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Blockchain-Enabled Reconstruction: A Comprehensive Framework for Transparent Aid Delivery, Secure Land Registry, and Digital Governance

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Abstract: Syria's 2011–present conflict has destroyed infrastructure, caused a 54% economic decline between 2011 and 2025, and displaced millions. Reconstruction is difficult due to insufficient financial resources, decreased institutional trust, fragmented land records, and a devastated banking sector. Blockchain technology—specifically DLT, smart contracts, and tokenization—can alter Syria's post-conflict rehabilitation. Drawing on empirical evidence from humanitarian blockchain deployments in Syria, including the World Food Programme's Building Blocks platform (which has prevented over USD 287 million in overlapping assistance across Syria, Ukraine, and Palestine), UNDP's Stellar-based payment pilots in Aleppo (which reduced distribution costs from 10% to 2%), and HesabPay's Stablecoin aid delivery programs in Northeast Syria, this paper proposes a multi-dimensional framework encompassing: transparent humanitarian aid coordination and disbursement; immutable land registry and property rights verification; efficient public financial management and governance; supply chain integrity for reconstruction materials; and digital identity infrastructure for citizen services. The findings indicate that blockchain technology offers a viable, cost-effective, and trust-enhancing pathway for Syria's reconstruction, with documented cost reductions of up to 80% in aid distribution and near-instant settlement times. However, successful implementation requires robust regulatory frameworks, digital literacy initiatives, and international cooperation. This paper concludes with actionable recommendations for policymakers, international organizations, and civil society actors seeking to leverage blockchain for sustainable post-conflict recovery.

Keywords: Blockchain Technology; Humanitarian Aid; Land Registry; Digital Governance; Post-Conflict Recovery; Smart Contracts; Economic Decline; International Cooperation.

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1. Introduction

Syria has been in a conflict since 2011, which has created a highly complex reconstruction environment, with widespread infrastructure damage, economic decline, displacement, institutional fragmentation and reduced public trust. The estimated 54% contraction of the Syrian economy between 2011 and 2025 has severely limited resources for reconstruction, and millions of Syrians continue to face challenges related to housing, employment, public services and economic security. Some 1.72 million Syrians have returned, an essential step toward recovery, but returnees still face localized insecurity, explosive-ordnance contamination, limited employment opportunities and inadequate access to essential services [1]. These conditions underscore the need for reconstruction strategies to be transparent, inclusive, resilient and able to operate under harsh institutional and infrastructural constraints [2]. Fragmented property records, limited financial resources, weakened administrative institutions and disruptions to conventional banking systems make the reconstruction process even more complex [3]. Traditional reconstruction approaches often rely on centralized agencies and manual record-keeping, which can make it difficult to track financial flows, verify beneficiaries, protect property rights, and coordinate aid across organizations and geographic areas [4]. These limitations can undermine the effectiveness of reconstruction programs and increase the risks of duplication, corruption, resource diversion and administrative inefficiency, especially in a post-conflict environment where institutional trust has been eroded. Blockchain technology could provide an alternative infrastructure to tackle some of these challenges.

Originally developed as the underlying technology of Bitcoin in 2008, blockchain has matured well beyond its cryptocurrency roots and is now being actively considered for use in financial services, supply-chain management, identity systems, humanitarian assistance, and public administration [5]. A blockchain is simply a shared ledger that records approved transactions across a network of computers rather than a single central database. Thus, depending on the architecture used, blockchain systems can provide tamper-resistant records, automated verification, transparent transaction histories, and programmable processes through intelligent contracts [6]. These are features especially relevant to post-conflict reconstruction. Blockchain can help build trust between parties that may not have full confidence in each other by using cryptographic verification and predefined validation mechanisms. Rather than relying on a single intermediary to verify each transaction, participating organizations can use shared digital records to verify relevant information [7]. This does not remove the need for trusted institutions, but may improve the transparency and traceability of institutional processes. Another big benefit is transparency. Well-designed blockchains can produce an auditable record of financial transfers, aid distributions, property transactions, and supply-chain activities [8]. Humanitarian organizations, donors, government agencies and authorized auditors can use such records to track the movement of resources and identify potential inconsistencies.

This is particularly useful in reconstruction programs where large amounts of international assistance and public expenditure need to be tracked over long periods. Blockchain can also reduce administrative costs by automating some processes using smart contract technology [9]. Smart contracts are programmable agreements that automatically execute predefined actions once certain conditions are met. For example, a reconstruction payment could be triggered when an authorized inspection confirms that construction materials have been delivered in accordance with agreed specifications. Similarly, humanitarian assistance could be transferred after verifying beneficiaries' eligibility [10]. Such automation can reduce delays and minimize unnecessary administrative intervention, though appropriate human supervision remains essential. The decentralized properties of distributed ledger technology may also contribute to resilience [11]. In the event of damage to physical facilities, communication networks or institutional systems, conventional databases and centralised information systems may become unavailable. A well-designed distributed system can offer multiple points of data availability and verification [12]. However, blockchain alone can't overcome all infrastructure limitations. For practical deployment, reliable electricity, internet connectivity, appropriate devices, cybersecurity protections, and trained personnel are still needed, especially in conflict- and displacement-affected areas [13].

Syria already has many humanitarian applications, which provide a strong foundation for assessing this potential. The World Food Program’s Building Blocks platform shows how blockchain can help coordinate humanitarian actors and avoid duplication of assistance. The system says more than USD 287 million in duplicate aid has been stopped in Syria, Ukraine and Palestine. This highlights the positive impact of shared digital records on coordination when several organizations deliver assistance to populations affected by conflict and displacement [14]. Another relevant example is UNDP's payment initiatives based on Stellar. "The cost of aid distribution has reportedly been reduced by 80 percent - from around 10 percent to 2 percent - through pilot activities in Aleppo. Such results suggest that blockchain-based digital payments could reduce transaction costs and accelerate the delivery of financial assistance. In environments where traditional banking infrastructure is weak or inaccessible, alternative digital payment mechanisms may allow beneficiaries to receive support more quickly [15]. Another indication of the promise of blockchain-based financial inclusion is HesabPay’s humanitarian payments programs based on stablecoins [6]. Transfers can be made without using traditional banking infrastructure with digital stablecoin systems. However, their deployment must consider regulatory requirements, exchange-rate risks, digital literacy requirements, cybersecurity, user accessibility and consumer protection [8].

Thus, stablecoins should be regarded as part of a broader financial and regulatory context rather than as a solution. In addition to humanitarian aid, blockchain could support several connected aspects of Syria's rebuilding [3]. One major application is land and property registration. Conflict, displacement and destruction can lead to missing, fragmented or contested property records. A land registry based on blockchain could provide tamper-proof records of property ownership, transfers, claims and supporting documentation. Such a system could assist returning refugees and internally displaced people in establishing legitimate property claims and reducing disputes [9]. But blockchain alone cannot verify legal property ownership, and authoritative legal verification and institutional processes are still needed. Blockchain could also improve public finance management. Rebuilding means spending a lot of money on things like roads, bridges, buildings, homes, health care, schools, power and water and other public services. Recording selected government transactions on an auditable distributed ledger could improve financial transparency and enable authorized stakeholders to trace the distribution and use of reconstruction funds. Smart agreements could be used to make payments based on milestones, procurement verification and expenditure controls [10]. This approach would build donor confidence and reduce opportunities for financial irregularities. Another promising application is supply-chain management [11]. Reconstruction will need large quantities of cement, steel, electrical equipment, machinery and other materials.

This is where blockchain-based tracking could come in to record the origin, transport, inspection, delivery and payment for these materials. This would allow authorised stakeholders to establish a verifiable chain of custody from the supplier to the construction site. This could help mitigate the risk of material substitution, unauthorized diversion, counterfeit documentation and fraudulent delivery claims [4]. A digital identity infrastructure could also help Syria recover. Displacement and loss of official documents can prevent people from accessing government services, financial institutions, education, health services, property systems and humanitarian assistance. Blockchain-enabled verifiable credentials could enable people to securely hold digital copies of authorized identity information and other credentials [7]. Well-designed systems could provide interoperability between public agencies and humanitarian organizations and reduce reliance on fragmented records [14]. However, one must not consider blockchain implementation as a technological solution to all reconstruction problems. Its success is dependent on the broader institutional, regulatory, social and infrastructure context. There should be clear legislation to define the legal status of digital transactions, digital resources, electronic records and intelligent contracts. Strong privacy and data protection safeguards are also needed, particularly when systems involve vulnerable populations. Personally sensitive information should not be stored on an immutable ledger without proper safeguards [15]. Another important factor is digital proficiency. Beneficiaries may not be familiar with blockchain applications, digital wallets, stablecoins or decentralized identity systems.

Training, multilingual interfaces, accessible support services and user-centered design are therefore crucial [6]. Systems should be designed to allow access for people with limited technological skills, and alternative access methods should be available when digital connectivity is not possible. Successful implementation will also require significant international cooperation [11]. Different forms of expertise, financing, infrastructure and technical support can be provided by UN agencies, international financial institutions, donors, technology providers, civil society organizations and Syrian institutions [13]. A coordinated implementation prevents fragmented systems and encourages interoperability between different blockchain initiatives. International partnerships can also assist in developing regulations, cybersecurity capacity, technical training and independent evaluation [5]. To put it simply, blockchain technology can provide a potentially useful digital infrastructure for Syria's post-conflict reconstruction. Its greatest contribution may not be to replace existing institutions, but rather to enhance transparency, traceability, coordination and accountability in reconstruction processes. Areas that are particularly pertinent for carefully controlled implementation include humanitarian payments, property registration, public financial management, supply-chain monitoring and digital identity [7]. The best approach would be incremental and evidence-based, starting with pilot projects that have shown measurable benefits, institutional preparedness, user acceptance and appropriate safeguards and expanding only where these are in place.

1.1. Research Objectives and Scope

This paper aims to:

- Analyze the current state of blockchain deployments in Syria and their documented impacts.
- Propose a comprehensive framework for blockchain-enabled reconstruction across multiple sectors.
- Identify the opportunities, challenges, and prerequisites for successful implementation.
- Provide evidence-based recommendations for policymakers and practitioners.

The scope encompasses humanitarian aid delivery, land registry and property rights, public financial management, supply chain integrity, and digital identity infrastructure. The analysis draws on primary case studies from Syria, including WFP's Building Blocks, UNDP's Stellar pilots, HesabPay's Algorand-based programs, and academic research on blockchain in conflict zones.

1.2. Research Gaps

Despite growing interest, significant gaps remain in the literature:

- **Empirical Evidence:** Limited systematic documentation of blockchain impacts in Syrian reconstruction contexts.
- **Scalability Frameworks:** Few comprehensive models for transitioning from pilots to national-scale deployment.
- **Regulatory Considerations:** Limited analysis of legal and policy frameworks needed for blockchain adoption in fragile states.
- **Integration Challenges:** Insufficient attention to interoperability with existing systems and institutional capacity building.

This paper addresses these gaps by synthesizing empirical evidence from Syrian deployments and proposing an integrated framework for blockchain-enabled reconstruction.

2. Literature Review

The humanitarian sector has increasingly looked to blockchain technology as a potential solution to long-standing problems in aid delivery, such as high transaction costs, a lack of transparency, aid duplication and poor coordination between organizations. The World Food Program launched its Building Blocks platform in 2017, and today it is one of the largest blockchain-based humanitarian systems in operation. Since 2022, Building Blocks has avoided over USD 270 million in overlapping assistance in Ukraine and some USD 287 million in Ukraine, Syria and Palestine. The platform allows humanitarian organizations to coordinate aid on a common digital infrastructure while protecting beneficiary privacy through anonymous identifiers. “This approach demonstrates how distributed ledger technology can enhance coordination, accountability and efficiency while minimizing unnecessary exposure of sensitive personal information.” It provides an important foundation for assessing blockchain applications in Syria’s reconstruction [4]. The United Nations Development Program (UNDP) has also played a major role in developing humanitarian payment systems based on blockchain technology. After some 16 months of pilot projects in 17 countries, from Haiti to Syria, Kenya to Guatemala and The Gambia, UNDP signed a formal agreement with the Stellar Development Foundation to help scale up the development of blockchain payment infrastructure. The agreement, which is valid until 2027, aims to develop appropriate governance frameworks, operational standards and implementation guidelines for blockchain-based payments. The move is part of a broader shift from experimental blockchain projects to formal institutional adoption.

Such developments can provide valuable lessons for conflict-affected countries like Syria on how to enhance the speed, transparency, accessibility and cost-effectiveness of humanitarian financial assistance [6]. Academic research on blockchain applications for post-conflict reconstruction is relatively limited, but steadily growing. AlOkaily and Alzoubi [1] conducted a study on the potential of blockchain technology for civil society organizations (CSOs) operating in Syria and identified several applications. These include tracking of humanitarian aid, monitoring and evaluation, financial accountability and emergency assistance based on cryptocurrency. The research also pointed to a decline in CSO funding since 2019, driven by geopolitical developments and the emergence of global conflicts. Blockchain might help organisations become more transparent and demonstrate the allocation of scarce resources. However, for the standard to be successfully adopted, sufficient technical capacity, suitable regulations, reliable infrastructure and strong data-protection mechanisms are required so that blockchain applications can effectively address the needs of Syrian communities [7]. Another key field of blockchain research in post-conflict Syria is land administration. Habib et al. [4] examined the challenges of land administration and highlighted the significance of multipurpose cadastre systems in facilitating post-conflict transitions. Accurate land records are necessary for protecting property rights, resolving ownership disputes and transferring property, especially where conflict and displacement have compromised or destroyed documentation.

More recent studies have proposed blockchain-based cadastral frameworks for conflict-affected communities. When linked with authoritative legal verification, blockchain could offer tamper-proof records and improve the traceability of property transactions. Such systems could help returning refugees and displaced populations establish legal property rights. But the technological implementation needs to be accompanied by legal institutions and verification procedures, privacy safeguards and mechanisms for correcting inaccurate or disputed records [9]. One of the new areas of research is tokenized reconstruction finance and the potential role of blockchain in mobilizing capital for Syria’s recovery. A risk-governed approach to infrastructure asset tokenisation in Syria, incorporating Sukuk (Islamic bonds) and mechanisms to enhance investor confidence, was proposed by Abedalrhman [2]. Tokenization can break down infrastructure-related assets or investment interests into smaller digital units, making them more accessible and liquid for investors. Moreover, blockchain provides transparent ownership records and financial transaction records that help investors more efficiently track project information. In addition, studies on diaspora capital mobilization suggest that blockchain-based crowdfunding platforms and diaspora bonds could

increase transparency and, consequently, strengthen confidence among overseas Syrian investors. However, these approaches require careful regulatory, financial and shariah compliance considerations before large-scale implementation [12].

3. Methodology

The study uses a mixed-method approach that combines case study analysis, documentary analysis, and comparative analysis. The case study component analyses three major blockchain deployments relevant to Syria: the World Food Program (WFP) Building Blocks platform, UNDP-Stellar blockchain-enabled payment initiatives, and HesabPay-Algorand programs. Documentary analysis consists of examining project reports, academic publications, institutional documents and materials from the humanitarian sector to understand the technological, operational and socioeconomic context of blockchain applications. A comparative analysis compares blockchain-enabled approaches with conventional reconstruction and aid-delivery methods based on key dimensions such as cost, transaction speed, transparency, operational resilience, and accessibility. The dual approach enables the study to analyse both the actual performance of existing blockchain deployments and their potential relevance to the broader post-conflict reconstruction needs of Syria. The study is based mainly on secondary data from reputable institutional, academic and humanitarian sources. Key inputs include documentation and impact reports for the WFP Building Blocks project, reports and materials related to UNDP's partnership with the Stellar Development Foundation, and available information on HesabPay deployment in Syria and other similar conflict-affected environments. The academic literature on blockchain applications in conflict and post-conflict settings is also reviewed, including work by AlOkaily and Alzoubi [1].

Additional evidence is taken from reports published by United Nations agencies, international organizations, humanitarian institutions, and other relevant scholarly and policy sources. These sources are critically reviewed to identify documented outcomes, implementation experiences, technological capabilities, limitations, and contextual factors influencing the successful adoption of blockchain technologies in reconstruction environments. The analytical framework is built on five main application areas found in the literature review and the analysis of documented blockchain projects. These domains include humanitarian aid coordination and disbursement, land registry and property-rights management, public financial management and governance, supply chain integrity, and digital identity infrastructure. For each domain of application, the analysis covers the challenges in the current Syrian context, the proposed blockchain-based solutions and their mechanisms, the observed impacts and available empirical evidence, and the requirements and implementation challenges. This framework provides a systematic basis for assessing the potential of blockchain technologies to overcome specific reconstruction challenges and for highlighting technological, institutional, regulatory, financial, and infrastructural conditions that may affect their scalability and sustainability. The delivery of humanitarian assistance in Syria faces significant challenges, including the fragmentation of aid programs across multiple organizations, the risk of overlapping benefits, high transaction and administrative costs, limited access to traditional banking services, and the need to safeguard sensitive beneficiary information.

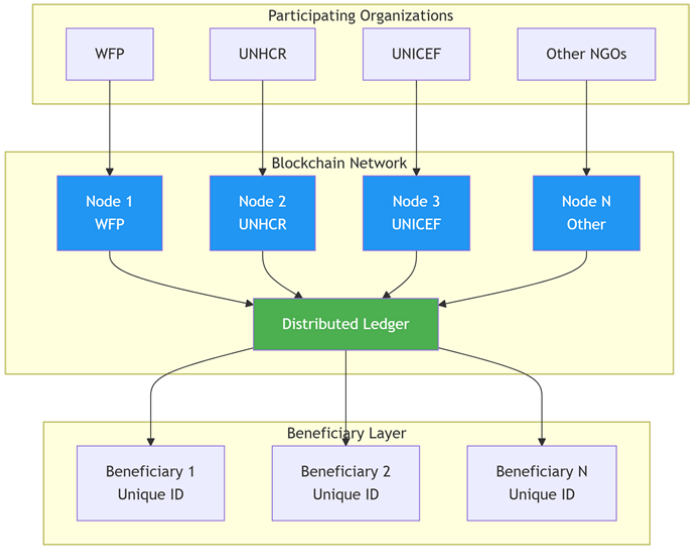

Figure 1: WFP building blocks network architecture

Traditional ways of delivering aid can involve many intermediaries, paperwork, centralized databases and complicated verification procedures. Such conditions may lead to increased administrative burdens and prevent humanitarian organizations

from having a full picture of the assistance an individual beneficiary receives. Blockchain technology provides an alternative mechanism for participating organizations to coordinate transactions, maintain reliable records, reduce unnecessary duplication and improve transparency. The WFP Building Blocks platform is a significant example of blockchain's application in humanitarian assistance. The platform, developed by the World Food Program, features a humanitarian blockchain network on which participating organisations can collaborate while maintaining shared visibility into assistance transactions. Each beneficiary is assigned a unique blockchain account to prevent unnecessary duplication of benefits, and participating agencies can verify whether benefits have already been distributed. The system contains anonymous identifiers that protect beneficiary privacy and reduce exposure to personally identifiable information. This approach demonstrates that blockchain-based coordination can enable more efficient humanitarian assistance, while meeting transparency, accountability and data protection requirements. Figure 1 illustrates the network architecture that enables multiple humanitarian organizations to coordinate assistance via a neutral, decentralized blockchain.

4. Result

UNDP's partnership with the Stellar Development Foundation has demonstrated significant operational improvements. In Aleppo, Syria, a Cash for Work program that recorded payments on-chain reduced distribution costs from approximately 10% to 2%.

Table 1: Comparative analysis of aid distribution costs

Distribution Method	Cost (% of Total)	Settlement Time	Transparency	Resilience
Traditional Banking	~10%	Days to weeks	Limited	Low
Blockchain (Stellar)	~2%	Near-instant	Full on-chain	High

The pilot recorded a 100% payment success rate and near-instant settlement. The system also provided on-chain transparency for every payment made. Table 1 compares traditional versus blockchain-based aid distribution in Aleppo, Syria. In Haiti, another pilot demonstrated the system's resilience by continuing to process aid payments despite a cellular network outage, showing that blockchain-based systems can operate even when conventional communications infrastructure is disrupted.

4.1. Blockchain Solution: HesabPay Stablecoin Payments

HesabPay, an Afghan startup, has developed a blockchain-based platform transforming humanitarian aid delivery in conflict zones. In Northeast Syria, Mercy Corps partnered with HesabPay and Pioneers Innovation for Sustainability and Impact to deliver digital aid using the Algorand blockchain. The pilot achieved:

- 60% lower distribution costs
- 96% faster fund delivery
- 72% of farmers preferred digital stablecoins to cash
- 100% traceability

The platform enables direct digital cash transfers via mobile wallets, supporting over 65 organizations including UNHCR and Mercy Corps.

4.2. Land Registry and Property Rights

4.2.1. The Challenge

After more than a decade of conflict, millions of Syrians live in displacement or diaspora, while many land records have been lost, damaged, or destroyed. The Syrian cadastral system faces challenges including fragmented records, disputed ownership claims, and the need for rapid verification to support returns and reconstruction.

4.2.2. Blockchain Solution

Blockchain-based land registry systems offer a path to secure, transparent documentation of property rights. As Graglia and Mellon [3] explain, blockchain can improve the prospects for formalizing property rights, modernize registries, and record land-related data. Recent research has proposed blockchain-based land registry systems that use Hyperledger Fabric and the Interplanetary File System (IPFS) for decentralised storage. UN-Habitat, in collaboration with OICT and LTO Network,

released an open-source urban land registry solution for Afghanistan, demonstrating the feasibility of blockchain-based land administration in conflict-affected contexts. For Syria, a blockchain-based land registry could:

- Provide an immutable record of ownership.
- Enable rapid verification of property claims for returning refugees
- Reduce disputes and corruption
- Facilitate property transactions and reconstruction planning

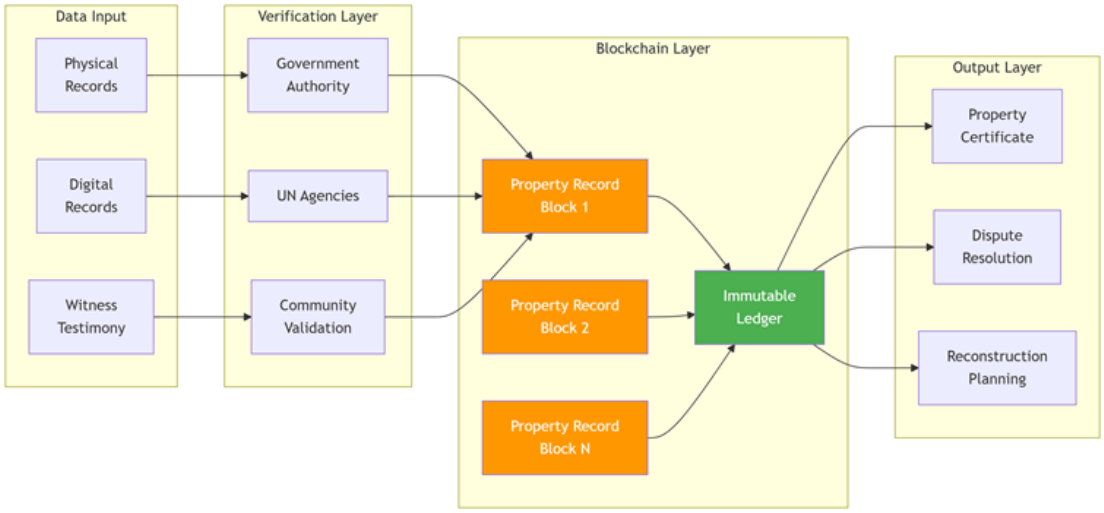

Figure 2: Blockchain-based land registry system for post-conflict Syria

Figure 2 shows that a blockchain-based land registry system for post-conflict Syria would integrate multiple data sources and verification mechanisms into an immutable property record.

4.3. Public Financial Management and Governance

4.3.1. The Challenge

Syria's public financial management systems have been severely degraded by conflict. Limited financial resources, weak infrastructure, and concerns about corruption remain major obstacles to the implementation of reconstruction plans. The transition from a centralized, opaque system to a transparent, accountable governance structure is essential for rebuilding public trust and attracting international investment.

4.3.2. Blockchain Solution

Blockchain technology offers significant potential for enhancing transparency and accountability in digital governance. Research has identified five pillars essential for sustainable blockchain integration in digital governance within developing countries. Blockchain-based e-government systems have been shown to significantly improve administrative transparency and reduce corruption vulnerabilities. For Syria, blockchain-enabled governance could include:

- **Transparent Budget Allocation:** Tracking public funds from allocation to expenditure.
- **Citizen Participation:** Enabling participatory budgeting and feedback mechanisms.
- **Anti-Corruption:** Creating immutable records of government transactions.
- **Service Delivery:** Verifying the provision of public services.

Figure 3 shows blockchain-enabled public financial management would provide transparent tracking of funds from donors to implementation, with smart contracts automating conditional fund releases. Rebuilding Syria means bringing in, shipping and delivering huge amounts of critical materials such as cement, steel, electrical components, machinery and specialized construction materials. The quality, authenticity, origin and proper application of these materials must be ensured to develop safe, durable infrastructure. However, the conventional supply chains operating in conflict-affected environments are

vulnerable to diversion, substitution of low-quality materials, fraudulent documentation and corruption. Such problems can increase reconstruction costs and undermine public and donor confidence.

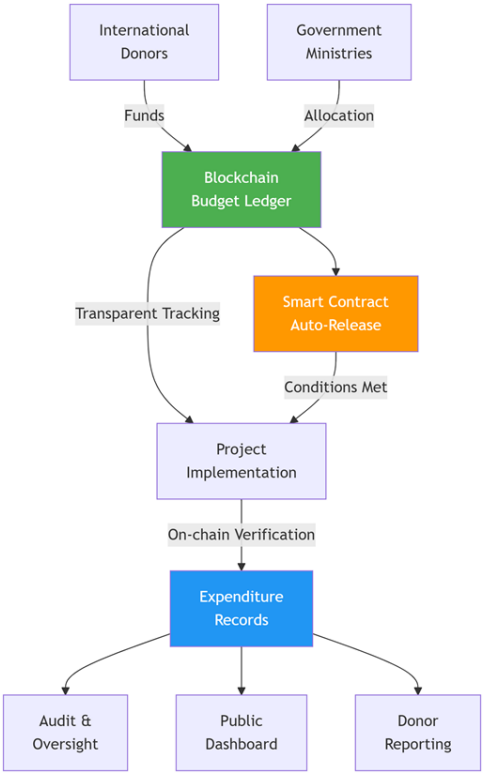

Figure 3: Blockchain-enabled public financial management

Blockchain-based supply-chain management can provide an end-to-end mechanism for logging and verifying the transfer of reconstruction materials. Distribution of materials can be tracked on a tamper-resistant distributed ledger, allowing authorised stakeholders to see how materials are moving from suppliers to construction sites in real time. Such a system can be used to verify the origin and authenticity of materials and to ensure that purchased products meet required technical specifications. It also enables a transparent chain of custody by recording every movement during transportation and delivery. Digital inspection results, certificates, testing records and supplier information can be linked to individual shipments or materials in the blockchain, further advancing quality assurance. Smart-contract mechanisms could also help with payment verification, releasing payments to suppliers once authorized parties verify that materials have been delivered and meet the agreed requirements. This can reduce disputes, increase accountability and limit the chances of fraudulent claims. The Syrian government has also explored blockchain applications for trade finance, suggesting the potential for broader digital use cases. Blockchain-based tracking of reconstruction supply chains could give donors, government agencies, contractors, and citizens more confidence that reconstruction resources are being delivered and used as intended.

But to do this, researchers would need robust digital infrastructure, standardized data formats, skilled personnel and clearly defined institutional responsibilities. Another important application of blockchain technology for Syria's reconstruction is the development of digital identity infrastructure. Millions of Syrians have faced loss of documentation, disruption of official records or displacement. Without reliable identification, people may face major obstacles to accessing public services, financial aid, education, healthcare, employment, property rights and other essential services. Centralized identity systems are also vulnerable to data loss, manipulation, limited accessibility, and institutional fragmentation. Decentralized digital identity systems built on blockchain could give people more control over their personal credentials. A self-sovereign identity model would allow an individual to securely manage verified identity information and share necessary credentials on a selective basis to gain access to services. Verifiable digital credentials could include government-issued documents, educational qualifications, property records, and other credentials that authorized institutions can verify without relying solely on a centralized database. Another possible benefit is privacy protection. Well-designed decentralized identity systems can enable users to present only what they need for a particular service, rather than requiring personal information to be stored in a single central repository.

Interoperability can also allow a verified identity to be used across different government agencies, humanitarian organizations, financial institutions and other authorized service providers. Easing the digital identity challenge could help returning refugees and internally displaced persons resume legal and economic participation. Individuals could use verified credentials to access public services, claim property rights, receive humanitarian assistance, open financial accounts, and participate in employment and reconstruction activities. Blockchain-enabled identity infrastructure could, in this context, become an important component of Syria's broader digital reconstruction strategy. But digital identity systems need to be deployed with strong safeguards. Blockchain should not be considered a solution for storing sensitive personal information directly in a permanent public ledger. Key elements include privacy-by-design principles, data minimization, encryption, access controls, legal protections and mechanisms for correcting inaccurate information. The system should also be accessible to people with limited digital knowledge or connectivity. Therefore, blockchain-based identity infrastructure should not be automatically replacing appropriate governmental identity institutions and legal structures, but rather be supplemented by them.

4.4. Discussions

Empirical evidence from the implementation of blockchain technology in Syria shows several significant and measurable benefits. One of the most important impacts is the reduction of cost. In the UNDP Stellar-based pilot in Aleppo, the cost of aid distribution was reduced from about 10% to 2%, an estimated 80% reduction in transaction and distribution costs. Similarly, the HesabPay project, based on the Algorand blockchain, stated that its distribution costs were approximately 60% lower than those of traditional methods. These reductions demonstrate the potential of blockchain to improve the efficiency of humanitarian resource allocation, especially in resource-constrained settings. Blockchain applications have also seen significant improvements in terms of speed and operational efficiency. Traditional banking and cash-based distribution systems can take several days or even weeks to complete transactions, especially in areas with weak or disrupted financial infrastructure. In contrast, blockchain-based payment systems could provide near-instant settlement and faster access to financial aid. The 96% improvement in delivery speed for HesabPay indicates that blockchain can go a long way toward reducing the time lag between the transfer of humanitarian funds and their receipt by beneficiaries. Another important benefit is financial transparency and accountability. It is a distributed ledger that records transactions. Blockchain technology enables authorized stakeholders to verify payment activities and track the flow of funds.

This provides greater visibility for donors, humanitarian organizations and program managers on how financial resources are being allocated. This kind of transparency can help reduce errors, improve accountability and build confidence in humanitarian programs. Blockchain systems can also enhance operational resilience in the event of infrastructure disruptions. The pilot in Haiti demonstrated that blockchain-based systems could continue processing transactions even when the current cellular networks were compromised. This characteristic is especially important in conflict-affected environments, such as Syria, where telecommunications and financial infrastructure may be damaged or unavailable. However, to be effective, deployment still requires the right connectivity, devices and supporting infrastructure. Another significant impact is improved coordination among humanitarian organizations. The World Food Program's Building Blocks initiative helped to avoid about USD 287 million in overlapping assistance in Syria, Ukraine and Palestine. This shows how blockchain-based information sharing can help humanitarian agencies avoid duplication of assistance, coordinate interventions and improve the overall allocation of scarce resources. Finally, there is evidence that beneficiaries are embracing blockchain-enabled financial services. In the HesabPay pilot, approximately 72% of participating farmers opted to receive digital stablecoins rather than cash.

Table 2: Comparative analysis of blockchain vs Traditional approaches

Dimension	Traditional Approach	Blockchain Approach	Improvement
Distribution Cost	~10%	~2%	80% reduction
Settlement Time	Days to weeks	Near-instant	96% faster
Transparency	Limited/opaque	Full on-chain	Complete visibility
Resilience	Infrastructure-dependent	Decentralized	High resilience
Fraud Prevention	Manual/limited	Cryptographic verification	Strong prevention
Coordination	Fragmented	Integrated	Reduced duplication

This level of acceptance suggests that beneficiaries may appreciate the speed, convenience and accessibility of digital payment mechanisms when they are appropriately designed and supported. In sum, these documented impacts indicate that blockchain can improve the cost-efficiency, speed, transparency, resilience, coordination and accessibility of humanitarian assistance in conflict-affected and reconstruction environments. Table 2 shows comparative analysis demonstrating the superior performance of blockchain-based approaches across multiple dimensions. Thus, the use of blockchain technology in Syria is dependent on the interplay of technological, institutional and social factors. Strong partnerships among UN agencies, NGOs, technology providers, government institutions and local organizations are critical for coordinating resources and expertise. Blockchain systems should also be designed around the needs, capabilities and limitations of the beneficiaries to ensure accessibility and

practical usefulness. Another important factor is scalable infrastructure. In these instances, mature blockchain platforms like Stellar and Algorand could provide the technical backbone for applications that might grow beyond small pilot projects. Regulatory engagement is equally important. Organizations need to operate within existing legal structures and work with policymakers to develop appropriate and supportive regulations. Training local organizations and individuals can build technical capacity and sustain blockchain initiatives (Figure 4).

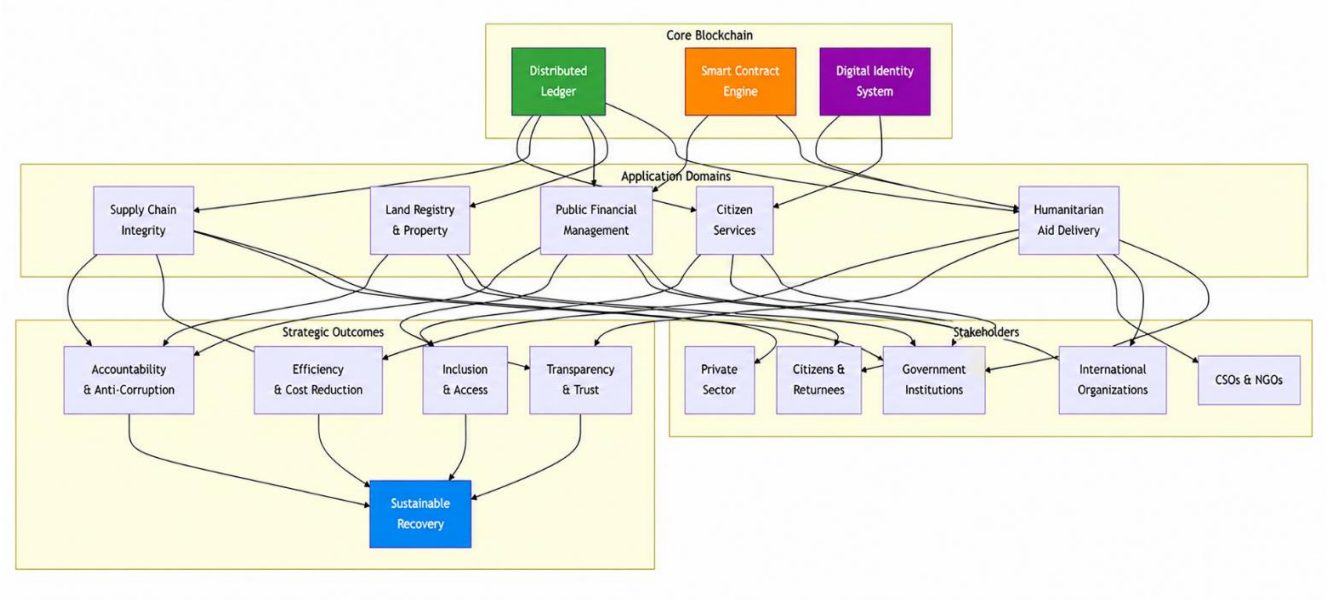

Figure 4: Integrated blockchain-enabled reconstruction framework for Syria

Priority should be given to privacy protection with anonymous identifiers, secure data management and proper data protection mechanisms. But there are several challenges to adopting blockchain in Syria. Regulatory uncertainty is still a key concern, as the legal status of blockchain-based transactions and cryptocurrencies may not be clearly defined. Poor internet connectivity and unreliable electricity supplies in some areas can also limit access to blockchain-enabled services due to infrastructure constraints. Another challenge is limited digital proficiency. Beneficiaries, administrators and local organizations may not be very familiar with blockchain technology. Institutional capacity may be insufficient to govern, regulate and maintain blockchain systems efficiently. Furthermore, scaling up from successful pilot projects to national deployment requires significant financial investment, technical expertise, institutional coordination and long-term planning. Finally, cybersecurity risks should be considered as blockchain-based systems can be exposed to cyberattacks, fraud, data breaches or exploitation by malicious actors. Successful implementation, therefore, requires a balanced approach that combines technological innovation with strong governance, capacity building, infrastructure development and effective security and privacy measures. The evidence presented in this paper supports the development of a comprehensive blockchain-enabled reconstruction framework for Syria. Such a framework would integrate the five application domains identified above into a coherent ecosystem.

4.4.1. Phased Implementation Approach

Given the scale and complexity of Syria's reconstruction needs, and the relatively nascent stage of blockchain adoption, implementation should be phased and carefully coordinated. The initial phase (roughly 0–12 months) could focus on expanding successful existing initiatives such as WFP Building Blocks, UNDP–Stellar, and HesabPay into other appropriate regions. Regulatory sandboxes should be created to enable testing of blockchain applications in a controlled setting. At the same time, local technical capacity should be enhanced through training programs and interoperability standards should be established to ensure that different blockchain platforms can communicate with existing digital systems. The second phase, which should last about 12 to 36 months, should aim to integrate at the sectoral level. A blockchain-based land registry system can be implemented first in a few selected cities to improve transparency, property ownership records, and the accessibility of property information. Blockchain-enabled public financial management systems can be designed to further enhance transparency of government spending. Researchers should develop digital identity infrastructure to support secure access to public services, and blockchain-based supply-chain tracking can improve oversight and accountability of reconstruction materials. The third phase, roughly 36-60 months, should be about scaling nationally. Successful land-registry and digital-identity systems can be scaled up to a national level, and then followed by broader integration of blockchain technologies into government functions. The

development of a comprehensive governance framework for blockchain should be a priority to coordinate implementation, security, data protection and institutional responsibilities.

Syria can also consider connecting to appropriate international blockchain networks to enhance the security and efficiency of cross-border transactions and humanitarian operations. Syrian government institutions should prioritize establishing a comprehensive regulatory framework for blockchain-based transactions and electronic assets. There is a need for a national blockchain strategy with clear objectives, implementation timelines and institutional responsibilities. Regulatory sandboxes can foster innovation in a controlled way, while limiting potential risks. The government should also invest in internet connectivity, electricity infrastructure, cybersecurity, and blockchain education to create an environment conducive to sustainable adoption. International organizations should continue to support successful blockchain pilot projects and help scale them up where evidence shows clear benefits. Technical assistance can help Syrian institutions develop appropriate legal and regulatory structures, and capacity-building initiatives can help strengthen the skills of government agencies and civil society organizations. International organizations should also promote knowledge sharing and best practices, and coordinate their blockchain initiatives to avoid fragmentation and duplication. Civil society organizations have to enhance their technical capacity to deploy blockchain applications effectively in humanitarian and reconstruction efforts. They should engage in pilot projects, share practical knowledge for system development, and promote regulatory structures that enable responsible innovation. Regular monitoring and evaluation should be used to assess the social, economic and operational impact of blockchain initiatives. Most importantly, blockchain systems should be beneficiary-centered, protecting privacy, ensuring data security, and remaining accessible to vulnerable and underserved communities.

5. Conclusion

Syria's reconstruction will be one of the most complicated development challenges of the 21st century. The scale of destruction, the fragility of institutions and the widespread humanitarian needs require innovative solutions that can operate in low-trust, resource-constrained environments. This study shows that blockchain technology is a practical and increasingly established way to face these challenges. The use of blockchain in humanitarian settings has shown several important benefits, including an 80% reduction in aid delivery costs, near-instantaneous settlement, greater transaction transparency, resilience against infrastructure disruptions and high user acceptance. The results show that the practical benefits of blockchain applications can exceed their theoretical potential. The World Food Program's Building Blocks has prevented more than USD 287 million in duplicate assistance. Similarly, UNDP's collaboration with Stellar illustrates how blockchain-based payments can transition from pilot projects to larger-scale operations. HesabPay has also demonstrated how aid delivery via stablecoins can benefit communities in remote and underserved areas.

However, in Syria, the full capabilities of a blockchain can only be realized through technological implementation. Researchers need clear rules and regulations that encourage innovation while also protecting citizens. Moreover, government agencies and civil society organizations need proper training and institutional support to operate blockchain-based systems efficiently. Equally important is investment in digital infrastructure, such as reliable electricity and internet connectivity. International collaboration of UN agencies, donors, technology providers and development organizations can provide the financial and technical resources required for successful implementation. At the same time, citizen engagement, online literacy, and user-centered design should be at the heart of blockchain initiatives. The potential benefits are great. Blockchain can help rebuild institutional trust, increase transparency, ensure that reconstruction resources reach their intended beneficiaries, and strengthen accountable governance. For a country emerging from over a decade of conflict, these capabilities are not just technological accomplishments, but essential building blocks for durable recovery, institutional development, and long-term peace.

5.1. Recommendations

Based on the findings, this research has made several recommendations to improve the use of blockchain technology for reconstruction and development. Governments should adopt a holistic national blockchain strategy that includes legal, regulatory, technical and social aspects. The regulatory sandbox is a controlled environment for testing blockchain applications with risk management controls in place. Investment in digital infrastructure such as internet access, electricity and mobile networks is also key to successful implementation. Government staff require training in blockchain technology, digital governance, and cybersecurity. Public digital literacy programs could increase awareness of and trust in blockchain-enabled services. International organisations and donors should scale successful blockchain initiatives such as Building Blocks, Stellar payments, and HesabPay to relevant regions and sectors. They should offer technical assistance in developing suitable regulatory structures and support capacity-building programs for local institutions, civil society organizations and technology professionals. Knowledge sharing platforms for best practices, lessons learned and technical standards should also be available. "Better coordination among international blockchain initiatives can reduce duplication, avoid fragmentation and increase overall impact." Civil society organizations should explore blockchain-based solutions for aid tracking, beneficiary management and financial accountability.

The staff should be trained in blockchain technology and digital banking systems to ensure effective implementation. Organizations should also engage with policymakers and develop rules and regulations to support blockchain projects. They should also regularly monitor and evaluate blockchain projects to determine benefits, challenges, and lessons learned. Special consideration should be given to the protection of beneficiaries, privacy, data security and user-oriented system design. Tech vendors and researchers should develop low-cost, well-performing blockchain solutions for environments with limited connectivity and resources. Blockchain platforms should be built with interoperability in mind so that they can be plugged into existing databases and digital systems. Researchers are required to undertake rigorous impact assessments to provide reliable evidence of how well blockchain applications work in reconstruction settings. Encourage the use of open standards and open-source solutions to improve accessibility and sustainability. Finally, local communities and Syrian stakeholders should be actively involved in the design and implementation of the system to ensure that blockchain solutions address real local needs and are practical, inclusive and sustainable.

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