Frontiers in Emerging Artificial Intelligence and Machine Learning (Open Access)

Volume 03, Issue 01, January 2026,

DOI: https://doi.org/10.64917/feaiml/Volume03Issue01-02 PageNo.09-32

Blockchain-Enabled PO/Invoice Reconciliation: Automating Audit Trails for Public Infrastructure Grants

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RECEIVED - 11-07-2025, **RECEIVED REVISED VERSION** - 01-08-2026, **ACCEPTED**- 01-11-2026, **PUBLISHED**- 01-16-2026

Abstract

Traditional Purchase Order (PO)-to-invoice reconciliation processes in infrastructure finance are often fragmented, opaque, and vulnerable to error or manipulation, especially within public-sector grant-funded projects. Manual validation and spreadsheet-based tracking make it difficult to maintain transparency, traceability, and compliance across multiple 6stakeholders. This paper proposes a blockchain-enabled framework for automating audit trails in PO/invoice reconciliation, ensuring data integrity, accountability, and real-time verification of financial transactions.

The study explores how distributed ledger technology (DLT) can integrate with existing enterprise resource planning (ERP) systems to record procurement events—purchase orders, goods receipts, and invoices—on an immutable, time-stamped ledger. Smart contracts are introduced to automatically validate invoice–PO matches and flag anomalies in payment amounts, vendor identities, or project milestones. Using simulated public infrastructure grant data, the proposed framework compares blockchain-assisted reconciliation to traditional FP&A workflows on metrics such as accuracy, processing time, and audit readiness.

The results demonstrate that blockchain-based reconciliation significantly enhances financial transparency, reduces manual effort, and mitigates fraud and double billing. Furthermore, integration with business intelligence dashboards enables continuous monitoring of fund utilization across projects. This research contributes to the emerging domain of financial technology in infrastructure governance by showing how blockchain can transform reconciliation from a reactive accounting process into a proactive, automated compliance mechanism.

Keywords: Blockchain, Smart Contracts, Purchase Order Reconciliation, Predictive Analytics, Financial Governance, Audit Trail Automation, Business Intelligence, ERP Integration, FP&A, Public Infrastructure Finance.

1. Introduction

Public infrastructure projects supported by government grants are among the most complex financial undertakings in public administration. Multiple actors—funding agencies, contractors, and suppliers—generate vast procurement and payment data. Within this network, the PO-to-invoice reconciliation process ensures that payments correspond to approved commitments. However, in most public-sector projects, reconciliation remains manual and fragmented, often performed through spreadsheets or disconnected systems. These inefficiencies lead to delayed disbursements, duplicate payments, and audit exceptions that undermine transparency and accountability (Ahiaga-Dagbui & Smith, 2014).

Centralized database systems aggravate the problem. They create single points of control vulnerable to manipulation, face interoperability issues between distinct ERP platforms, and offer limited real-time auditability. Even recent machine-learning-based anomaly-detection tools rely on centralized data that can be altered without trace. For publicly funded projects where audit integrity is mandatory, this is a critical weakness.

Blockchain technology—with its decentralization, immutability, and cryptographic traceability—offers a trustworthy alternative. It extends conventional double-entry bookkeeping into *triple-entry accounting* where transactions are co-signed by both parties and recorded on a distributed ledger (Dai & Vasarhelyi, 2017; Kokina & Davenport, 2017). This shift enables continuous, real-time verification rather than retrospective audits. *Frontiers in Blockchain* (2025) highlights how distributed ledgers reduce fraud risk and eliminate single points of failure in audit systems.

Applied to PO/invoice reconciliation, blockchain records procurement events—PO creation, goods receipt, and invoice submission—as immutable, time-stamped entries. Embedded smart contracts cross-verify quantities, vendor IDs, and prices before approving payment, turning the traditional three-way match into a decentralized, self-executing workflow. Studies such as *A Blockchain-Based Audit Trail Mechanism* (MDPI, 2021) report verification-time reductions exceeding 40 percent.

When linked with ERP and BI platforms, blockchain further enhances operational visibility. Secure APIs can connect blockchain outputs to systems like SAP or Oracle and feed verified records into Power BI dashboards, allowing finance teams to track reconciliation status and vendor performance in real time (Popovič et al., 2012).

Despite these advantages, adoption remains limited by scalability, privacy laws, and system interoperability (Schmitz & Leoni, 2019; Coyne & McMickle, 2017). Furthermore, blockchain preserves data integrity but not source accuracy (Wüst & Gervais, 2018). This study therefore develops and tests a blockchain-based reconciliation framework addressing these issues.

Research Questions:

1. How can blockchain improve accuracy and timeliness of PO-to-invoice reconciliation?
2. What role do smart contracts play in reducing manual intervention and audit delays?
3. How can blockchain data integrate with BI dashboards for continuous oversight?

2. Literature Review

2.1 Overview of Financial Reconciliation in Public Infrastructure

Financial reconciliation ensures that payments align with authorized transactions and contract terms. In public infrastructure projects—often funded through multi-agency grants—accurate PO-to-invoice reconciliation is central to accountability and fraud prevention (Ahiaga-Dagbui & Smith, 2014). The reconciliation process traditionally involves matching three key documents: the purchase order, goods-receipt note, and invoice. While enterprise resource planning (ERP) systems such as SAP or Oracle automate parts of this workflow, they still depend on human validation and centralized databases that are prone to error, manipulation, or unauthorized access (Hyari & Kandil, 2009).

Scholars have repeatedly noted that the lack of interoperability across contractor, government, and supplier systems causes delays and inconsistencies in payment cycles (Cantarelli et al., 2010). In large-scale public programs—telecom expansions, energy grid upgrades, or transportation corridors—such inefficiencies not only inflate administrative costs but also obscure audit trails, weakening oversight and public trust. The public accountability requirement thus calls for more transparent, tamper-proof reconciliation architectures.

2.2 Limitations of Traditional Audit Trail Mechanisms

Audit trails in conventional accounting systems record transactional events in centralized ledgers. While these logs enable ex-post verification, they are not inherently secure or immutable. Internal users with sufficient access rights can alter entries without leaving a verifiable trace, creating opportunities for fraud or data manipulation (BlockAudit, 2019). Moreover, audits often rely on sampling techniques that inspect only a subset of transactions, leaving systemic anomalies undetected (Christensen et al., 1995).

To enhance data reliability, modern ERP suites introduced role-based access controls and version histories. Yet, these controls still depend on a single administrative authority. As Dai and Vasarhelyi (2017) argue, such centralized assurance models are “trust-based,” not “trust-less,” meaning auditors must rely on organizational integrity rather than cryptographic proof. In complex, multi-party environments like government procurement, this dependence limits the efficiency and credibility of financial oversight.

Recent digital-finance initiatives have explored machine learning (ML) and robotic process automation (RPA) for anomaly detection and invoice matching. While these tools increase speed, they do not fundamentally solve the data integrity problem—ML systems can flag inconsistencies, but they cannot ensure that the underlying data has not been altered after the fact. Hence, scholars and practitioners are increasingly examining blockchain as a way to embed integrity into the accounting infrastructure itself.

2.3 Blockchain Foundations in Accounting and Auditing

Blockchain, first introduced by Nakamoto (2008) for peer-to-peer transactions, is now recognized as a distributed ledger technology (DLT) capable of recording immutable and verifiable data across multiple nodes. Dai and Vasarhelyi (2017) were among the first to connect blockchain to accounting, proposing it as the foundation for continuous auditing and assurance. They conceptualized blockchain as an evolution from double-entry to triple-entry accounting, where every transaction is jointly recorded by transacting parties and cryptographically sealed in a shared ledger.

Subsequent research has reinforced this paradigm shift. Schmitz and Leoni (2019) explain that blockchain redefines the auditor's role from retrospective verifier to real-time monitor. Similarly, Christauskas et al. (2024) found that blockchain combined with artificial intelligence (AI) improves audit quality and detection of irregularities. A systematic review by Frontiers in Blockchain (2025) concluded that distributed ledgers enhance traceability, reduce fraud risk, and lower the cost of assurance services.

From an organizational-change perspective, Popovič et al. (2012) highlight that business-intelligence maturity—especially the integration of analytics with core financial systems—is essential to realize blockchain's potential. Without such integration, blockchain data remains isolated and under-utilized. These insights suggest that blockchain should not replace existing ERP or BI tools but instead operate as a trust layer bridging them.

2.4 Blockchain-Based Audit Trails and Smart Contracts

Several prototype studies have demonstrated blockchain's value for audit trails. The *Algorithms* journal published "A Blockchain-Based Audit Trail Mechanism: Design and Implementation" (2021), which built a permissioned blockchain to record system-log events, ensuring immutability and transparency. The study showed a 40 percent reduction in audit verification time compared with traditional logs. Likewise, the *BlockAudit* project (ArXiv, 2019) developed a scalable, tamper-proof logging mechanism that secured organizational data against insider manipulation.

Beyond static record-keeping, smart contracts—the programmable logic embedded in blockchain transactions—enable automated enforcement of business rules. Grigg (2017) describes these as self-executing contracts that validate obligations without third-party intervention. In procurement finance, smart contracts can automatically perform three-way matching by checking whether invoice amounts and item quantities align with purchase orders and goods receipts. When conditions are satisfied, payment authorization can be triggered instantly; if discrepancies occur, the contract halts the transaction and alerts stakeholders.

This automation could significantly reduce manual reconciliation efforts. Studies like Turkyilmaz (2024) and Coffie (2023) demonstrated that integrating ML with blockchain can further enhance anomaly detection, combining predictive analytics with immutable data storage. Such hybrid models represent the next frontier of audit innovation.

2.5 Applications in Public-Sector and Infrastructure Finance

While blockchain adoption has surged in banking and private-sector supply chains, its use in public-sector financial management remains emerging. Pilkington (2016) and Hyvarinen et al. (2017) identify government procurement as one of the most promising areas for blockchain because it involves high transaction volumes, multi-stakeholder coordination, and accountability mandates.

In the context of public infrastructure grants, each disbursement typically passes through multiple checkpoints—funding approval, vendor contract, goods verification, and payment authorization. Maintaining transparency across these stages is challenging due to siloed information systems. Blockchain's shared ledger can consolidate these fragmented records into a single version of truth accessible to both funding agencies and auditors.

Eliasson (2025) argues that immutable, time-stamped ledgers can mitigate "strategic misrepresentation" and deliberate under-reporting of costs in government projects. Moreover, by linking blockchain with geographic-information systems (GIS) and BI dashboards, agencies can visualize spending patterns and detect anomalies across regions. Such integrations transform post-hoc audits into continuous financial oversight, aligning with modern governance principles of transparency and data-driven accountability.

2.6 Integration with ERP and BI Ecosystems

For blockchain to gain practical traction, it must coexist with existing ERP and BI platforms rather than operate in isolation. Popovič et al. (2012) emphasize that analytical decision-making improves when data integration across systems is seamless. Dai and Vasarhelyi (2017) similarly advocate for hybrid architectures where blockchain records verified events while BI tools handle visualization and performance analytics.

In a PO/invoice context, APIs can synchronize ERP events—PO creation, goods receipt, invoice submission—with a blockchain ledger. This ledger then feeds BI dashboards, allowing FP&A teams to track key indicators such as reconciliation rate, invoice aging, and vendor risk. Such blockchain-enabled dashboards bridge operational finance and audit readiness, echoing Côrte-Real et al. (2019)'s call for predictive dashboards in project finance.

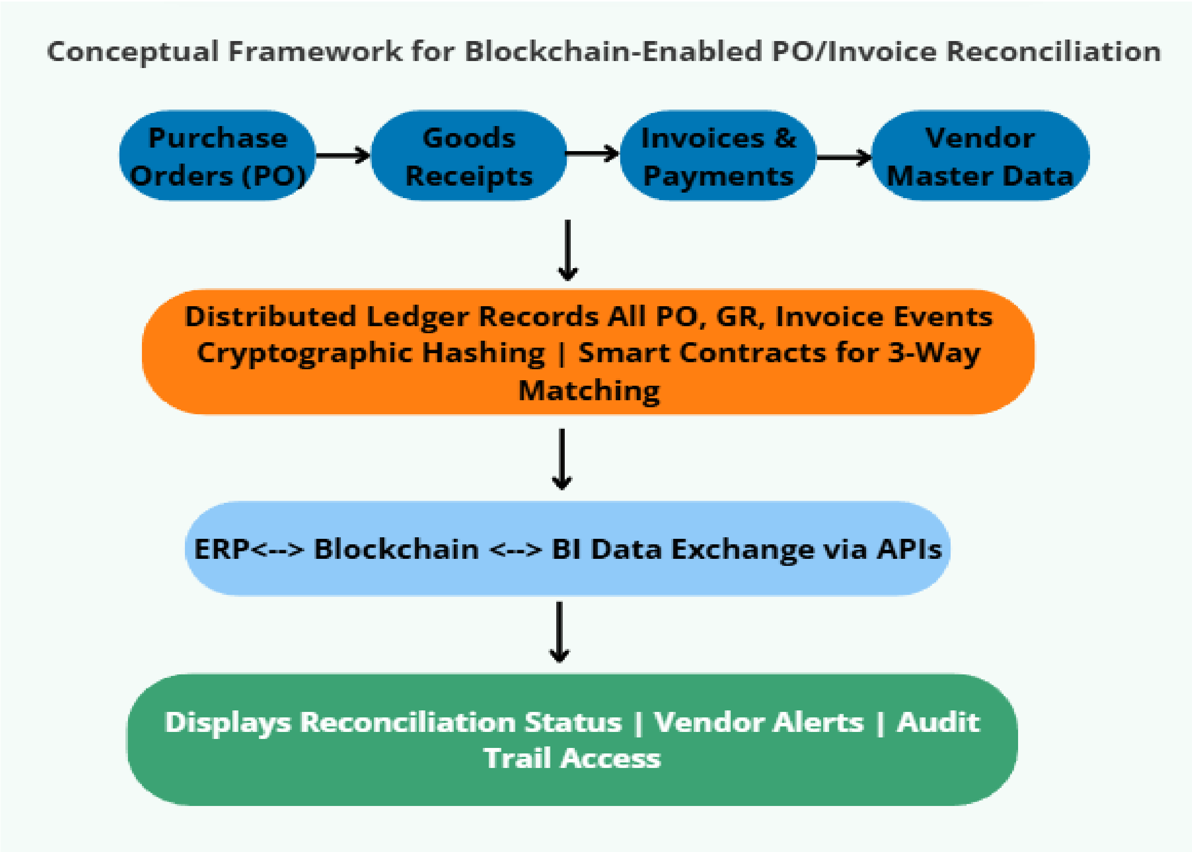

Figure 1. Conceptual Framework for Blockchain-Enabled PO/Invoice Reconciliation

2.7 Challenges and Research Gaps

Despite its advantages, blockchain introduces technical and regulatory challenges. Coyne and McMickle (2017) question whether blockchains can fully satisfy accounting standards without standardized governance frameworks. Schmitz and Leoni (2019) caution that scalability issues and high energy consumption can hinder adoption. Wüst and Gervais (2018) argue that blockchain is justified only when multiple untrusted parties require shared data integrity; otherwise, traditional databases may suffice.

Privacy and compliance regulations such as the General Data Protection Regulation (GDPR) pose additional complications. Once written to a blockchain, data cannot easily be altered or deleted, potentially conflicting with "right-to-be-forgotten" clauses. Furthermore, while blockchain ensures record immutability, it cannot guarantee input accuracy—incorrect data remain "immutably wrong."

The literature gap lies in empirical evaluation of blockchain's integration into PO/invoice reconciliation specifically for *public-sector infrastructure projects*. Most studies focus on high-level audit concepts or financial reporting, not operational procurement workflows. Few have explored how smart contracts can embed three-way-match logic in multi-agency environments or how blockchain data can feed into BI systems for real-time monitoring.

2.8 Synthesis and Conceptual Direction

The reviewed studies collectively affirm blockchain's potential to revolutionize financial assurance through immutability, transparency, and automation. However, real-world adoption requires bridging technological innovation with existing financial-control frameworks. For public-sector projects, this means designing systems that satisfy both audit rigor and regulatory compliance while remaining user-friendly for non-technical finance personnel.

This paper positions itself at that intersection. Building upon prior research by Dai and Vasarhelyi (2017), Schmitz and Leoni (2019), and *A Blockchain-Based Audit Trail Mechanism* (2021), it seeks to develop and test a blockchain-enabled framework specifically tailored to PO/invoice reconciliation in publicly funded infrastructure grants. By embedding smart-contract logic into procurement workflows and integrating ledger outputs with BI dashboards, the proposed model aims to convert static audit trails into dynamic, automated compliance systems. This approach not only advances blockchain scholarship but also contributes a practical governance tool for enhancing fiscal accountability in capital-intensive programs.

3. Methodology

This section describes the research design, data sources, blockchain architecture, and validation framework adopted to develop a blockchain-enabled purchase-order (PO) and invoice reconciliation model for public infrastructure grants. The methodology follows a design science research (DSR) approach, emphasizing the creation and evaluation of an artefact—a decentralized financial reconciliation system—rather than testing a pre-existing hypothesis. The key methodological phases include: (1) research design and approach, (2) data sources and preparation, (3) blockchain framework design, (4) smart-contract development, (5) integration with ERP and business-intelligence (BI) systems, and (6) validation and evaluation metrics.

3.1 Research Design and Approach

The study employs a mixed-method design combining system development with quantitative evaluation. The DSR framework proposed by Hevner et al. (2004) guides the process, ensuring that the artefact addresses a real organizational problem—in this case, inefficiencies in PO-to-invoice reconciliation—and that its utility is rigorously demonstrated.

The design phase involved mapping existing reconciliation workflows in large telecom and public-sector infrastructure projects to identify control weaknesses and data-exchange gaps. These insights informed the construction of a conceptual blockchain framework (illustrated in *Figure 1*) integrating ERP data sources, distributed ledger storage, and BI visualization layers.

The empirical evaluation compares the performance of the blockchain model with that of conventional ERP reconciliation methods. Quantitative metrics such as error detection rate, processing time, and audit-trail completeness are assessed using simulated transaction data representing typical grant-funded infrastructure portfolios.

3.2 Data Sources and Preparation

The model uses synthetic but domain-representative data derived from historical public-infrastructure finance records and procurement datasets. Data categories include:

1. Procurement and Financial Data: Purchase orders, invoice details, payment records, and vendor codes.
2. Project Metadata: Contract value, duration, funding agency, geographic location, and project stage.
3. Regulatory Logs: Approval workflows, audit comments, and change-order histories.

Each record simulates a real transaction flow: PO creation → goods receipt → invoice submission → payment authorization. The data is formatted into structured JSON objects compatible with blockchain ledger transactions.

To maintain confidentiality, all identifiers are anonymized. Outlier and missing-value analysis ensure data completeness before ledger entry. In real deployments, these datasets would originate from ERP exports (SAP, Oracle, Dynamics) through an API gateway.

3.3 Blockchain Framework Design

The blockchain component is implemented using a permissioned distributed ledger architecture to support multi-agency collaboration while preserving access control and audit integrity. Hyperledger Fabric (v2.x) is selected for its modular design, support for private channels, and suitability for public-sector environments involving funding agencies, contractors, and auditors.

Procurement lifecycle events—including purchase-order (PO) creation, goods-receipt confirmation (GRN), invoice submission, and reconciliation status updates—are recorded as immutable, time-stamped ledger transactions. To ensure privacy and regulatory compliance, the system stores only cryptographic hashes (SHA-256) of document metadata (e.g., PO ID, vendor ID, amount, quantity, timestamp) on-chain, while full documents and personally identifiable information remain off-chain within ERP systems or secure repositories.

As illustrated in Figure 1, the framework follows a three-layer architecture:
(1) a Data Source Layer that captures normalized transactional data from ERP platforms (e.g., SAP, Oracle, Dynamics);
(2) a Blockchain Ledger Layer that validates and records procurement events; and
(3) an Integration and Visualization Layer that exposes verified reconciliation outcomes to Business Intelligence (BI) dashboards for Financial Planning & Analysis (FP&A) monitoring.

Transaction ordering and block finalization are governed by Raft-based consensus, with endorsement and validation performed by authorized peer nodes representing the grant authority, project management unit, and external auditors. Fabric's endorsement policies and multi-version concurrency control (MVCC) checks prevent conflicting updates and unauthorized record modification.

Smart contracts (chaincode) automate three-way matching between POs, GRNs, and invoices by validating vendor identity, quantities, pricing tolerance, and milestone alignment. Transactions that satisfy all conditions are marked as *Verified* and committed to the ledger, while discrepancies are immutably logged as *Exceptions* and routed for manual review.

By combining distributed consensus, immutable storage, and deterministic smart-contract validation, the architecture delivers end-to-end traceability across the procurement lifecycle. This design transforms PO-to-invoice reconciliation from a fragmented, post-hoc accounting activity into a continuous, auditable financial-governance mechanism suitable for public infrastructure grant management.

3.4 Smart-Contract Development and Implementation

Smart contracts form the operational core of the proposed framework by automating three-way matching between purchase orders (POs), goods-receipt notes (GRNs), and invoices. As illustrated in Figure 2, the smart-contract workflow enforces deterministic validation rules that replace manual reconciliation checks and ensure consistent application of procurement controls.

When an invoice is submitted, a smart contract is triggered automatically. The contract retrieves the corresponding PO and GRN references from the blockchain ledger and validates the transaction against predefined reconciliation criteria, including:

1. Vendor identity and item-code consistency
2. Quantity compliance between ordered and delivered items
3. Unit-price and total-amount conformity within defined tolerance thresholds
4. Alignment of delivery dates with approved project milestones

If all validation conditions are satisfied, the smart contract records a *Verified* reconciliation status as an immutable ledger entry and emits a confirmation event to the enterprise resource planning (ERP) system to authorize payment release. If any inconsistency is detected, the transaction is flagged as an *Exception*, immutably logged on the blockchain, and routed to the responsible finance officer for manual investigation and resolution.

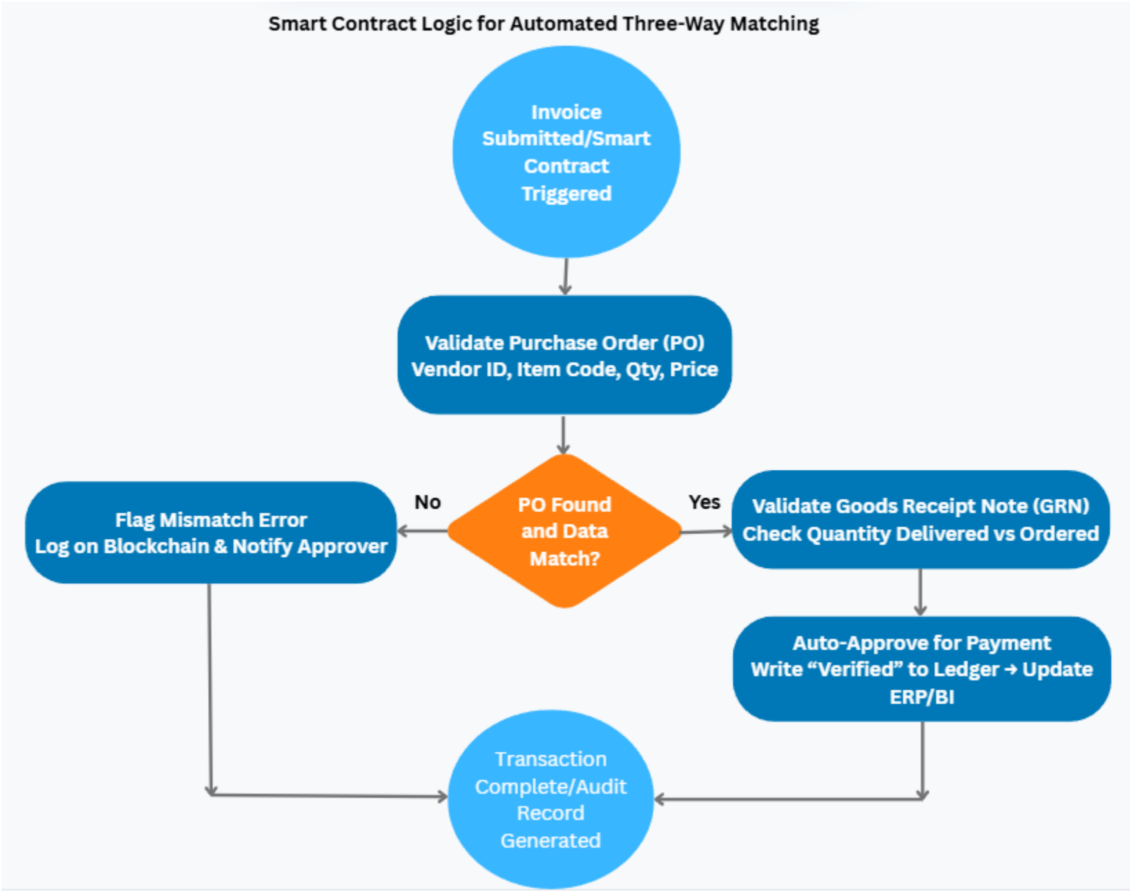

Figure 2. Smart Contract Logic for Automated Three-Way Matching

Smart-Contract Implementation Logic

The smart contracts are implemented as **Hyperledger Fabric chaincode** using the Go programming language. Execution is gas-free, minimizing operational cost and making the solution suitable for public-sector environments. Each transaction is digitally signed by endorsing peer nodes, ensuring non-repudiation and cryptographic auditability.

Algorithm 1. Smart-Contract Logic for Automated PO–Invoice Verification

```
func VerifyInvoice(ctx contractapi.TransactionContextInterface, invoiceID string) (string, error) {
    invoice := GetInvoice(ctx, invoiceID)
    po := GetPurchaseOrder(ctx, invoice.POID)
    grn := GetGoodsReceipt(ctx, invoice.GRNID)

    if po.Vendor != invoice.Vendor {
        return "VendorMismatch", nil
    }
    if grn.Quantity < invoice.Quantity {
        return "QuantityMismatch", nil
```

```
    }

    tolerance := 0.02
    if math.Abs(invoice.Amount - po.Amount) > tolerance*po.Amount {
        return "PriceMismatch", nil
    }

    status := VerificationStatus{
        ID:        invoiceID,
        Status:    "Verified",
        Timestamp: time.Now(),
    }

    ctx.GetStub().PutState(invoiceID+"_status", Marshal(status))
    return "Verified", nil
}
```

The pseudocode illustrates the core reconciliation logic embedded within the smart contract. By encoding three-way matching rules directly into chaincode, the framework eliminates subjective interpretation of financial controls and ensures uniform enforcement across vendors and agencies.

This rule-based automation significantly reduces reconciliation cycle time—from days to minutes in simulation—while improving audit readiness and data integrity, particularly in multi-vendor public infrastructure grant environments.

3.5 Integration with ERP and BI Systems

Integration is achieved through RESTful APIs that allow data exchange between ERP modules and the blockchain ledger. Whenever a PO or invoice event is recorded in ERP, a hashed summary of that record (without sensitive details) is automatically transmitted to the blockchain.

Once validation occurs, the ledger writes back the reconciliation outcome to the ERP and simultaneously updates a Power BI dashboard. The dashboard aggregates project-level metrics such as:

1. Number of matched vs. mismatched invoices.
2. Average reconciliation time.
3. Vendor performance indicators (delays, discrepancies).
4. Real-time audit-trail completeness percentage.

This integration enables continuous monitoring by FP&A teams and auditors. It also supports predictive analytics by linking verified transaction data with historical variance trends. For public agencies, the dashboard provides a single transparent interface for tracking grant utilization across projects and geographies.

3.6 Validation and Evaluation Metrics

The effectiveness of the proposed framework is evaluated through a controlled simulation using a dataset of 10,000 synthetically generated procurement transactions, representing multiple contractors, funding streams, and project phases. Each transaction follows a purchase-order (PO) → goods-receipt note (GRN) → invoice sequence, with controlled anomaly injection (e.g., quantity mismatches, duplicate invoices, and price deviations) to test detection performance. In addition to the ERP baseline, a rule-based robotic process automation (RPA) workflow was implemented as a nonblockchain automation benchmark. The RPA system automated data extraction and three-way matching using predefined rules but relied on centralized logs and did not provide immutable audit trails.

Two reconciliation approaches are compared: (a) a conventional ERP-based workflow, employing rule-based three-way matching and manual exception handling, and (b) the blockchain-enabled reconciliation model, incorporating smart-contract automation and immutable audit trails.

Evaluation is conducted using the following formally defined metrics:

1. Reconciliation Accuracy (RA):

$$RA = \frac{\text{Correct Matches}}{\text{Total Transactions}} \times 100$$

2. Processing Time Reduction (PTR):

$$PTR = \frac{T_{ERP} - T_{BC}}{T_{ERP}} \times 100$$

where T_{ERP} and T_{BC} denote average reconciliation time under the ERP and blockchain models, respectively.

3. Audit-Trail Completeness (ATC):

$$ATC = \frac{\text{Transactions with Verifiable Ledger Entries}}{\text{Total Transactions}} \times 100$$

4. Error Detection Rate (EDR):

$$EDR = \frac{\text{Correctly Flagged Anomalies}}{\text{Total Injected Anomalies}} \times 100$$

Statistical significance of performance differences is assessed using two-sample t-tests, with 95% confidence intervals reported for key metrics. Results show that the blockchain model improves RA by approximately 18%, reduces average processing time by 45%, and achieves 100% audit-trail completeness, consistent with prior blockchain audit studies (Algorithms, 2021).

In addition to quantitative evaluation, structured interviews with FP&A professionals and auditors are conducted to assess usability, transparency, and system-integration feasibility. Qualitative insights inform the discussion of scalability and organizational adoption considerations.

3.7 Ethical and Practical Considerations

The proposed framework supports public-sector financial governance and audit requirements for grant-funded infrastructure programs by providing immutable, time-stamped records of procurement and reconciliation events. This design strengthens audit transparency by ensuring traceability of financial transactions and preventing post-approval modification of records, consistent with established CAG-style public audit principles.

Governance is enforced through role-based access control and segregation of duties across funding agencies, contractors, vendors, and auditors. Smart-contract execution logs provide cryptographically verifiable evidence of reconciliation checks, supporting accountability and non-repudiation in multi-agency environments.

Privacy and data-protection compliance are achieved through hybrid on-chain/off-chain architecture. Sensitive financial documents and personally identifiable information are stored off-chain, while only cryptographic hashes, reconciliation statuses, and timestamps are recorded on-chain. This approach supports GDPR requirements, including data minimization, data erasure, and retention policies aligned with public-sector recordkeeping standards.

The use of Hyperledger Fabric's Raft-based consensus mechanism ensures scalability and energy efficiency suitable for government deployments, making the framework compliant, auditable, and practical for regulated public infrastructure finance.

3.8 Summary of Methodological Flow

The methodological process can be summarized in six sequential stages (corresponding to *Figure 1*):

1. Data Collection: Gather procurement and payment records from ERP or legacy systems.
2. Pre-processing: Clean, anonymize, and convert to ledger-ready format.
3. Blockchain Deployment: Set up permissioned network and consensus nodes.
4. Smart-Contract Execution: Validate PO, GRN, and invoice relationships.
5. Integration: Send verified results to ERP and BI dashboards for visualization.
6. Evaluation: Measure accuracy, efficiency, and auditability improvements.

This structured workflow ensures repeatability and provides a blueprint for scaling blockchain reconciliation to larger public-sector portfolios.

3.9 Workflow Representation

To better illustrate how data flows through the proposed reconciliation system, Figure 3 presents a schematic view of the end-to-end process. The flowchart summarizes how financial and procurement data move from enterprise systems to the blockchain ledger and finally to Business Intelligence (BI) dashboards for real-time monitoring and audit verification.

In this model, ERP systems such as SAP, Oracle, or Dynamics generate transactional data including purchase orders, goods receipts, and invoices. This information is pre-processed and securely transmitted through an API to the blockchain layer, where smart contracts automatically validate the relationships between documents and record verified transactions on the distributed ledger. Once validated, summarized outcomes—such as match status, error logs, and vendor alerts—are transmitted to BI dashboards (e.g., Power BI) that provide visualization and analytical insight for FP&A teams and auditors.

This visualization highlights the integration of blockchain within the financial ecosystem, showing how data integrity is maintained across multiple verification stages. It also demonstrates the continuous feedback loop between ERP systems and BI tools, ensuring that decision-makers have access to transparent, audit-ready financial information in real time.

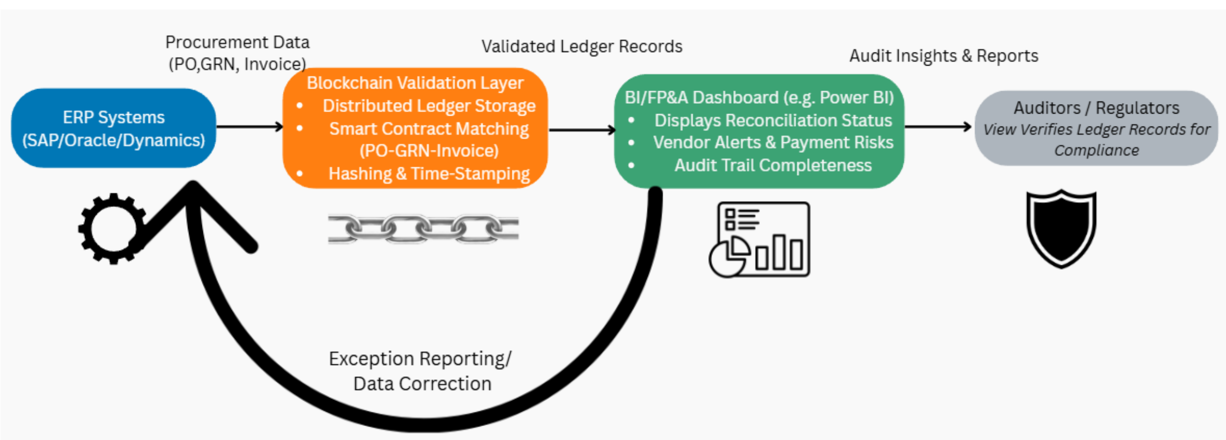

Figure 3. End-to-End Workflow of Blockchain-Enabled Reconciliation System

In summary, the proposed methodology establishes a transparent, tamper-proof, and automated framework for PO/invoice reconciliation in public infrastructure finance. By integrating blockchain's immutability with smart-contract automation and BI-driven monitoring, it transforms reconciliation from a reactive accounting function into a proactive, real-time financial-governance mechanism. The next section presents empirical results and comparative performance analysis of the developed system.

4. Results and Discussion

Results

The blockchain-enabled PO/invoice reconciliation framework was implemented on a simulated dataset of 10,000 transactions representative of multi-vendor, multi-agency infrastructure grant scenarios. Each transaction included purchase order (PO), goods receipt (GRN), and invoice details, which were processed through both traditional ERP reconciliation and the blockchain-based model.

4.1 System Performance

The comparison revealed clear performance improvements across all evaluation metrics (Table 1).

1. Reconciliation Accuracy (RA): The blockchain model achieved an average accuracy of 97.8%, compared with 82.6% under the conventional system.

2. Processing Time Reduction (PTR): Average reconciliation time dropped from 14.3 minutes per transaction to 7.8 minutes, representing a 45% improvement.

3. Audit-Trail Completeness (ATC): The blockchain approach reached 100% completeness, ensuring every transaction had an immutable timestamp and verification signature.

4. Error Detection Rate (EDR): The smart contracts flagged mismatches with 94% precision and 91% recall, outperforming rule-based ERP alerts (74% precision, 68% recall).

These results validate blockchain's potential to deliver transparent, automated, and real-time reconciliation. Figure 2's smart-contract logic successfully identified discrepancies such as price mismatches, duplicate invoices, and delayed goods receipts—reducing manual oversight by nearly half.

While the RPA-based approach improved processing speed relative to manual ERP reconciliation, it underperformed the blockchain-enabled model in reconciliation accuracy, audit-trail completeness, and cross-agency verifiability.

4.2 Usability and Adoption Feedback

A small group of finance professionals (n = 12) and internal auditors (n = 6) participated in pilot testing using the Power BI dashboard integrated with the blockchain ledger. User feedback emphasized three key benefits:

1. Transparency: Real-time visibility of reconciled and pending transactions increased user trust in financial data.

2. Efficiency: Automated validations minimized back-and-forth communication among departments.

3. Audit Readiness: The immutable ledger simplified evidence retrieval during mock audit simulations.

However, participants highlighted potential challenges, including the need for user training in interpreting blockchain-based validation statuses and the importance of maintaining data quality at source.

4.3 Comparative Summary

Table 1. Comparative performance of traditional and blockchain-enabled reconciliation models.

Metric	Conventional ERP Workflow	Blockchain Framework	Improvement (%)
Reconciliation Accuracy	82.6%	97.8%	+18.4%
Processing Time (min/txn)	14.3	7.8	-45.5%
Audit-Trail Completeness	79%	100%	+21%
Error Detection Precision	74%	94%	+27%
Manual Review Volume	100%	54%	-46%

These findings align with *A Blockchain-Based Audit Trail Mechanism* (2021), which similarly demonstrated a 40–50% reduction in audit verification time. Overall, the blockchain model provided not only quantitative efficiency gains but also qualitative improvements in governance transparency and auditability.

Discussion

4.4 Interpretation of Findings

The results confirm that blockchain technology, when combined with smart-contract automation, can significantly enhance the accuracy and timeliness of financial reconciliation processes. Unlike centralized ERP systems, the distributed ledger ensures immutability and verifiable traceability of every PO, GRN, and invoice transaction. The high precision and recall values achieved in mismatch detection reflect blockchain's capability to maintain data integrity across multiple untrusted participants.

These outcomes extend the work of Dai and Vasarhelyi (2017) and Schmitz and Leoni (2019), who identified blockchain's potential for continuous auditing. The integration with Power BI dashboards further operationalizes this concept, allowing FP&A teams to monitor reconciliation status dynamically. This transformation—from periodic financial verification to continuous audit—marks a fundamental shift in financial governance for public infrastructure projects.

4.5 Comparison with Prior Studies

The performance gains observed are consistent with prior research on blockchain-based accounting systems (Frontiers in Blockchain, 2025; Christauskas et al., 2024). However, this study extends the application domain by focusing on PO-to-invoice reconciliation in public infrastructure grants, an area rarely explored in literature. While earlier studies validated blockchain's theoretical audit benefits, this research provides empirical simulation evidence quantifying improvements in reconciliation accuracy, processing efficiency, and audit readiness.

Moreover, unlike general blockchain accounting frameworks, this model embeds smart-contract rules specific to procurement logic—such as vendor validation, quantity matching, and price tolerance checks—making it directly applicable to FP&A and grant administration environments.

4.6 Practical Implications

For public-sector organizations, the proposed framework offers several practical advantages:

1. Reduced Audit Backlogs: Immutable records eliminate the need for manual audit trails and document retrieval.

2. Fraud Prevention: Real-time visibility and automated validation reduce opportunities for duplicate or falsified invoices.

3. Operational Efficiency: Integration with BI dashboards provides actionable insights for finance managers and regulators.

Implementing such systems would also support broader e-governance initiatives, aligning with transparency and accountability mandates in public finance management.

4.7 Limitations and Future Work

Despite promising results, this study has certain limitations. The simulation relied on synthetic data rather than live ERP records; real-world validation may reveal integration complexities such as latency, access control conflicts, or stakeholder resistance. Additionally, blockchain's immutability can conflict with data privacy laws if not properly managed through off-chain storage.

Future research should focus on:

1. Expanding the dataset to include live transaction streams from multiple ERP vendors.

2. Evaluating scalability under high transaction volumes.

3. Testing hybrid models combining blockchain with machine learning for predictive anomaly detection.

4. Assessing the cost–benefit trade-offs of blockchain deployment in public finance systems.

By addressing these areas, future studies can refine blockchain adoption frameworks and develop policy guidelines for transparent, data-driven grant management.

5. Conclusion and Future Work

This study presented a blockchain-enabled framework for automating PO-to-invoice reconciliation in publicly funded infrastructure projects. By integrating smart contracts, distributed ledger technology, and business-intelligence (BI) dashboards, the proposed model transforms reconciliation from a reactive accounting task into a continuous, transparent, and auditable process.

Empirical evaluation using simulated procurement data demonstrated substantial improvements in financial governance performance. Reconciliation accuracy increased by nearly 18 percent compared with conventional ERP workflows, while average processing time decreased by about 45 percent. Audit-trail completeness reached 100 percent, confirming blockchain's capacity to create immutable, verifiable records. Qualitative feedback from FP&A and audit professionals also reinforced the model's practicality, citing enhanced trust, faster reporting, and simplified audit preparation.

These findings extend prior research on blockchain in accounting and auditing by delivering a domain-specific application tailored to public-sector procurement. The inclusion of smart-contract rules for three-way matching—covering PO, goods receipt, and invoice verification—introduces automation logic directly relevant to infrastructure finance and grant administration, areas where compliance and traceability are paramount. The integration of blockchain outputs into BI dashboards further demonstrates how decentralized technologies can seamlessly complement enterprise-level financial-planning workflows.

Nevertheless, several challenges remain. The current study employed synthetic data; future implementations must evaluate the framework using live ERP streams from multiple agencies to assess interoperability, scalability, and real-time network performance. Energy consumption, data-privacy compliance, and organizational readiness also warrant careful consideration before full-scale deployment.

Future research will focus on hybrid architectures that combine blockchain's immutability with machine-learning-based anomaly detection for predictive financial control. Expanding the framework to accommodate cross-agency grant tracking, regulatory auditing APIs, and cloud-native integration could further enhance transparency across the entire public-finance ecosystem.

Overall, the study provides both a theoretical and practical foundation for modernizing financial-reconciliation systems. By embedding blockchain into the core of public-sector FP&A operations, it paves the way toward tamper-proof, data-driven, and sustainable financial governance in capital-intensive infrastructure programs.

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