated analytical support for thematic classification, formal compliance verification, and originality analysis. In parallel, an AI-assisted formal compliance verification module analyzes the completeness and correctness of submitted documentation, including deadlines, formal parameters, and mandatory attachments, and generates structured compliance indicators to support administrative screening at early evaluation stages. A dedicated AI module performs plagiarism and originality analysis using semantic similarity models capable of identifying both direct textual overlap and paraphrased content, providing annotated results for further expert review.

During the expert selection stage, the system employs a specialized AI-based matching module that considers experts' scientific profiles, publication activity, prior evaluation experience, and potential conflicts of interest. The algorithm produces an objective ranking of experts, enabling selection of the most suitable candidates for each project. This approach reduces manual assignment errors, improves the quality of the expert pool, and prevents hidden influence on expert composition, as selection decisions are automatically generated and recorded within the system.

Throughout the expert evaluation stage, artificial intelligence functions as an intelligent assistant. Criterion-based AI analysis supports identification of project strengths and weaknesses and produces preliminary analytical insights that inform, but do not replace, expert judgment. The use of blind review mechanisms, in which applicant identification data are concealed from reviewers, further enhances objectivity and reduces potential bias. Expert assistance tools provide access to structured knowledge bases, automated literature generation, and a specialized analytical chat interface that supports reasoning, structuring of conclusions, and generation of standardized expert evaluation reports. These tools reduce evaluation time for complex proposals and promote consistency in assessment structure.

At the final stages, AI-based analytical modules perform deep analysis of expert evaluation reports, identifying contradictions, assessing inter-reviewer agreement, and generating integrated analytical indicators. This provides a transparent and structured foundation for final decision-making. The automated protocol generation module aggregates all evaluation data into standardized documents fully compliant with regulatory requirements. Automation at this stage reduces the risk of technical errors, accelerates processing, and ensures a consistently high standard of documentation.

4.2. Blockchain-Enabled Evaluation Workflow

This section does not redefine the evaluation workflow presented in Section 3, but illustrates how blockchain technology is applied as a transversal integrity and traceability layer across its key stages.

The integration of blockchain technology into the evaluation process of scientific and scientific-technical projects establishes a fundamentally new data governance architecture in which each procedural stage is recorded in a distributed ledger and protected by cryptographic mechanisms. This transformation significantly increases resistance to data tampering, enhances the reliability of evaluation outcomes, and ensures the legal validity of final decision documents. Within the proposed workflow, blockchain mechanisms are applied at key stages, including originality and plagiarism verification, expert pool formation, fixation of expert evaluation reports, and generation of final protocols and recommendations. Each record is associated with a timestamp and a unique cryptographic hash, guaranteeing data immutability and enabling subsequent retrospective verification.

As shown in Figure 3, blockchain technology is integrated into the baseline research project evaluation workflow as a transversal integrity layer without altering the original

procedural structure. Figure 3 further extends the same baseline workflow by introducing blockchain mechanisms as a transversal layer for integrity fixation and traceability of key evaluation events. Blockchain-based logging is applied at key control points, including automated compliance checks, expert selection, expert evaluation reports, and final evaluation protocols, ensuring immutability and traceability of critical decisions. Expert assessments and final recommendations are recorded with cryptographic hashes and timestamps, preventing post hoc modification and external interference. This integration enhances transparency, trust, and governance of the evaluation process while preserving established expert decision-making mechanisms.

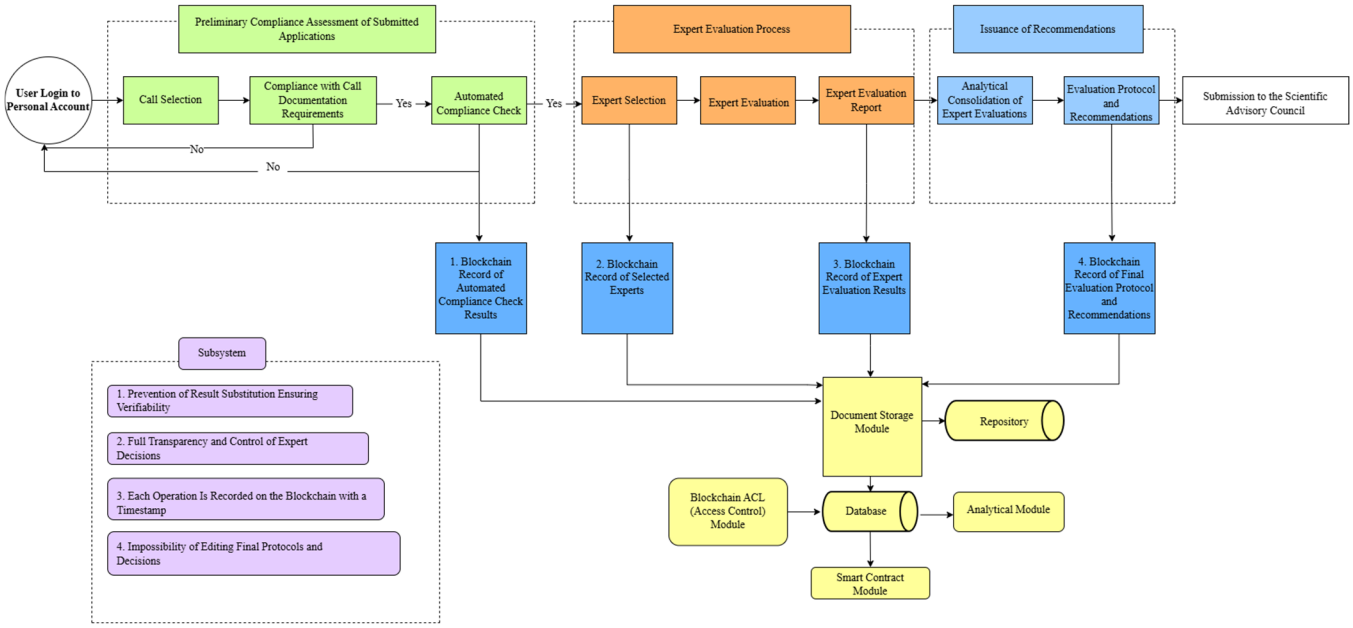


Figure 3. Blockchain-Enabled Workflow for Scientific and Scientific-Technical Project Evaluation.

The first observed outcome of distributed ledger integration is the establishment of a transparent control mechanism for the quality and authenticity of submitted materials. Recording plagiarism verification results on the blockchain eliminates the possibility of report substitution or post-analysis modification. In this context, the ledger serves as a digital proof of the originality and integrity of the initial project documentation, thereby increasing trust among experts and decision-making bodies. In practical terms, this prevents situations in which project proposals are altered after submission and misrepresented as original versions. The second significant effect relates to improved transparency and objectivity in the expert selection procedure. Fixation of assigned experts in the blockchain prevents undisclosed rotation of reviewers, reduces the risk of informal influence, and ensures equal conditions for all applicants.

The third key outcome concerns the immutable recording of expert evaluations and conclusions with associated timestamps. This approach eliminates the possibility of retroactive modification of evaluation results and protects experts from external pressure, as any interference with assessment data becomes technically detectable. As a result, conditions are created for more independent, well-justified, and ethically sound expert review. The blockchain ledger also serves as a reliable data source for analytical modules, supporting holistic assessment of evaluation quality and identification of anomalies, such as sharp discrepancies in expert scores.

The final component of the blockchain-enabled workflow involves fixation of final evaluation protocols and recommendations, which may be digitally signed using smart contracts. This practice ensures legally significant electronic signatures and creates a

secure digital trace confirming the immutability of final decisions. Smart contracts allow formalization of decision-making logic and enable automated initiation of document transmission to higher-level advisory or governing bodies. This increases procedural predictability, reduces the likelihood of human error, and enhances overall manageability of the evaluation process.

Overall, the integration of blockchain technology into the research project evaluation system leads to the formation of a resilient ecosystem oriented toward trust, transparency, and a high level of data protection. It strengthens interaction between experts, applicants, and regulatory institutions by establishing a unified digital framework for analysis and decision-making. In practice, these changes reduce the risk of corruption-related practices, support independent project endorsement, and, in the long term, provide an objective foundation for selecting scientific initiatives with the highest potential impact on scientific and technological development.

4.3. Conceptual System Architecture of the Evaluation Platform

The proposed system architecture is presented as a conceptual reference model for integrating artificial intelligence and blockchain technologies into a national research project evaluation framework. The architecture formalizes the structural organization and interaction logic of key system components required to support transparent, auditable, and scalable evaluation processes, without implying a fully implemented or operational system. Figure 4 illustrates the overall conceptual architecture of the proposed framework, highlighting the main functional modules and their logical relationships.

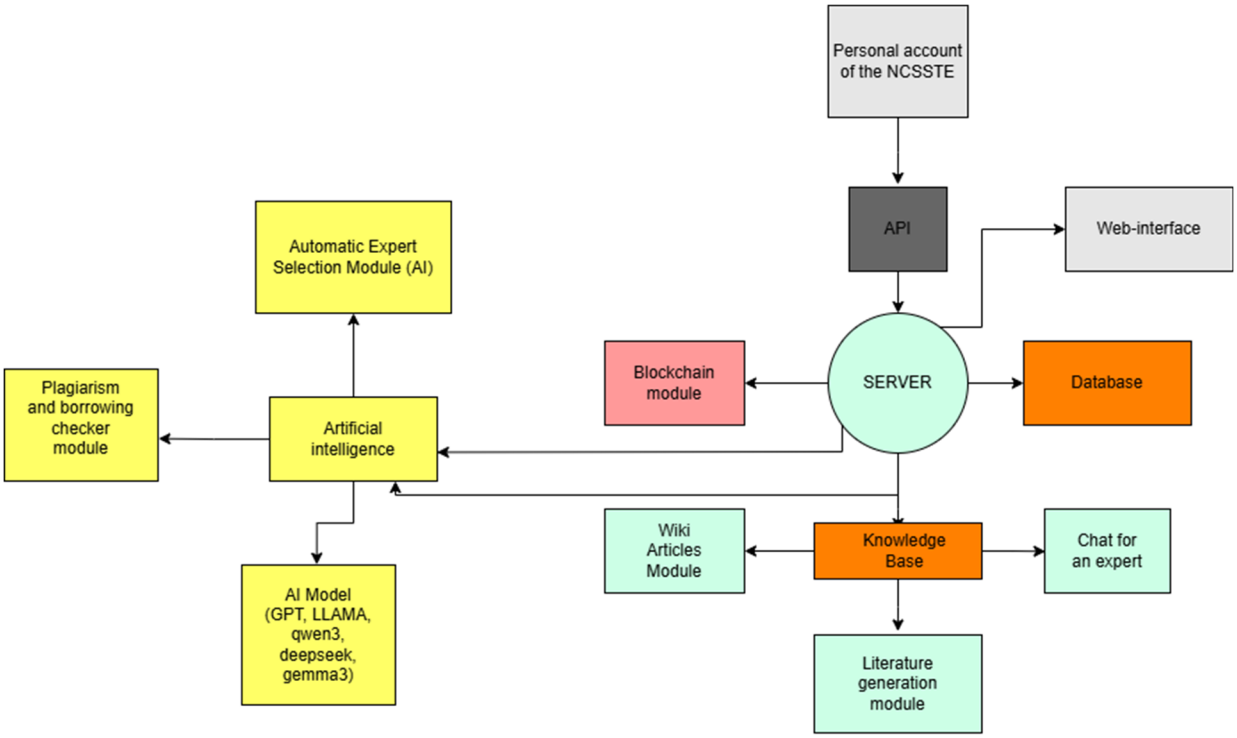


Figure 4. Conceptual system architecture of the proposed AI- and blockchain-enabled research project evaluation framework.

Within the proposed architecture, artificial intelligence and blockchain technologies play complementary but clearly separated roles. Artificial intelligence modules operate as analytical services that generate recommendations and structured evaluation artifacts, while the blockchain layer provides immutable fixation of these analytical results and key procedural events. AI outputs are not executed or enforced by the blockchain; instead, their

cryptographic hashes and metadata are recorded to ensure traceability, reproducibility, and resistance to post hoc modification. This separation allows analytical flexibility on the AI side while preserving integrity and auditability through the blockchain layer.

The architecture follows principles of modularity and distributed interaction, enabling flexibility, scalability, and future system evolution without disrupting its core structure. At the center of the architecture is a server layer that conceptually acts as the coordinating core of the system. This layer is designed to manage request routing, enforce procedural logic, orchestrate interactions among functional modules, and control data exchange between system components. All major subsystems—including artificial intelligence services, blockchain mechanisms, analytical modules, data repositories, and user interfaces—are logically connected through this central server, ensuring consistency of data flows and procedural sequencing across the evaluation lifecycle.

Artificial intelligence is positioned within the architecture as an autonomous analytical and decision-support component, rather than as an independent decision-making authority. The AI block is designed to interact with multiple subsystems and to support advanced data processing across different evaluation stages. Conceptually, it leverages large language and analytical models to enable semantic analysis, thematic classification, similarity assessment, and structured content generation. This design supports intelligent assistance during proposal processing, including originality analysis, expert matching, and analytical consolidation of expert assessments, while preserving the primacy of human expert judgment.

A dedicated plagiarism and text similarity analysis module is conceptually integrated within the AI-supported components. Its role is to perform semantic comparison of submitted materials using neural-network-based information retrieval techniques in order to identify both direct and indirect textual borrowing, including paraphrased fragments. The outcomes of originality analysis are prepared for subsequent fixation within an integrity-preserving registry.

Blockchain technology is incorporated into the architecture as a transversal data integrity and traceability layer. The blockchain module is conceptually connected to the server layer and is intended to record cryptographic hashes and timestamps associated with critical evaluation events, such as formal compliance verification, expert assignment, submission of expert reviews, and approval of final evaluation protocols. By storing cryptographic proofs rather than full document contents, the architecture supports auditability and non-repudiation while maintaining confidentiality and compliance with data protection requirements.

The automatic expert selection module is conceptualized as an AI-assisted system that analyzes expert profiles, scientific competencies, publication records, prior evaluation experience, and potential conflict-of-interest indicators. Based on these attributes, the module is intended to generate ranked recommendations for expert assignment aligned with the thematic scope of submitted proposals. This mechanism supports objectivity and consistency in expert allocation while allowing final validation by authorized administrators.

Data management within the proposed architecture is conceptually divided into two complementary components: a database and a knowledge base. The database is intended to store structured information related to project applications, expert profiles, evaluation results, and formal protocols. The knowledge base functions as an intellectual repository aggregating regulatory documents, curated scientific literature, analytical summaries, and historical evaluation data. Controlled access to the knowledge base enables artificial intelligence components to incorporate contextual information into analytical processes, thereby improving recommendation quality and interpretability.

Additional conceptual components include a literature generation module, a wiki-based information module, and an expert-oriented conversational interface. These elements are intended to support experts by providing structured reference materials, analytical overviews, and contextual background information relevant to evaluated proposals, as well as interactive assistance during the formulation of expert conclusions.

The upper layer of the architecture addresses user interaction and system access. Personal accounts for applicants, experts, and administrators, together with web-based interfaces, are conceptually implemented through an application programming interface (API). This layer provides standardized, secure, and role-based access to system functionality, enabling submission, monitoring, evaluation, and documentation activities within a unified digital workspace while preserving data integrity and access control.

5. Discussion

The present study contributes to the ongoing discourse on the digital transformation of research project evaluation systems by proposing a conceptual framework that integrates artificial intelligence and blockchain technologies within a unified governance-oriented architecture. Rather than reporting empirical outcomes of system deployment, this discussion focuses on the theoretical implications, design rationale, and potential effects of the proposed framework when applied to national and institutional evaluation environments.

Unlike comparative studies focused on benchmarking digital evaluation platforms, the methodological approach adopted in this study relies on process modeling and system-level abstraction. The baseline workflow is used as a reference structure to identify points where analytical support, transparency, and traceability can be enhanced, rather than to directly compare operational efficiency or tool performance with other national or international systems. This approach enables methodological generalization while preserving alignment with nationally regulated evaluation procedures.

In contrast to the established evaluation the existing frameworks [17–23] the proposed framework does not aim to redefine evaluation principles or criteria. Instead, it focuses on the architectural integration of decision-support and integrity mechanisms across the full evaluation lifecycle. While existing systems predominantly rely on centralized digital platforms with limited end-to-end traceability, the proposed framework introduces a systematic separation between analytical support (artificial intelligence) and integrity assurance (blockchain), enabling verifiable audit trails without altering expert-driven decision logic. This comparison is qualitative and architectural in nature and reflects differences in system design rather than performance outcomes.

Within this framework, blockchain is conceptualized not as a standalone repository for selected documents, but as a transversal integrity and traceability layer consistently applied to critical evaluation events, including formal compliance verification, expert assignment, submission of expert reports, and fixation of final decisions. This approach links integrity guarantees to procedural sequencing and event consistency, extending prior work that focuses primarily on isolated records or transactions.

Similarly, while many AI-driven evaluation systems reported in the literature emphasize autonomous scoring, ranking, or decision-making, the present framework deliberately positions artificial intelligence as a decision-support mechanism. AI modules assist thematic classification, compliance analysis, expert matching, and analytical consolidation, while final judgments remain under human expert and institutional control. This design choice directly addresses concerns related to explainability, bias, and accountability and aligns with hybrid human–AI governance models discussed in recent research evaluation literature.

From an architectural perspective, the proposed framework differs from monolithic evaluation platforms by adopting a modular system design, in which artificial intelligence

services, blockchain components, analytical modules, and user interfaces are decoupled and interact through standardized interfaces. As demonstrated in the methodological sections, this modularity supports scalability, adaptability to regulatory change, and controlled evolution of analytical models, while preserving reproducibility and auditability across the evaluation lifecycle.

From a governance and data integrity perspective, the integration of blockchain technology addresses long-standing challenges related to traceability, auditability, and trust in expert-based evaluation processes. By conceptualizing blockchain as a transversal integrity layer, the framework ensures immutable recording of critical evaluation events—such as compliance verification, expert assignment, submission of expert reports, and fixation of final decisions—linking integrity guarantees to procedural sequencing rather than to isolated records.

Artificial intelligence is incorporated as a decision-support mechanism rather than an autonomous decision-making component. AI modules assist early-stage processing and analytical consolidation, while final judgments remain under human expert and institutional control. This design preserves alignment with ethical, regulatory, and governance norms and mitigates risks related to explainability and bias.

At the architectural level, the proposed modular design decouples AI services, blockchain components, analytical modules, and user interfaces. This modularity supports scalability, adaptability to policy or regulatory changes, and long-term sustainability, distinguishing the framework from monolithic evaluation platforms and enhancing its applicability across institutional contexts. Several limitations of the proposed framework should be acknowledged. As a conceptual and methodological study, the framework has not been validated through long-term deployment, large-scale datasets, or real funding cycles. Consequently, quantitative performance indicators—such as reductions in processing time, administrative costs, or expert workload—are not reported in this study, as the proposed framework is conceptual and design-oriented rather than based on pilot deployment or operational evaluation. In addition, although the framework anticipates the use of AI to support objectivity, issues related to algorithmic bias, explainability, and fairness remain open and require careful consideration during future implementation stages.

As a conceptual and methodological study, the proposed framework does not provide quantitative estimates of blockchain throughput, storage consumption, or operational costs. These parameters depend on specific implementation choices, deployment scale, and institutional constraints and therefore require empirical evaluation through pilot deployments or prototype systems. The absence of such metrics represents a limitation of the current work and defines a clear direction for future research focused on performance benchmarking and cost–benefit analysis.

Future research should therefore focus on empirical validation of the proposed framework through pilot implementations, controlled experiments, or retrospective analysis of historical evaluation data. Further work is also required to integrate explainable artificial intelligence techniques, assess user acceptance among experts and administrators, and explore cross-national interoperability with international research evaluation frameworks. These efforts will be essential to translating the proposed conceptual model into a robust and operational evaluation system.

6. Conclusions

The framework formalizes the complete evaluation lifecycle and systematically maps each stage to appropriate forms of digital support. Artificial intelligence is positioned as a decision-support mechanism that assists thematic classification, expert matching, and analytical processing of expert evaluations, while blockchain technology is conceptualized

as a transversal integrity layer ensuring immutable recording of critical evaluation events. This hybrid design addresses key limitations of existing evaluation platforms, which typically rely on fragmented digital tools and provide limited end-to-end traceability.

At the same time, the study has several limitations that should be acknowledged. The proposed framework is design-oriented and has not yet been validated through large-scale deployment, pilot implementation, or quantitative performance evaluation. As a result, metrics such as processing time reduction, administrative cost savings, or expert workload optimization are not empirically assessed. In addition, while the framework anticipates the use of artificial intelligence to support objectivity and efficiency, challenges related to algorithmic bias, explainability, model drift, and user trust require careful consideration during future implementation stages.

Future research should therefore focus on empirical validation of the proposed framework through pilot studies or controlled experiments using real evaluation data. Further work is also needed to integrate explainable artificial intelligence techniques, assess stakeholder acceptance among experts and administrators, and analyze legal and regulatory implications, particularly in relation to data protection and long-term auditability. Addressing these challenges will be essential for translating the proposed conceptual framework into a robust and operational research project evaluation system.

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