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A Blockchain-Based Framework for Transparent and Accountable Financial Management on Humanitarian Aid Distribution

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Abstract: *Humanitarian aid delivery is often compromised by financial mismanagement, corruption, and limited transparency, undermining donor trust and aid effectiveness. This study proposes a Multi-Tier Smart Contract Governance (MTSG) framework built on blockchain technology to enhance financial accountability in humanitarian operations. Unlike existing solutions that focus solely on transaction traceability, the MTSG introduces a layered permission system allowing stakeholders such as donors, NGOs, and local partners to access and manage funds based on defined roles. It also incorporates smart contract-based auditing and dispute resolution mechanisms, reducing reliance on central oversight and enabling real-time financial verification. Employing a design science research approach, this conceptual model demonstrates how blockchain can enforce financial integrity, minimize fraud, and foster transparent and ethical fund management. The framework offers a scalable solution for humanitarian organizations seeking to strengthen financial governance in crisis contexts.*

Keywords: Blockchain for Humanitarian Aid, Smart Contract Governance, Financial Transparency, Humanitarian Finance, Multi-Tier Blockchain Framework

1. Introduction

Humanitarian crises ranging from natural disasters and pandemics to armed conflicts, have intensified the need for efficient and trustworthy financial management in aid distribution systems. As billions of dollars are disbursed annually for humanitarian relief efforts, persistent challenges such as corruption, fund diversion, lack of transparency, and mismanagement continue to undermine the impact of such initiatives (Akinola et al., 2023). In many low- and middle-income countries (LMICs), where institutional trust is fragile, these systemic inefficiencies erode donor confidence and reduce the ability of aid to reach intended beneficiaries.

Blockchain technology, with its core attributes of decentralization, immutability, and transparency, has emerged as a promising paradigm for addressing these challenges (Mukherjee & Pal, 2022). Unlike traditional aid disbursement systems, blockchain can provide a secure and tamper-resistant ledger that tracks the movement of funds in real time, from donors to end recipients. Several pilot studies have demonstrated blockchain's potential in supply chain management, digital identity systems, and even direct cash transfers in humanitarian contexts (Jamil et al., 2021). Yet, most existing frameworks are limited in scope, lacking comprehensive governance structures and multilayer stakeholder integration.

This study proposes a novel Multi-Tier Smart Contract Governance (MTSG) framework tailored to humanitarian aid contexts. The framework leverages permissioned blockchain networks and role-specific smart contracts to ensure transparency, traceability, and conditional disbursement of funds. Unlike prior models, MTSG incorporates an embedded audit layer, biometric-enabled verification, and decentralized dispute resolution mechanisms to prevent corruption and optimize accountability.

The proposed framework fills a critical research gap by unifying technical innovation with institutional trust requirements. It builds upon existing literature but extends it by offering a scalable architecture that supports dynamic, multistakeholder participation while enforcing compliance through programmable logic (Ajadi & Ojo, 2023). Through simulation and conceptual design, this research lays the groundwork for practical implementation in real-world aid programs managed by governments, NGOs, and international donor agencies.

2. Literature Review

Blockchain technology has emerged as a transformative tool for enhancing transparency and accountability across various sectors. Numerous studies have examined its application in supply chain tracking, digital identity, payment systems, and decentralized

governance. This section presents a critical synthesis of recent works, highlighting how this research builds upon and diverges from existing knowledge.

Rani et al. (2023) investigated the use of NFTs and Ethereum-based contracts to track humanitarian assets, demonstrating how blockchain could improve fund visibility but lacked a layered control mechanism. Similarly, Negi (2024) explored blockchain's use in healthcare aid, employing a qualitative design to propose decentralized storage solutions but did not offer a full governance model. Fallucchi et al. (2022) introduced a digital certification system for education finance using smart contracts. While innovative, the solution's high gas fees and limited scalability revealed its constraints in broader humanitarian contexts. Song et al. (2023) emphasized fund disbursement transparency in disaster zones but focused heavily on platform development, omitting integrated audit or dispute resolution layers. Sholeh et al. (2023) proposed a DApp on Ethereum for fund distribution using biometric verification. Despite promising results, their work lacked a tiered access system and real-time audit mechanisms. Another notable contribution, Rehman et al. (2022), addressed donor trust using a permissioned blockchain but was limited by the absence of conditional pay out rules and oracle integration.

The CryptoScholarChain project by Swati and Nitin (2023) targeted academic funding through blockchain, using IPFS for document storage. It showcased the potential for trustless systems but had scalability and redundancy limitations. Dounas et al. (2021) explored collaborative governance in the built environment, proposing a blockchain model for participatory decision-making. However, their focus was primarily on design governance rather than financial management. Khan et al. (2023) presented a decentralized solution for funding allocation in crisis response but lacked automated compliance checks and resolution protocols. Overall,existing frameworks predominantly concentrate on traceability, identity verification, and tokenization. However, none of them incorporated a multi-tier smart contract governance (MTSG) structure combining role-based permissions, conditional logic, and dispute management. This gap reveals the need for a more holistic approach—particularly in complex aid ecosystems involving multiple layers of authority and verification.

3. Framework Design

Fig 1 shows the Multi-Tier Smart Contract Governance (MTSG) framework, which is designed to manage financial flows in humanitarian aid using blockchain technology, smart contracts, and a tiered permission structure. It ensures transparency, accountability, and auditable control of funds across various actors in the aid delivery chain.

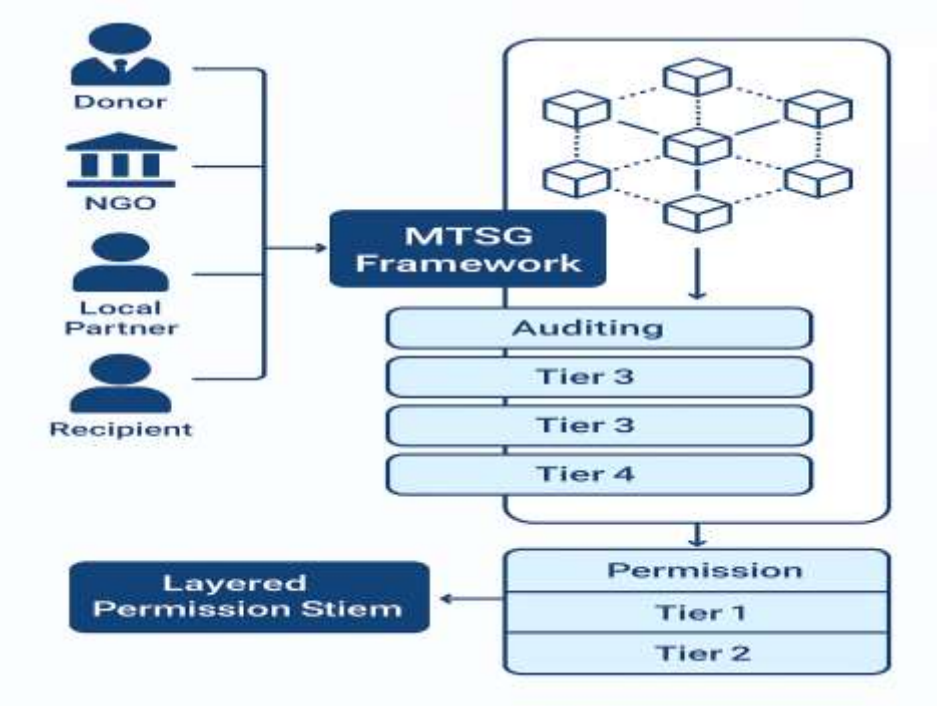

Fig 1 Proposed framework design

3.1 Stakeholders (Left Column)

There are four key actors who participate in the humanitarian aid life-cycle, the first actor is donor which, provides funds for humanitarian interventions. Requires transparency and assurance that funds are used properly. The second actor is NGO (Non-Governmental Organization), they coordinates and manages the aid project. Oversees procurement, local partnerships, and reporting. The third actor is local partner, that works on-the-ground (e.g., local clinics, distributors), and implements aid distribution directly to beneficiaries. The fourth actor is Recipient, which is the final beneficiary of the aid (e.g., individuals, schools, clinics). Each of these actors has different access levels and roles defined by smart contracts.

3.2 MTSG Framework Core (Middle Section)

A hierarchical structure that assigns roles and actions to different stakeholders based on responsibility and trust level.

- **Tier 1** – Full control: Donors and major NGOs have full access to set budgets, approve disbursements, and initiate audits.
- **Tier 2** – Management level: NGOs manage allocations, verify reports from local partners, and trigger secondary contracts.
- **Tier 3** – Operational level: Local partners execute tasks like distribution and submit evidence (photos, receipts, etc.).
- **Tier 4 –** Verification/Read-Only level: Beneficiaries and the public may verify fund status or report discrepancies.

3.3 Smart Contract Components (Right Column)

This part operates within the blockchain network and consists of three main layers:

a. Smart Contracts

Automate fund disbursements, enforce rules, and maintain immutable records of actions. Each tier triggers smart contracts that manage:

- Budget release
- Delivery confirmation
- Compliance checks
- Time-based conditions (e.g., release X after 30 days)

b. Auditing Module

Built into the blockchain as a smart auditing contract, it continuously:

- Tracks every transaction
- Verifies if deliverables were met
- Sends real-time compliance reports to donors

c. Dispute Resolution Module (Optional layer)

In case of errors, fraud, or disagreements:

- Smart contracts initiate a resolution protocol
- May include third-party or DAO-based arbitration
- Protects all parties from malicious actions

3.4 Blockchain Network

The blockchain network is backend where all smart contracts are deployed. Key features includes:

- **Immutability** – Transactions and data cannot be changed once recorded.
- **Transparency** – All actors can access verified and timestamped logs.

- **Security** – Eliminates manipulation risks by decentralizing control.

4. Methodology

4.1 Algorithm for the Proposed Framework

```
1. INITIATE Blockchain Network
2. DEFINE SmartContracts:
   a. FundDisbursementContract
   b. AuditContract
   c. DisputeResolutionContract

3. ASSIGN Actors TO Roles:
   FOR each actor IN Actors[] DO
      actor.assignPermission(Tier)

4. RECEIVE Total Funds FROM Donor
   SmartContract.lockFunds(Funds)

5. FOR each milestone IN Milestones[] DO
   a. WAIT FOR ProofSubmission FROM LocalPartner
   b. IF verify(Proof, Conditions[milestone]) == TRUE THEN
      FundDisbursementContract.releaseFunds(to = LocalPartner or NGO)
      AuditContract.logTransaction(milestoneID, actorID, amount, timestamp)
   ELSE
      trigger(DisputeResolutionContract)
      HALT current milestone
   END IF

6. FOR each Tier:
   a. Tier 1: Can view and override contracts, initiate audits
   b. Tier 2: Can approve budgets and view all reports
   c. Tier 3: Can submit reports, upload evidence
   d. Tier 4: Can view status of funds, raise alerts (optional)

7. ON completion of all milestones:
   a. AuditContract.generateReport()
   b. Notify Donor and Public

8. IF any actor violates Conditions THEN
   a. trigger(DisputeResolutionContract)
   b. freezeFunds()
   c. notifyAuditor()

END
```

5. Conclusion

The persistent challenges of financial mismanagement, corruption, and lack of transparency in humanitarian aid distribution have underscored the urgent need for an accountable and trustworthy financial governance model. This research has proposed the Multi-Tier Smart Contract Governance (MTSG) framework, which leverages blockchain's transparency, immutability, and decentralization to enable real-time financial verification and layered access control. By integrating role-based smart contracts, automated auditing, and a decentralized dispute resolution mechanism, the MTSG framework offers a scalable and adaptable solution to ensure that aid funds are efficiently managed and ethically distributed. The framework addresses critical gaps in existing blockchain implementations by providing a structured governance mechanism that accommodates diverse stakeholders, from donors to beneficiaries. Ultimately, this model fosters greater donor confidence, reduces fraud, and promotes ethical and transparent humanitarian aid distribution.

6. Recommendations

1. Pilot application in conflict areas: The MTSG framework should be tested in a limited number of applicable humanitarian interventions (governmental and NGO implementation) in order to expose it to real conditions and further refine its elements
2. Biometric and IoT Integrations: Integration with biometric systems for more accurate verification and IoT asset tracking to ensure operational accountability.
3. Stakeholder training: All stakeholders across the ecosystem—donors, NGOs and local partners, etc, should be trained in how blockchain functions, how the management of smart contracts works, and how digital accountability protocols can be implemented.
4. Regulation and Standards Development: Policymakers should establish clear regulation covering of blockchain applications with respect to humanitarian finance with legal support and international acceptance.
5. Further Research and Simulation Testing: Future research should focus on simulation-based testing under varying crisis scenarios, and compare MTSG's performance with traditional aid distribution methods in terms of cost-efficiency, fraud reduction, and fund traceability.

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