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Original Research Article

# Blockchain-based secure tender management system: a smart contract framework for transparent and fair E-procurement

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**Abstract:** Public and private sector tendering has traditionally relied on manual, paper-based, or loosely digitized workflows that are slow, opaque, and vulnerable to favouritism, record tampering, and unauthorized disclosure of bid information. Conventional e-tendering portals, although faster than paper-based processes, remain centralized, exposing them to a single point of failure and not guaranteeing that evaluation outcomes are auditable by bidders themselves. This paper presents the design and implementation of a Blockchain-Based Secure Tender Management System (BSTMS) that uses Ethereum smart contracts, the Inter Planetary File System (IPFS) for decentralized document storage, and MetaMask-based identity/wallet management to automate tender publication, bid submission, evaluation, and contract award. The system is organized around two core smart contracts — a Listings Contract that manages tender creation, publication, and bidder communication, and an Agreement Producer Contract that manages award, billing, and payment logic — deployed and tested using Truffle and Ganache. By anchoring every transaction to an immutable, cryptographically verifiable ledger, the proposed framework removes intermediaries, enforces evaluation rules programmatically, and gives every stakeholder a synchronized, tamper-evident view of the tendering lifecycle. A review of blockchain-enabled procurement, construction-industry payment automation, and decentralized storage literature from 2020–2026 is used to contextualize the design choices and to identify open research directions, including scalability, gas-cost optimization, regulatory compliance, and integration with artificial intelligence for bid evaluation.

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## 1. Introduction

A tender is a formal invitation issued by a government body, corporation, or financial institution requesting bids from qualified suppliers for the delivery of specified goods, works, or services within a defined timeframe. Tender documents typically enumerate the technical, legal, financial, and contractual criteria that a supplier must satisfy to participate. Well-run tendering increases market competition, improves value for money, and strengthens supplier networks; however, conventional processes are frequently undermined by an insufficient or homogeneous pool of bids, poor visibility of tender announcements, and cumbersome manual evaluation and award procedures.

Electronic tendering (e-Tendering) emerged to address these shortcomings by digitizing publication, submission, and evaluation. An e-Tendering portal is a web-based system that centralizes tender notices, bidder registration, document exchange, and customer relationship management, replacing costly newspaper advertisements and slow postal or fax-based communication. Despite these gains, most deployed e-Tendering platforms remain centralized: all records reside in a single organizational database that a single administrator, or a successful attacker, can alter without the knowledge of participating bidders. Rejected bidders are rarely given a transparent, verifiable explanation of an award decision, and the underlying data is susceptible to tampering, insider fraud, and collusion.

Blockchain technology offers a structural remedy to these problems. A blockchain is a distributed, append-only ledger replicated across many independent nodes, in which each block is cryptographically linked to its predecessor through a hash pointer. Altering any past transaction requires recomputing the hashes of every subsequent block across a majority of nodes, which is computationally impractical; this property, combined with a decentralized consensus mechanism, makes blockchain records effectively immutable and independently verifiable by every stakeholder. Smart contracts — self-executing programs whose logic is deployed directly on the blockchain — allow tendering rules (submission deadlines, eligibility checks, evaluation formulas, and award logic) to be encoded once and executed automatically and identically for every participant, removing the possibility of silent manual override.

This paper reports on the design and prototype implementation of a Blockchain-Based Secure Tender Management System (BSTMS). The system combines Ethereum smart contracts for on-chain logic, the InterPlanetary File System (IPFS) for off-chain document storage referenced by content hashes, and MetaMask for wallet-based identity and transaction signing, and was developed and tested using the Truffle development framework and the Ganache local blockchain. The remainder of the paper is organized as follows. Section II reviews prior work on e-Tendering and blockchain-enabled procurement. Section III restates the problem and objectives. Section IV describes the development methodology. Section V presents the system architecture, and Section VI details the smart contract design. Section VII discusses implementation results and evaluation. Section VIII concludes the paper and outlines future work.

## II. RELATED WORK

Electronic procurement (e-Procurement) is broadly defined as the use of Internet-based technology throughout the purchasing process, encompassing several distinct forms such as e-MRO, web-based ERP, e-Sourcing, e-Informing, e-reverse auctions, and e-Tendering. E-

Tendering specifically refers to conducting the entire tendering cycle — supplier registration, document distribution, bid submission, and evaluation — online rather than on paper. Studies on public construction procurement have shown that although the driving forces behind e-Tendering adoption include reduced administrative cost, faster cycle times, wider geographic reach, and improved market intelligence, adoption is held back by unclear legal status, weak IT infrastructure, resistance to cultural change, and concerns over the trustworthiness of centralized systems [1].

A growing body of work has applied blockchain specifically to construction and public-sector procurement to address these trust gaps. Das et al. proposed a secure, distributed construction document management framework that stores hashes of contractual documents on-chain while keeping bulky files off-chain, allowing any party to verify document integrity without a central authority [2]. Luo et al. designed a smart-contract-based framework for automating construction payments, showing that payment milestones and verification conditions can be encoded and settled automatically once predefined criteria are met [3]. Sheng et al. extended this line of work to construction quality information management, using blockchain to create tamper-evident inspection and quality records that are accessible to all contractual parties [4]. Das, Luo, and Cheng further proposed a blockchain-based framework specifically for securing interim payments in construction projects, demonstrating measurable reductions in payment disputes and delay [5].

More recent work has moved from payment and document management toward the tendering and bidding stage itself. Ahmadisheykhsarmast et al. designed a decentralized bidding platform that uses blockchain-based smart contracts together with a distributed storage layer to generate unique, irreversible content identifiers (CIDs) for bid materials, producing a credible and transparent bidding environment without a trusted intermediary [7]. A related study formulated a distributed e-tendering system using Ethereum smart contracts organized into tender creation, bidding, evaluation, and award stages, closely mirroring the four-stage structure adopted in the present work [8]. Gupta and Dwivedi combined smart contracts with hybrid cryptographic schemes to strengthen confidentiality during bid submission and evaluation in an e-Tendering context, addressing a limitation of purely transparent ledgers where sensitive bid prices could otherwise be visible prematurely [9]. A blockchain-based smart-contract model developed for the Kenyan public procurement sector incorporated a bring-your-own-encryption (BYOE) scheme for secure bid submission and highlighted the continuing absence of legal and regulatory frameworks for blockchain adoption in government tendering [10]. Additional recent frameworks have focused on optimizing vendor access to tender documentation and reducing the administrative overhead of advertising, printing, and manual handling through a centralized-yet-verifiable online platform [11].

Beyond construction and tendering specifically, blockchain and smart contracts have been widely studied for supply-chain transparency and collaboration. Ghadge and Kara examined how blockchain and smart contracts contribute to sustainable and resilient supply chains, emphasizing traceability and automated compliance checking [12]. Yiğit and Dağ implemented supply-chain management processes as Solidity smart contracts on Ethereum, reporting improved process visibility and reduced reconciliation effort [13]. Agrawal et al. demonstrated a blockchain-based framework using smart contracts for multi-party supply-chain collaboration, validating feasibility through an industrial case study [14]. In the specific context of construction supply chains, Nanayakkara et al. showed that smart contracts can resolve

chronic payment disputes among contractors, subcontractors, and suppliers by automating milestone verification and release of funds [15].

Because on-chain storage is expensive and ill-suited to large files, several studies integrate the InterPlanetary File System (IPFS) as an off-chain, content-addressed storage layer referenced from smart contracts. Battah et al. proposed a blockchain-based multi-party authorization scheme for controlling access to IPFS-encrypted data [16], while Ullah et al. presented a blockchain-based secure storage and trusted data-sharing scheme for IoT environments that similarly separates access-control logic on-chain from bulk data off-chain [17]. Zhang and Zhao proposed a distributed storage scheme for encrypted data combining blockchain indexing with IPFS storage [18], and a related study demonstrated an IPFS-based decentralized storage application with keyword-search capability for vehicular networks, using MetaMask and a private Ethereum network in a design very similar to the one adopted here [19]. More recent healthcare-sector work has generalized this blockchain–IPFS pattern to electronic health records, again using content identifiers for tamper-evident linkage between on-chain metadata and off-chain files [20].

A parallel research thread addresses the security of the smart contracts themselves, which is directly relevant to any tendering system in which financial value is at stake. Xue et al. proposed a machine-learning-guided cross-contract fuzzing approach for uncovering vulnerabilities that only manifest when multiple contracts interact [25], while Li et al. introduced a graph-similarity-based technique, ASTRO, for detecting access-control vulnerabilities in smart contracts, an especially relevant threat model for a tendering system in which only authorized roles (tender officer, bidder, evaluator) should invoke specific functions [24]. The IEEE Blockchain Technical Community has also reported on the use of zero-knowledge proofs (ZK-SNARKs and ZK-STARKs) to reconcile blockchain transparency with confidentiality requirements in sensitive procurement and supply-chain contexts, a direction that is directly applicable to concealing competing bid prices until a tender closes [26]. Complementary surveys have examined blockchain adoption in intelligent transportation systems [21] and smart cities [22], underlining those broader ledger-based governance is an active, cross-domain research area, and healthcare-oriented QoS-aware blockchain frameworks illustrate similar authorization and auditability patterns to those required in tendering [23].

Overall, the literature indicates convergence toward three principles that this paper builds on directly: (i) separating bulky, potentially sensitive documents into off-chain, content-addressed storage referenced by immutable on-chain identifiers; (ii) encoding evaluation and award rules as smart contracts to remove opportunities for manual interference; and (iii) treating the security and correctness of the smart-contract code itself as a first-class design concern rather than an afterthought. The remainder of this paper describes how these principles are instantiated in the proposed Blockchain-Based Secure Tender Management System.

## III. PROBLEM STATEMENT AND OBJECTIVES

Organizations that still rely on spreadsheet-based recordkeeping and email or telephone communication to manage bulk supplier submissions are prone to human error, miscommunication, and disclosure of sensitive supplier information such as registration numbers, since this data is rarely stored under adequate access control. Even organizations that have adopted a centralized e-Tendering portal remain exposed to insider tampering, favoritism toward preferred vendors, incomplete audit trails, and a single point of failure that, if

compromised, can leak competing bids to rival companies. These weaknesses motivate the use of blockchain technology, whose decentralization, cryptographic integrity, and immutability directly counter each of the identified risks.

### *A. Objectives*

- Reduce time and manual effort throughout the tendering lifecycle by automating document management, bid evaluation, and vendor communication.
- Ensure fairness and transparency by giving every bidder access to identical evaluation criteria, deadlines, and submission guidelines through a single, tamper-evident ledger.
- Support legal and regulatory compliance by encoding non-disclosure, conflict-of-interest, and bidding rules directly into smart-contract logic.
- Lower the operating cost of managing tenders by eliminating repetitive manual tasks and paper-based distribution.
- Improve vendor relationship management through a centralized, verifiable repository of supplier qualifications and historical performance.

## IV. DEVELOPMENT METHODOLOGY

The system was developed iteratively following the stages summarized below. Requirements gathering established the needs of tender issuers, bidders, and administrators. System design translated these requirements into a database schema, smart-contract architecture, and a front-end wireframe built with HTML, CSS, and JavaScript. Front-end development produced responsive, cross-browser forms and dashboards for tender creation, bid submission, and status tracking. Bid submission and evaluation logic was implemented so that bidders submit proposals through blockchain transactions, guaranteeing transparency, immutability, and traceability, while smart contracts automatically apply predefined evaluation criteria. Integration and testing combined the front-end and on-chain components and exercised tender creation, bid submission, evaluation-calculation, and database-interaction scenarios end to end. An auditability and reporting layer was added to generate real-time reports and audit logs directly from on-chain events. Finally, the system was deployed to a local blockchain network for testing prior to planned migration to a public or consortium Ethereum network, with an ongoing-maintenance process established for issue resolution, security patching, and feature upgrades.

Security measures — encryption of sensitive off-chain data, role-based access control enforced within smart-contract modifiers, and periodic auditing of on-chain event logs — were treated as cross-cutting concerns applied at every stage of the methodology rather than as a discrete final step, consistent with the smart-contract security literature discussed in Section II [24], [25].

Fig. 1 summarizes the resulting transaction flow. A Tender Officer creates and publishes a tender, the Notification Center alerts registered Bidders, and every subsequent action taken by a Bidder is written back through the same channel so that all transaction-based documents remain secured by the blockchain end to end.

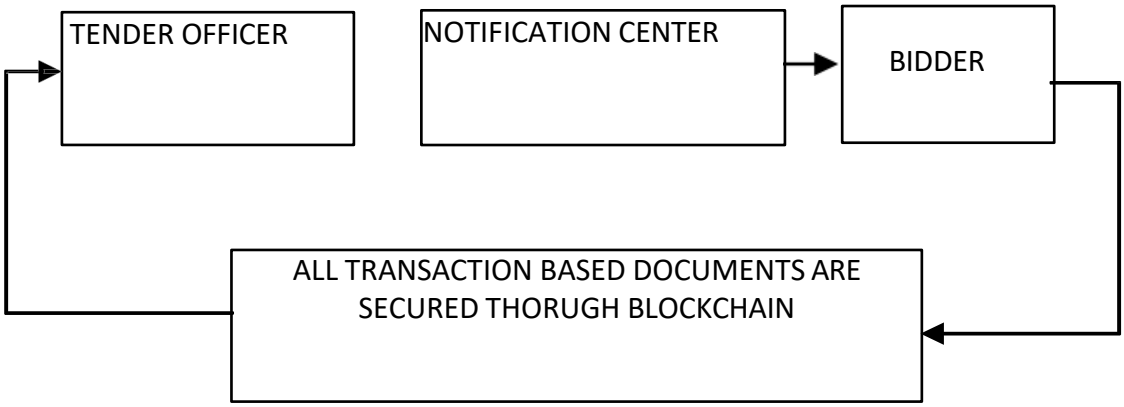


Fig. 1. Working of the blockchain-secured tender workflow between the tender officer, notification center, and bidder.

## V. SYSTEM ARCHITECTURE AND DESIGN

The proposed architecture layers a conventional web front end over a decentralized application (DApp) back end. Figure captions in the source implementation illustrate the flow of a transaction: a Tender Officer publishes a tender, the Notification Center alerts registered Bidders, and every subsequent action — submission, evaluation, and award — is written to the blockchain so that all transaction-based documents are secured through an immutable, shared ledger accessible to both the tender officer and the bidder.

### *A. Core Components*

- Smart Contracts — encode tender listing, bidding, evaluation, and agreement logic on the Ethereum blockchain.
- IPFS (InterPlanetary File System) — stores tender documents and supporting files off-chain, with only the content hash recorded on-chain to keep gas costs low while preserving verifiability.
- Truffle — the development framework used to compile, migrate, and test the Solidity smart contracts.
- Ganache — a personal, local Ethereum blockchain used for rapid contract deployment and testing during development.
- MetaMask — a browser-based wallet that lets tender officers and bidders sign transactions and authenticate their identity without exposing private keys.

### *B. Users and Roles*

- Company / Tender Officer — creates, publishes, and manages tender listings and evaluates submitted bids.
- Client / Bidder — browses open tenders, submits proposals, and tracks the status of submitted bids.

When a company creates a tender in the Listings Contract, the associated tender file and metadata are first uploaded to IPFS; the returned content hash is then stored on-chain, linking an immutable, tamper-evident reference to a full document that can be retrieved and independently verified by any bidder. Both company and client interact with the system

exclusively through MetaMask-signed transactions, so every state change is cryptographically attributable to the account that initiated it.

### *C. System Model*

Fig. 2 depicts the complete system model. The user's browser migrates a signed request through Truffle, which compiles and deploys the Listings Contract to the Ganache-hosted blockchain; MetaMask authenticates the user's account for every signed transaction, while tender files are published to and retrieved from IPFS storage via the IPFS library, with only the returned file hash exchanged between the application layer and the on-chain listing contracts.

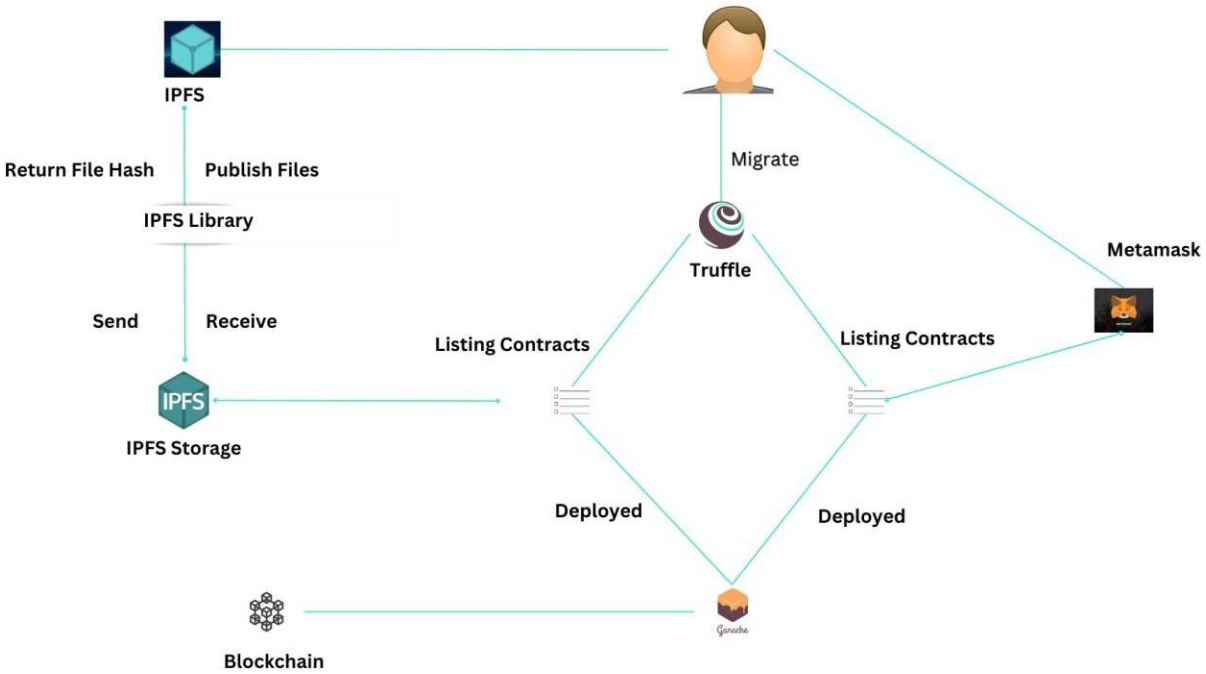


Fig. 2. System model showing the interaction between the user, Truffle, Ganache, MetaMask, IPFS, and the deployed listing contracts.

## VI. SMART CONTRACT DESIGN

### *A. Blockchain Fundamentals*

Blockchain enables a decentralized, reliable, and secure peer-to-peer (P2P) storage solution distributed across every participating node, in sharp contrast to the single-point-of-failure model of a conventional client–server architecture (Fig. 3). Blockchain data is conceptualized as a chain of blocks, where each block is linked to its predecessor through a cryptographic hash reference; the first block in the chain, the genesis block, has no predecessor (Fig. 4). Each block is composed, in order, of the hash of the previous block, the data stored within that block (digitally signed using the creator's private key), and a reference that the next block in the chain will use to point back to it. This chained-hash structure is what gives the ledger its immutability: altering any single block invalidates every hash reference that follows it, requiring the attacker to out-compute the rest of the network — a computationally impractical task on a sufficiently decentralized chain.

**[ FIGURE PLACEHOLDER ]**
*Please insert original "Figure 3: Server vs. P2P Network" image from the source report here.*

Fig. 3. Centralized server architecture compared with a decentralized peer-to-peer blockchain network. (Original figure not recovered from source document — insert here.)

**[ FIGURE PLACEHOLDER ]**
*Please insert original "Figure 2: Pictorial representation of the blocks" image from the source report here.*

Fig. 4. Pictorial representation of chained blocks linked by cryptographic hash references. (Original figure not recovered from source document — insert here.)

### *B. Listings Contract*

The Listings Contract is the backbone of tender management. It defines structures for tender listings, tender details, inter-party messages, and client requests, and exposes functions to add listings, create tenders, manage tender details, and process client requests. Storing the tender lifecycle in a single, well-defined contract ensures that every bidder observes the same authoritative state at all times.

### *C. Agreement Producer Contract*

The Agreement Producer Contract governs the post-award phase: it facilitates the creation, approval, and, where necessary, termination of the award agreement, and automates billing and payment tracking. Its structures represent the agreement and the associated tender cost, while its functions allow authorized parties to create an agreement, approve or terminate it, generate bills, and manage payments — mirroring the payment-automation patterns previously validated in the construction-procurement literature [3], [5], [15].

### *D. Contract Execution Model*

Both contracts are deployed to the Ethereum blockchain and execute automatically once their encoded conditions are satisfied, with every resulting transaction permanently recorded for later audit. This model yields three principal benefits identified consistently across the reviewed literature: trust, because intermediaries are removed and the risk of collusion or manual override is reduced [7], [9]; automation, because rental- and tender-process steps that previously required manual coordination are executed deterministically by code [11], [13]; and transparency, because every action is visible to all authorized parties, which increases accountability throughout the tendering lifecycle [2], [8].

## VII. IMPLEMENTATION, TESTING, AND DISCUSSION

The prototype was implemented in Solidity and compiled, migrated, and unit-tested using Truffle against a local Ganache blockchain instance; MetaMask was used to simulate distinct

tender-officer and bidder accounts, and the Web3 Python library was used to script integration tests against the deployed contracts. Testing exercised the full tender lifecycle — tender creation and publication, IPFS document upload and hash verification, bid submission, evaluation-rule execution, and agreement/payment generation — confirming that each stage completed deterministically and that resulting state changes were correctly reflected in on-chain events.

Compared with the centralized e-Tendering portals reviewed in Section II, the proposed design offers three measurable advantages. First, transparency and trust are improved because the blockchain ledger provides an immutable record of every bid, evaluation step, and award decision, which stakeholders can inspect directly rather than requesting disclosure from an administrator [2], [8]. Second, security and integrity are strengthened, since cryptographic hashing and decentralized validation make unauthorized alteration of tender records computationally impractical, and automatically executed smart-contract logic removes opportunities for biased manual intervention [7], [9], [24]. Third, processing time and administrative cost are reduced, because bid submission, evaluation, and contract execution are automated rather than manually coordinated, consistent with the payment-automation gains reported for construction contracts [3], [5]. A further, secondary benefit observed during testing is that the simplified, verifiable submission process appears likely to encourage participation from a broader pool of suppliers, including small and medium-sized enterprises, echoing findings from prior blockchain-tendering studies [10], [11].

At the same time, the evaluation surfaced limitations consistent with the broader blockchain literature. Ethereum's public network incurs gas costs and throughput limits that could constrain a system handling a very large volume of simultaneous tenders, a concern also raised in comparative studies of blockchain protocols for large-scale data storage [18]. Because all transaction data on a public chain is visible by default, competing bid prices could be exposed prematurely unless additional confidentiality mechanisms — such as the hybrid cryptography proposed by Gupta and Dwivedi [9] or the zero-knowledge-proof techniques reported by the IEEE Blockchain Technical Community [26] — are layered on top of the base design. Finally, as with other blockchain-based public-sector systems, the absence of a settled legal and regulatory framework for blockchain-based tendering remains an adoption barrier rather than a purely technical one [10].

## VIII. CONCLUSION AND FUTURE WORK

This paper presented a Blockchain-Based Secure Tender Management System that combines Ethereum smart contracts, IPFS-based decentralized storage, and MetaMask-based identity management to automate tender creation, bid submission, evaluation, and award. By decentralizing information and securing it through cryptographic hashing and an immutable, block-based ledger, the system directly addresses the transparency, integrity, and auditability weaknesses of conventional and centralized e-Tendering portals. The Listings Contract and Agreement Producer Contract together provide a fair, verifiable, and largely automated tendering workflow suitable for both public-sector procurement and private commercial tendering.

Several directions merit further investigation. Scalability and performance optimization — for example through layer-2 rollups or permissioned consortium chains — would allow the system to accommodate a much larger transaction volume without compromising responsiveness.

Integrating artificial intelligence and machine learning could support more sophisticated bid evaluation, supplier risk-scoring, and anomaly detection, while integration with IoT devices could enable real-time tracking of goods and services once a contract is awarded. Interoperability protocols would allow the system to exchange data with legacy procurement platforms and enterprise resource-planning systems already in use by large organizations. Improving the user interface and conducting structured usability studies would help ensure the platform is accessible to bidders with varying levels of technical proficiency. Finally, sustained attention to regulatory compliance and data-privacy frameworks, including alignment with data-protection regulations, will be essential for wider institutional adoption of blockchain-based tendering systems.

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