2025 European Conference on Computing in Construction

CIB W78 Conference on IT in Construction

Porto, Portugal
July 14-17, 2025

REVOLUTIONIZING CONSTRUCTION PROCUREMENT: BLOCKCHAIN AND SMART CONTRACTSDRIVING TRANSPARENCY AND MONITORING WASTE PRODUCTION

Silvia Meschini[1], Lavinia Chiara Tagliabue[1], Stefano Rinaldi[2], Giovanni Miri[1], Andrea Bracciali[1], Nai Roberto[1], Rosa Meo[1], and Giuseppe Martino Di Giuda[1]
[1]University of Turin, Italy
[2]University of Brescia, Italy

Abstract

The construction procurement remains inefficient, paper-based, and lacks transparency. Current systems fail to ensure reliable bid evaluations and sustainability compliance, particularly in waste management. This research proposes a blockchain-based framework integrating BIM, smart contracts, and process normalization to automate tender evaluations, ensuring tamper-proof data storage and verifiable assessments. A prototype was tested through an Italian Design-Build procurement with improved transparency and efficiency. Results highlight enhanced compliance monitoring and fairer bid selection based on sustainability criteria. By establishing standardized processes for data submission and verification, this approach fosters trust and promotes digital transformation in public procurement, setting a standard for transparency.

Introduction

The construction industry, particularly public procurement, faces persistent challenges due to low digitalization, inefficiency, and lack of transparency (European Commission, 2022; Pellegrini et al., 2021). Despite e-procurement platforms and EU-driven digitalization policies, tendering remains largely paper-based, leading to delays, errors, and corruption risks (OECD, 2019). Public procurement inefficiencies contribute to economic losses of up to €1.2 trillion globally, with Italy performing below the EU average in decision-making efficiency and SME inclusion (OECD, 2019; European Commission, 2022). Transitioning to data-driven procurement is essential to improving transparency, sustainability, and compliance with Green Public Procurement (GPP) regulations (Lavagna et al., 2019; OAV, 2022; Sapir et al., 2022). Even a 1% increase in efficiency could generate €43 billion in savings annually across OECD countries (OECD, 2019).

Background and motivation

Recent years have seen growing interest in blockchain and smart contracts as tools to enhance transparency, trust, and automation in public procurement. These technologies promise to address several persistent inefficiencies in the tendering phase, including subjectivity in bid evaluation, vulnerability to fraud, lack of traceability, and the limited enforceability of sustainability policies such as GPP. Smart contracts, self-executing agreements that operate under predefined conditions, are gaining traction for their ability to eliminate intermediaries and automate critical steps of the procurement workflow (Pattini et al., 2022; Sreckovic et al., 2022).

Despite this potential, research and practical implementations remain fragmented. Several studies have proposed blockchain-based procurement models, but most either focus narrowly on single aspects (e.g., bid storage, confidentiality) or remain conceptual in nature. For instance, (Ahmadisheykhsarmast et al., 2023) developed a decentralized system for tendering using smart contracts and decentralized storage, yet it lacked automation of compliance or structured sustainability scoring. (Torkanfar et al., 2023) introduced BidChain to address transparency and security in public tenders, leveraging blockchain and IPFS, but did not integrate BIM or standardized evaluation models. (Gunasekara et al., 2022) applied blockchain to facilities management procurement, highlighting efficiency gains but with no direct link to public-sector regulatory criteria. Meanwhile, (Tezel et al., 2021) explored blockchain for supply chain management in construction, offering empirical insights on payment flows and auctions, but without specific focus on the Most Economically Advantageous Tender (MEAT) criteria, data modeling, or tender evaluation automation.

Collectively, these studies highlight the potential of blockchain and smart contracts to improve data integrity, accountability, and efficiency in the procurement phase. Yet they also expose some gaps: the lack of integration with structured data models such as BIM, the absence of standardized workflows for automated evaluations, and limited compliance with regulatory frameworks, rules, standards, and environmental protocols like GPP or MEAT. Another gap concerns data privacy, as compliance with regulations like the EU GDPR (General Data Protection Regulation), requires solutions such as off-chain storage and permissioned blockchains to protect sensitive procurement data. Furthermore, challenges

persist in scalability, interoperability with existing platforms, legal enforceability, and stakeholder adoption. Addressing these limitations is essential for unlocking the transformative capacity of blockchain-based procurement systems in real-world public construction settings

Research contribution and paper structure

This research aims to address the limitations observed in the current procurement procedures by proposing a transition from document-based systems to fully digitalized, data-driven tendering processes. The proposed framework combines blockchain, BIM, smart contracts, and Business Process Model and Notation (BPMN 2.0) to enable secure, transparent, and regulation-compliant public procurement workflows.

Unlike prior studies focused on conceptual models or partial implementations, the research proposes a functional procurement platform that enables the automation of bids' verification and evaluation. It exploits Industry Foundation Class (IFC) structured BIM data to assess compliance with client and regulatory Information Requirements (IRs), enforces MEAT criteria via smart contracts, and supports the monitoring of sustainability parameters such as waste management. Blockchain is used not only for immutable data storage but also for auditability and traceable interaction among stakeholders.

By combining technical, regulatory, and procedural layers, the proposed framework offers a replicable solution to enhance automation, reduce subjectivity in tender evaluations, and align public procurement practices with EU circular economy policies. The paper begins by outlining the research methodology and design approach, followed by a detailed presentation of the system architecture and underlying framework. It then describes the implementation of the proposed solution through a real-world case study. The discussion highlights key findings and their broader implications, while the final section reflects on future developments and potential directions for advancing digital public procurement.

Methodology

This study adopts a design-oriented research approach to address the lack of structured, automated, and regulation-compliant procurement systems in public construction. While previous research has proposed blockchain frameworks or digital procurement concepts, few have implemented and tested a fully integrated solution that aligns with both technical workflows (BIM, BPMN) and regulatory criteria (GPP, MEAT).

The main objective consists in developing and testing a prototype that automates tender evaluations using smart contracts and leveraging IFC-structured BIM data to assess sustainability criteria.

The research implicitly addresses two key questions:

- Can blockchain and smart contracts be used to automate transparent and tamper-proof evaluation of public construction tenders?
- Can BIM and standardized digital workflows (BPMN 2.0) support regulatory compliance check and GPP adoption?

With the aim of addressing these questions implicitly, the following elements are presented: (i) a conceptual framework design integrating blockchain, BIM, and smart contracts with a system architecture developed on a web-based platform; and (ii) a proof-of-concept (PoC) case study applied to a real Italian Design-Build (DB) tender, involving sustainability criteria.

Proposed framework based on a blockchain- platform, smart contracts, and full process digitalization

During the tendering phase, bidders must develop their projects in compliance with client specifications and regulatory requirements. Smart contracts function as a ledger that securely records all interactions among stakeholders, ensuring high levels of transparency and reliability. This is essential for fostering collaborative approaches and trust in the procurement process. A blockchain-powered platform enables a fully digitalized and automated bidding process, allowing bidders to develop their models based on either the preliminary or final BIM representation, in accordance with the guidelines specified in the tender documentation.

At this aim, current procurement procedures must shift to a model-based, open-source approach, facilitating the full digitalization of tender evaluation. This transformation demands a paradigm shift in procurement workflows (Meschini et al., 2023, Meschini et al. 2024). The proposed system operates via a web platform, incorporating data, IFC models, and BPMN 2.0 workflows. To achieve this, current procurement procedures must shift to a model-based, open-source approach, facilitating the full digitalization of tender evaluation. This transformation demands a paradigm shift in procurement workflows (Meschini et al., 2023).

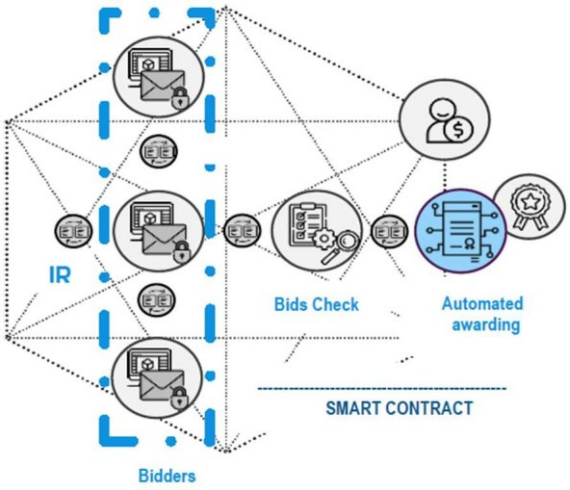

Figure 1: Scheme of the automated tender process

The workflow follows a structured approach:

1. The public client disseminates tender documentation through the platform.

2. Bidders download the required files and the corresponding IFC model.
3. Bidders prepare their bids and upload their IFC-based bid models.
4. Each bid is assigned a unique hash identifier, enabling verification against the client's and regulatory IRs.
5. Non-compliant bids are automatically disqualified, with explanations provided, while compliant bids proceed to evaluation.
6. The judging commission evaluates bids using the MEAT criterion, with automated scoring based on predefined, objective metrics

This automated evaluation process enhances objectivity and transparency. Open formats, evaluation algorithms, and real-time dashboards facilitate bid comparison, streamlining decision-making. Furthermore, the winning bid is securely stored on the blockchain, ensuring data integrity and serving as a reference for the construction phase. Through blockchain and smart contracts, the winning project remains unalterable, functioning as a verified prototype aligned with the client's specifications. This approach strengthens information modeling and management, ensuring consistency, traceability, and compliance throughout the procurement and construction phases (Kim and Kim, 2024; Meschini et al., 2023, Meschini et al., 2024) (Figure 2).

Automating Bid Evaluation and Smart Contract Deployment

A replicable methodology has been developed to automate bid evaluation by extracting data from BIM models and structuring the procurement process into a digital, machine-readable system. This approach involves four key steps:

1. BPMN Normalization: The procurement and evaluation process are structured using BPMN 2.0, ensuring that information exchanges and automatable tasks are clearly identified.
2. Information Requirements (IRs) Definition: IRs are mapped into IFC models through standard or customized property sets, enabling automated compliance checks.
3. Data Conversion and Evaluation: IFC models are converted into CSV format using the NIST IFC Analyzer tool, allowing for automated extraction of required quantities and bid scoring through an evaluation algorithm (Meschini et al., 2023).
4. Analytic Dashboards Development: Dashboards provide real-time visual comparisons of bids based on individual criteria, sub-criteria, and overall scoring metrics.

The NIST tool enables comprehensive entity and attribute visualization, generating spreadsheets directly from IFC files (Meschini et al., 2023). The procurement process is formalized within BPMN 2.0, linking it to data-driven automation and smart contracts, ensuring process transparency, efficiency, and trustworthiness.

The BPMN is not reported here due to space issues, but was published in (Meschini et al. 2023), and it incorporates four key lanes:

- The web-based platform as a centralized hub for data exchange.
- Public Client and Judging Committee: responsible for tender administration and evaluation.
- Bidders: submitting their proposals and interacting with the system.

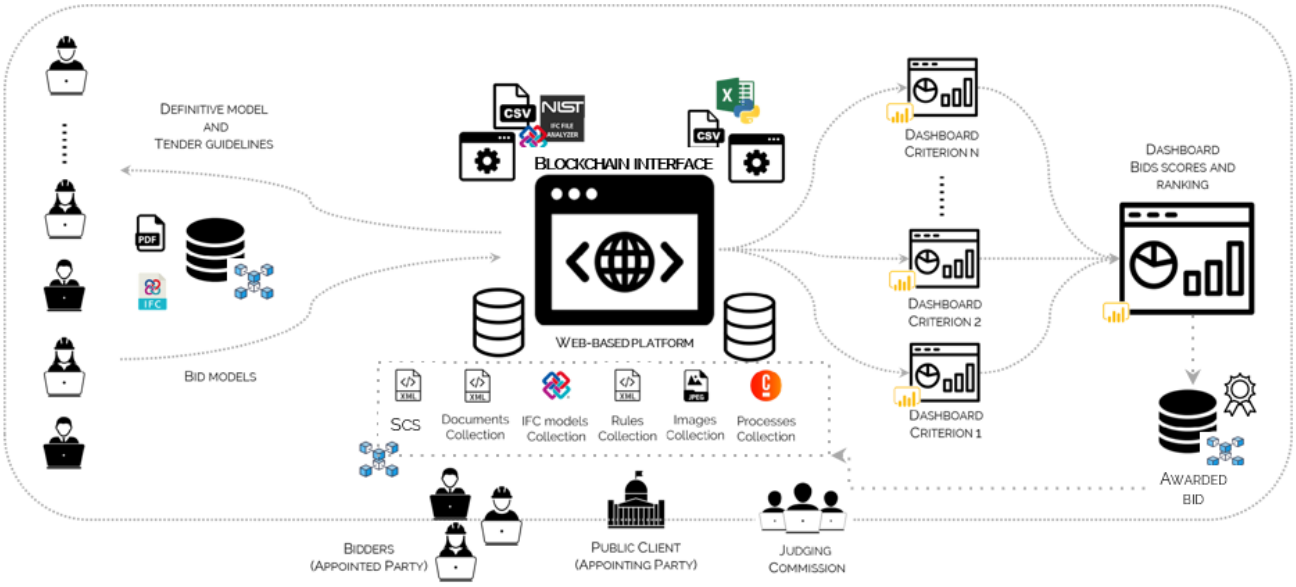

Figure 2: Digital, model-based, open-source and semi-automated system for bid evaluation and tender awarding

Within this structure, information flows are notarized via blockchain, ensuring data integrity, immutability, and transparency. The Public Client initiates the process by uploading tender documentation, including IRs, preliminary or definitive models, and evaluation criteria with their respective weightings. Submitted bidding models are notarized, preventing tampering and ensuring secure data sharing. The verification process is automated, assessing compliance with acceptance thresholds and anomaly detection, leading to the automatic acceptance or exclusion of bid models.

A Smart Contract records the verification results and links to the contract for bid evaluation against awarding criteria. This contract automatically triggers if bid parameters meet the minimum acceptance thresholds and do not fall within predefined anomaly ranges. Once the most compliant bid is identified, the Smart Contract finalizes the award process, with notarization of the awarded model. This ensures that the winning model remains immutable, facilitating construction phase monitoring and compliance tracking.

The envisioned impacts of this framework include:

1. Increased Transparency & Collaboration: Stakeholders operate within a secure and tamper-proof environment, enhancing trust in procurement decisions.
2. Accelerated Design Validation: Automated validation of bid submissions reduces appointment delivery times.
3. Automated & Accurate Compliance Verification: Ensures precise adherence to Information Requirements (IRs) without manual intervention.
4. Support for GPP: Enables data-driven decision-making, facilitates circular economy principles, and optimizes waste management.
5. Incentivization of Stakeholders: Automated payment releases and token-based rewards improve process objectivity and reduce delays.

Smart Contract Development and AI Integration

The Smart Contract creation process follows a structured workflow:

1. Defining Objectives & Requirements: Establishing tender rules and contract conditions.
2. Selecting the Blockchain Platform: Based on scalability, security, and transaction costs, options such as Ethereum or Hyperledger are chosen.
3. Developing the Smart Contract: Using Solidity or similar languages, contracts are coded to accurately reflect tender conditions.
4. Testing & Validation: The contract undergoes rigorous testing in a controlled environment before being deployed.
5. Deployment & Monitoring: The contract is published on the blockchain, ensuring accessibility and transparency for all stakeholders.

Given the complexity of business logic in smart contracts, Generative AI (Artificial Intelligence) can be leveraged to automate contract drafting (Petrovic et al., 2023). AI-powered models, such as GPT-4, can generate precise contract clauses based on structured input data, significantly reducing development time.

AI-generated contracts follow predefined rules, ensuring accuracy and minimizing errors, making them ready for immediate deployment (Petrovic et al., 2023; Nguyen et al., 2024).

So, the AI-Assisted Smart Contract Workflow consists of the following steps:

1. Input Requirement Gathering: Contract conditions are structured and fed into AI models.
2. AI-Based Drafting: The system automatically generates the initial contract.
3. Expert Review: Legal and technical experts verify contract validity and compliance.
4. Automated Testing & Deployment: Contracts undergo validation, testing, and blockchain deployment.

By integrating AI-driven smart contracts, the procurement process benefits from reduced legal and development costs, ensuring greater affordability and efficiency. It also enhances contract standardization, minimizing discrepancies and promoting consistency across procurement agreements. Additionally, the automation of contract execution and deployment significantly accelerates the process, reducing delays and improving overall operational efficiency.

Despite these advantages, ensuring regulatory compliance and maintaining human oversight is essential to validate AI-generated contracts, preventing inconsistencies and errors (Petrovic et al., 2023; Nguyen et al., 2024).

Proof-of-Concept: sustainable waste management in construction procurement

The proposed framework was tested within a Design Build (DB) procurement, which is particularly suited for model-based approaches as the building geometry is defined, and bids are evaluated based on their proposed improvements.

The study specifically focused on the semi-automated evaluation of waste management criteria, which are typically difficult to assess due to extensive data requirements. Indeed, even though Legislative Decree 50/2016 introduced GPP and the MEAT awarding criterion, later expanded to BIM and IFC standards, GPP and related CAM (Minimum Environmental Criteria) adoption remains low. This is due to the lack of data-driven evaluation tools, prolonging procurement and affecting bid quality (Lavagna et al., 2019; Sapir et al., 2022; OAV, 2022). Integrating waste management considerations at the tendering phase through a digital, automated system with blockchain notarization could facilitate GPP adoption and CAM application, reducing the environmental impact of construction projects.

The proposed approach is scalable and could be extended to evaluate additional CAM criteria and entire tendering processes (Meschini et al., 2023). A proof-of-concept case study was conducted on a new school project in Melzo, near Milan, a DB procurement with the MEAT awarding criterion. Although GPP and CAM criteria were not mandatory, there were similar awarding criteria, and the study piloted how Information Modelling and Management can support and improve the MEAT evaluation framework (Figure 3).

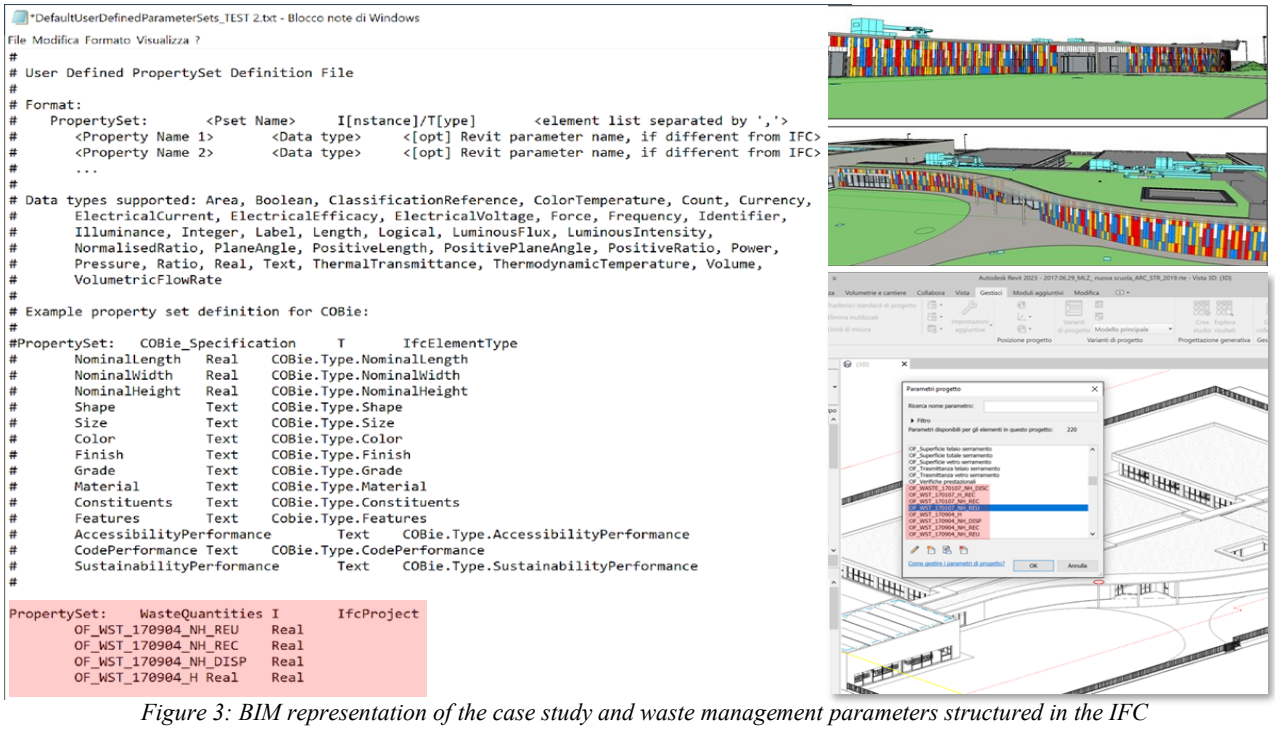

Figure 3: BIM representation of the case study and waste management parameters structured in the IFC

The focus was on criterion C 2.3 (Table 1), which pertains to waste management during construction. This criterion mandates the development and implementation of a waste management plan to maximize reuse and recycling efforts while minimizing landfill disposal (Pellegrini et al., 2021). Following the proposed methodology, IRs were defined and exported using the IFC open format with a customized property set. This Property Set categorized materials using European Waste Codes (EWC) and quantified four key waste management parameters: reused, recycled, landfilled hazardous, and landfilled non-hazardous materials. To allow maximum flexibility and customization, the "DefaultUserDefinedParameterSets" feature was employed. This process required a .txt file containing a tailored script to define the property set "Waste Quantities", ensuring structured and efficient waste data management within the BIM environment (Figure 3).

Smart contract and blockchain for the PoC

A Smart Contract was developed to manage transactions and store data on the blockchain, involving the Public Client (Authority/PA), Bidders, and the Judging Committee. All participants undergo registration and verification through Know Your Customer (KYC) and Anti-Money Laundering (AML) protocols, as required by regulators.

The stakeholders interact with the system by submitting transactions, making payments, sending data, and invoking Smart Contract functions. The process is divided into three key phases. The first is the "Privacy-Preserving Committal Bidding" phase. Bidders submit encrypted (hashed) offers containing documents, quotes, and a deposit (Figure 4).

The deposit ensures genuine participation, discouraging bid retractions or multiple bid submissions for unfair advantage. Bids are stored off-chain (via IPFS) with an immutable blockchain link to reduce costs.

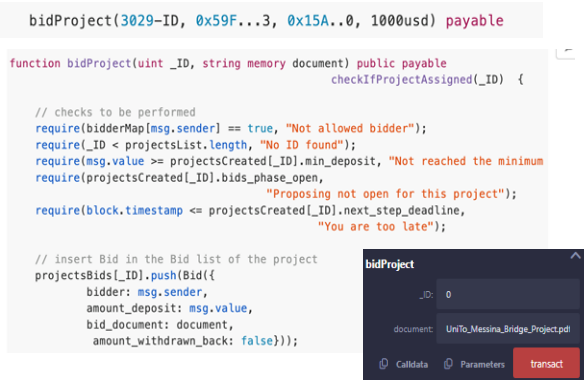

Figure 4: Overview of the protocol and interface handling the bidders' committal deposit process

Then the "Validation phase". Once the bidding phase ends, either at a predefined deadline or through client action, the system verifies bid authenticity. A dedicated interface (Figure 5) allows verified experts to vote, ensuring credential verification and correct vote submission. Votes are recorded on the blockchain, enhancing transparency and stakeholder visibility. When

bidders reveal their encrypted bids, the Smart Contract verifies consistency with prior commitments.

Table 1: Procurement evaluation criteria with emphasis on selected CAM-related requirements

Category	Criterion	Sub-criterion
A – Passive elements	A.1-Thermal transmittance A.2-Building materials A.3-Environmental requirements	…. A.3.1 – Contractor certification (UNI EN ISO 14001) A.3.2 – Producers' certifications (UNI EN ISO 14001)
B – Active elements	B.1Plant system operation B.2-Plant system component B.3-Increased electricity from renewable sources B.4-Smart resources use	….. …..
C – Construction phase	C.1-Safety C.2-Construction solution and site management	C.1.1-Contractor certification (OHSAS 18001) C.2.2-Construction site layout C.2.3 – Waste management ….
D – Maintenance	D.1-Building maintenance D.2-Plant system maintenance	…..

Figure 5: Overview of the protocol and interface governing the validation of expert evaluations.

The last phase is the "Awarding and Notarization". The best bid is deterministically selected using a quantifiable, verifiable evaluation process. The winner's cryptographic address confirms identity, preventing bid alterations or retractions. Upon bid revelation, deposits are refunded, and experts assign numerical scores. The system can record expert justifications via a voting mechanism or integrate an expert reputation framework. A commit/reveal system backed by deposits promotes fairness and mitigates bias in qualitative assessments (Figure 6).

Figure 6: Overview of the protocol and interface managing the bidders' committal deposit

Conclusion and further developments

This research presents a comprehensive methodology that integrates digital technologies to automate and streamline procurement processes, traditionally reliant on manual, subjective, and error-prone tasks. The framework supports MEAT-based evaluation by linking tender assessments to structured, policy-aligned sustainability data, enabling objective, transparent, and regulation-compliant decision-making. Blockchain ensures traceability, confidentiality, and tamper-proof bid storage, while smart contracts automate verification, evaluation, awarding, and even payment processing, reducing reliance on intermediaries and minimizing corruption risks. By aligning with GPP goals, the methodology allows for rapid verification of CAM criteria and other environmental benchmarks, reducing project impact and promoting accountability. This approach also enhances data management across the tendering lifecycle, ensuring compliance with Client and regulatory IRs through standardized IFC property sets. Real-world prototyping and process standardization via BPMN demonstrate the system's feasibility and scalability. Nonetheless, key challenges remain, including defining machine-readable IRs, managing complex datasets, integrating with national platforms, and adapting to outdated regulatory frameworks. Technical hurdles such as smart contract reliability, stakeholder privacy, and IT skill gaps also require attention. Furthermore, minimizing blockchain's environmental footprint is key and leveraging sustainable High-Performance Computing (HPC) infrastructure, such as the renewable-energy-powered center in development at the University of Turin, can help mitigate this. Ensuring compliance with data privacy regulation through architecture such as off-chain data handling, will also be critical for adoption in sensitive procurement contexts. Future research will focus on overcoming these barriers to advance the adoption of transparent, secure, and efficient digital procurement in public construction. Additionally, the use of Large Language Models (LLMs)

will be explored to enhance procurement data structuring, retrieval, and analysis, improving compliance and decision-making processes.

Acknowledgments

Work supported by the NRRP project NODES, Spoke 2 – MUR - grant agreement no. ECS000036.

References

Ahmadisheykhsarmast, S., Senji, S. G., & Sonmez, R. (2023). Decentralized tendering of construction projects using blockchain-based smart contracts and storage systems. *Automation in Construction*, *151*, 104900.

BPMN (2011) Business Process Model and Notation, Version 2.0 Standard. Object Management Group (OMG).

European Commission (2017) Making public procurement work in and for Europe. Available at: [URL if available].

European Commission (2022) EU Single Market Scoreboard - Public Procurement.

Gunasekara, H. G., Sridarran, P., & Rajaratnam, D. (2022). Effective use of blockchain technology for facilities management procurement process. Journal of Facilities Management, 20(3), 452-468.

Guu, K., Lee, K., Tung, Z., Pasupat, P., and Chang, M. (2020) 'Retrieval augmented language model pre-training', International Conference on Machine Learning,pp. 3929–3938.

Kim, M. and Kim, Y.W. (2024) Applications of blockchain for construction project procurement', Automation in Construction, 165, 105550.

Lavagna, M., Bessi, A., Meneghelli, A., and Moschini, P. (2019) The environmental dimension of detailed design. Experiences and future perspectives', TECHNE- Journal of Technology for Architecture and Environment.

Meschini, S., Di Giuda, G. M., Tagliabue, L. C., Locatelli, M., and Pellegrini, L. (2023) 'BPMN 2.0 to redefine Italian design-bid procurement in an innovative model-based, open-source approach', EC3 Conference, 4, pp. 1-8. doi:10.35490/EC3.2023.327.

Meschini S., Cacciaguerra E., Gasbarri P., Tagliabue L.C., Di Giuda G.M. (2024). Promoting Green Public Procurement: a model-based and open-source waste management evaluation in the Italian Design-Build procedure. 41st International Conference of CIB W78, Marrakech, Morocco, 2-3 October, ISSN: 2706-6568. (ISSN: 2706-6568)

Nai, R., Sulis, E., Fatima, I., and Meo, R. (2024) Large Language Models and Recommendation Systems: A Proof-of-Concept Study on Public Procurements', NLDB Proceedings.

Nguyen, C.T., Liu, Y., Du, H., Hoang, D.T., Niyato, D., Nguyen, D.N., and Mao, S. (2024) 'Generative AI-enabled blockchain networks: Fundamentals, applications, and case study', IEEE Network.

OECD (2019) G20 Compendium of Good Practices in Infrastructure Development.

OAV, Osservatorio Appalti Verdi (2022) I numeri del Green Public Procurement in Italia. Legambiente: Rome, Italy.

Pattini, G., Di Giuda, G. M., and Tagliabue, L. C. (2022) 'The Integration of Automatic BIM Validation and Smart contracts for Design Compliance and Payment Reliability in the Design Process', in Dounas, T. and Lombardi, D. (eds.) Blockchain for Construction. Cham: Springer Nature, pp. 47–73.

Pellegrini, L., Locatelli, M., Meschini, S., Pattini, G., Seghezzi, E., Tagliabue, L.C., and Di Giuda, G.M. (2021) 'Information Modelling Management and Green Public Procurement for Waste Management and Environmental Renovation of Brownfields', Sustainability, 13(15), 8585. doi:10.3390/su13158585.

Petrović, N. and Al-Azzoni, I. (2023) 'Model-driven Smart Contract generation leveraging ChatGPT', in International Conference On Systems Engineering, pp. 387-396. Cham: Springer Nature Switzerland.

Robertson, S., Zaragoza, H., et al. (2009) 'The probabilistic relevance framework: BM25 and beyond', Foundations and Trends in Information Retrieval, 3(4), pp. 333–389.

Sapir, A., Schraepen, T., and Tagliapietra, S. (2022) 'Green public procurement: A neglected tool in the European Green Deal toolbox?', Intereconomics, 57(3), pp. 175-178.

Sreckovic, M., Sibenik, G., and Breitfuß, D. (2022) 'Capturing and Transforming Planning Processes for Smart Contracts', in Dounas, T. and Lombardi, D. (eds.) Blockchain for Construction. Cham: Springer Nature, pp. 75–88.

Torkanfar, N., Azar, E. R., & McCabe, B. (2023). BidChain: a blockchain-based decentralized application for transparent and secure competitive tendering in public construction projects. Journal of Construction Engineering and Management, 149(7), 04023050.

Tezel, A., Febrero, P., Papadonikolaki, E., & Yitmen, I. (2021). Insights into blockchain implementation in construction: models for supply chain management. Journal of management in engineering, 37(4), 04021038.