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Smart Contract-Driven Disaster Relief: A Case Study on QR-Integrated Blockchain Systems in the 2023 Kahramanmaraş Earthquake Recovery

Gökhan Çaybaşı¹, Gülşah Ayvazoğlu^{2,*}, İskender Peker³

¹ Department of Law, Erzincan Binali Yıldırım University, Vocational School, Yalnızbağ Campus, 24000 Erzincan, Türkiye; gokhan.caybasi@erzincan.edu.tr

² Department of Emergency Aid and Disaster Management, Faculty of Health Sciences, Hatay Mustafa Kemal University, Tayfur Sökmen Campus, Alahan, 31060 Antakya, Hatay, Türkiye; gulsahayvazoglu@mku.edu.tr

³ Department of Business Administration, Faculty of Economics and Administrative Sciences, Gümüşhane University, Gümüşhanevi Campus, Bağlarbaşı Neighborhood, Kazım Karabekir Street, 29100 Gümüşhane, Türkiye; iskenderpeker@gumushane.edu.tr.

* Correspondence: gulsahayvazoglu@mku.edu.tr.

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ABSTRACT

In the aftermath of the 2023 Kahramanmaraş earthquakes, this study examines how blockchain technology might be incorporated into humanitarian aid efforts, with a particular focus on an AFAD-supervised container city in Hatay. To promote accountability and transparency, the research field-tested a QR-integrated Ethereum-based prototype for food-package distribution on 9 April 2025. The technology created an immutable and independently verifiable record of documented distribution transactions by using smart contracts to automate delivery verification. The field implementation demonstrated the technical feasibility of the proposed workflow, while expert assessments indicated potential operational benefits in areas such as data integrity, traceability, and package-level duplicate control. These assessments reflect expert judgments rather than directly measured performance improvements against the conventional system. Practical considerations for the future implementation of decentralized ledger technology in humanitarian logistics are outlined in the study's conclusion.

KEYWORDS

Blockchain technology; disaster management; humanitarian aid; QR-integrated blockchain systems; smart contracts; Ethereum.

1. Introduction

Globally, humanitarian crises—from natural disasters to industrial accidents—are occurring more frequently and having a greater impact. This tendency raises serious questions about the effectiveness of humanitarian aid programs since it makes it difficult for a sizable section of the world's population to obtain necessities. Even though 33% of the world's food production is wasted each year (Food and Agriculture Organization of the United Nations [FAO], 2013), the sharp contrast between waste in developed countries and shortages in places like Sub-Saharan Africa highlights pervasive disparities in the distribution of aid (Demir, Turetken, & Ferworm, 2020). These disparities are frequently a sign of structural inefficiencies in humanitarian supply chains, especially with regard to last-mile visibility and traceability. Large-scale earthquakes and other natural disasters pose significant obstacles to humanitarian logistics. In these high-pressure settings, it is critical to provide delivery that is transparent, timely, and responsible. However, fragmented data structures, poor traceability, and the possibility of resource misappropriation sometimes hinder traditional systems (Tapia, Bajpai, Jansen, Yen, & Giles, 2011; Van Wassenhove, 2006). Since knowledge asymmetry and environmental uncertainty are greatest during last-mile activities, these constraints are particularly severe.

Hatay continues to be one of Turkey's most disaster-prone provinces. This vulnerability was sadly confirmed by the devastating earthquakes that occurred on February 6, 2023, with Hatay accounting for over half of all fatalities (Duruel, 2023). Operational complexity was greatly increased by the loss of local labor forces, high population density, and destroyed infrastructure (Boz, 2025; Partigöç & Dinger, 2025). Multi-actor coordination is made more difficult by these structural limitations, particularly during times of high demand like Ramadan when distribution networks are under more strain. Critical bottlenecks, such as manual data entry errors, duplicate home records, and a lack of real-time performance monitoring, were found through contextual queries and first field inspections carried out with AFAD (Disaster and Emergency Management Presidency) staff.

Blockchain technology provides a promising framework with decentralization, immutability, and automated execution through smart contracts to address these issues (Nakamoto, 2008; Suganthi, Beena, Sumathi, & Poongodi, 2021). Beyond its financial roots, blockchain is becoming more widely acknowledged in humanitarian logistics due to its capacity to provide reliable and unchangeable records (Casino, Kanakaris, Dasaklis, Moschuris, & Rachaniotis, 2019; Rejeb & Rejeb, 2020). Blockchain-based solutions can reduce the risk of corruption and improve confidence throughout the supply chain by automating identification, verification, and donation tracking (Demir et al., 2020; Sarumathi, Johnny, Mol, Khandare, & Keerthi, 2025; Treiblmaier & Rejeb, 2023). Conceptual blockchain models and their actual implementation in active crisis areas, however, still differ significantly. Although prior research indicates that resilience and coordination have improved (Dubey, Gunasekaran, Bryde, Dwivedi, & Papadopoulos, 2020; Khan, Imtiaz, Parvaiz, Hussain, & Bae, 2021), there is still little empirical data on operational metrics like delivery accuracy and duplicate rates. The performance of smart contracts in high-stress, infrastructure-constrained contexts is understudied because the majority of research relies on simulations (Chen, He, Sun, Zheng, & Wu, 2024).

In order to close this gap, this study examines the practical application of a blockchain-based humanitarian distribution system in Hatay after the 2023 earthquakes. We made end-to-end tracking possible using an Ethereum-based blockchain framework by giving QR codes to food parcels that were dispersed across an AFAD-coordinated container city during Ramadan. This study offers key field-based insights from an operational disaster context, in contrast to earlier conceptual studies. To the best of our knowledge, this is one of the earliest field-based applications of decentralized ledger technology for tracking food delivery following an earthquake. The following research questions are addressed in this context:

RQ1. In a disaster area, how might blockchain integration reduce conventional operational inefficiencies such as aid duplication and human entry errors?

RQ2. How does the system support data integrity, verifiability, and traceability standards during last-mile distribution?

RQ3. In terms of operational planning and resource allocation, what potential advantages does the created framework provide to field staff and decision-makers?

The rest of the document is structured as follows: The literature study is presented in Section 2. The technique and system architecture are described in Section 3. The execution and results are described in Section 4. The implications are discussed in Section 5, and future research directions are concluded in Section 6.

2. Literature Review

Lack of openness in intermediary-led procedures is frequently the root cause of the ongoing problem of corruption and knowledge asymmetry in disaster aid. A paradigm change toward decentralized verification methods is required due to trust deficiencies between donors and centralized relief groups. This study, which focuses on an ongoing humanitarian effort in a temporary shelter area, examines blockchain integration through an applied field-based perspective. The current literature is examined under three topical subheadings in order to provide a solid conceptual framework: (i) general application domains, (ii) donor ecosystems, and (iii) disaster management frameworks.

2.1. General Application Domains

Blockchain technology has emerged as a transformative digital infrastructure with applications across multiple sectors. Its core characteristics—decentralization, immutability, and smart contracts—enable secure, transparent, and verifiable interactions in multi-stakeholder systems (Yang, Bi, Liang, Zhou, & Yang, 2020). Related discussions of the basic blockchain architecture and decentralization can be found in Mahajan and Kadam (2019) and Zhang et al. (2022).

In the literature, blockchain has been widely applied in financial systems for secure cryptocurrency-based transactions (Haryani, Matharu, Nagar, & Verma, 2024; Mincewicz, 2022), in supply chain management to improve traceability and security (Makkar & Costa, 2020; Reddy & Manjunath, 2024), and in healthcare to ensure secure data sharing and patient information protection (Halkiopoulos, Antonopoulou, & Kostopoulos, 2023; Shynar et al., 2025). It also supports transparency and security in voting systems (Lee, 2023; Muthukumar & Meenakshi, 2025), identity verification and document authentication (Arun & Mathiyalagan, 2021; Karale, 2025), and timestamp-based verification in notarial services (Uikey, Brarskar, & Ahirwar, 2024). In addition, blockchain has been explored in food supply chains to enhance traceability and safety (Duan, Onyeaka, Pang, & Meng, 2024; Suthar, Suryawanshi, & Gavane, 2019). Broader work also considers blockchain-enabled sustainability within supply chains (Sabeti et al., 2019).

Across these domains, the primary contribution of blockchain lies in strengthening data integrity, traceability, and trust in distributed environments where centralized verification is limited or inefficient. These properties make blockchain particularly relevant for systems requiring coordination among multiple independent actors.

In humanitarian logistics, these same characteristics are critical, as timely, accurate, and tamper-proof information flow directly affects aid allocation, resource distribution, and operational coordination. Therefore, blockchain's underlying features provide a conceptual foundation for improving decision-making processes in disaster response systems. Related analyses examine humanitarian information coordination, technology-adoption factors, and blockchain applications in logistics (Chen, Hendalianpour, Feylizadeh, & Xu, 2023; Dubey, Gunasekaran, & Foropon, 2024; Gopal & Garcia, 2021).

2.2. Donor Ecosystems

Demir et al. (2020) demonstrated that blockchain technology improves disaster relief operations by increasing transparency and reducing fraud risks, while also encouraging donor participation. Similarly, Shevtekar and Raut (2023) argue that transparency significantly increases willingness to donate, as centralized systems often suffer from trust deficits. This lack of transparency has become more critical with the rise of fraudulent donation campaigns, highlighting the need for auditable and reliable systems (Saraswat et al., 2022). In this context, blockchain is increasingly recognized as an innovative tool for improving trust, transparency, and accountability in humanitarian operations (Adediran et al., 2024). Smart contracts, in particular, are considered key mechanisms for automating processes and ensuring fair, efficient, and corruption-resistant aid distribution (Jha, Priya, Chandrakar, & Pradhan, 2024).

In the literature, several blockchain-based systems have been proposed for donation tracking and post-disaster aid distribution (Jain & Simha, 2018; Kumari, Dixit, Prakash, & Sharma, 2022; Patil & Kadam, 2022). Platforms such as Ethereum enable end-to-end automation of donation flows via smart contracts, reducing intermediary-related trust issues and corruption risks (Jha et al., 2024; Saraswat et al., 2022). Real-world initiatives such as Binance Charity, AidChain, The Giving Block, and Charity DAO aim to enhance transparency and trust in donation ecosystems; however, these are mostly evaluated at the conceptual or system-design level, with limited empirical validation in real disaster environments. Publicly available descriptions of blockchain-supported donation initiatives include AidChain, Binance Charity, BitHope, CharityDAO, and The Giving Block (AidChain, n.d.; Binance Charity, n.d.; BitHope, n.d.; CoinMarketCap, n.d.; The Giving Block, n.d.). Broader studies address blockchain-based donation tracking in disaster-affected regions (Rai, Srivastava, Rai, & Patanashetti, 2024).

The presence of intermediaries in traditional aid chains continues to reduce transparency and weaken donor confidence (Demir et al., 2020). Blockchain systems address this limitation by ensuring that all transactions are immutably recorded and verifiable, allowing donations to be traced transparently to end beneficiaries (Srivatsa, Thammaiah, MV, & AP, 2024). This strengthens trust not only among donors but also among all stakeholders involved in humanitarian operations. A review of studies on secure and transparent donation platforms built on blockchain reveals a growing body of both theoretical and practical research. These studies are grouped and presented in Table 1.

Table 1. Summary of the Literature on the Use of Blockchain Technology in Donation Systems.

Author(s)	Year	Purpose	Method / Network	Type
Jadhav et al.	2025	Tracking educational scholarship donations via a platform	Ethereum and smart contract	Practical
Hoque et al.	2024	Increasing transparency in philanthropy	Hyperledger Fabric i	Practical
Sammer et al.	2024	Solving food and nutrition insecurity	AI and Ethereum	Practical
Ahmed et al.	2024	Ensuring transparency in donation processes	Ethereum and smart contract implementation	Practical
He et al	2024	Secure donation system with encryption	Ethereum and cryptography	Practical
Patil & Kadam	2022	Blockchain architecture for aid processes	Architectural modeling	Theoretical
Barger et al.	2022	Testing blockchain applicability	Hyperledger Fabric	Theoretical & Practical
Kumari et al.	2022	Transparent donation system development	Applied solution	Practical
Khalil et al.	2021	Architecture for blockchain-based aid	Design-based	Theoretical
Shaheen et al.	2021	Security in crisis donations	Blockchain system	Practical
Wu & Zhu	2020	Security of donation systems	System architecture	Theoretical
Singh et al.	2020	Auditability of aid processes	Hyperledger-based case	Practical
Saleh et al.	2019	Donation tracking during crises	Case study on blockchain network	Practical
Jain & Simha	2018	Blockchain donation architecture	Theoretical design	Theoretical

The traceability and security mechanisms provided by donation systems can also be directly adapted to the physical distribution processes of humanitarian aid. Thanks to immutable record structures and automated verification processes, it is possible to track the movement of aid packages, verify deliveries, and reliably manage stock levels. Thus, blockchain-based donation systems provide an infrastructure that strengthens the integrity of end-to-end humanitarian logistics processes. There is a clear trend toward Ethereum-based practical implementations, according to a comprehensive review of the literature compiled in Table 1 (e.g., Ahmed, Fumimoto, Nakano, & Tran, 2024; Jadhav, Mohite, & Pise, 2025). The vast majority of this “practical” research, however, is carried out in controlled settings or small-scale pilot testing, underscoring the dearth of long-term data from extensive catastrophe areas.

2.3. Disaster Management Frameworks

Blockchain has gained increasing attention in disaster management as a tool to enhance transparency, trust, coordination, and operational efficiency. In complex and multi-stakeholder environments, it is positioned not merely as a data storage system but as a trust-enabling digital infrastructure. Early studies (e.g., Bhat, Pranaav, Mini, & Tosh, 2021; Demir et al., 2020) proposed blockchain-based architectures to address key challenges such as supply chain disruptions, lack of trust, and corruption risks. Subsequent research expanded this perspective by integrating complementary technologies such as IoT and AI to support real-time monitoring and decentralized decision-making (Gao, Chen, Huang, & Hezam, 2024; Kaur, Kaur, & Sood, 2022). Recent research similarly emphasizes the growing role of emerging technologies in strengthening disaster-management capabilities and supporting information-based response processes (Hanspal & Behera, 2024). Research has also examined blockchain-enabled resource sharing during emergency operations, technology integration in humanitarian supply chains, and exploratory uses for disaster and refugee relief (L’Hermitte & Nair, 2021; McIsaac, Brulle, Burg, Tarnacki, Sullivan, & Wassel, 2019; Rodríguez-Espíndola, Chowdhury, Beltagui, & Albores, 2020). Recent work also considers the organizational practice of disaster risk reduction (Dennison & Coldwell, 2025). Research on the combination of blockchain and the Internet of Things further addresses security, algorithms, and application settings (Nazareth, Sathyaprakash, Shetty, & Poojary, 2025).

More recent studies focus on application-oriented solutions, including systems for aid tracking, victim identification, logistics coordination, and donation transparency (Das, Basu, & Bit, 2022; Kolhatkar et al., 2023; Lathkar, Deshmukh, Patil, & Shelke, 2024; Parildar, Sayin, Türkzeybek, Küçüköz, & Erten, 2023). In addition, national-scale and mobile-based implementations demonstrate blockchain’s potential for secure data sharing and equitable aid distribution (Darmawan, Okitasari, Dwi-yanti, Pratama, & Haritman, 2024; Shiozaki & Hasegawa, 2024). Overall, blockchain-based platforms—particularly Ethereum-based systems—are increasingly utilized to ensure traceability and transparency in disaster assistance processes (Ghani, Zinedine, & El Mohajir, 2025; Sarumathi et al., 2025). However, most studies remain limited to prototype or pilot implementations, highlighting the lack of empirical evidence from real-world disaster environments. Despite these developments, a large portion of the existing literature is still trapped in what is known as a “pilot-testing trap.” Although these frameworks represent a step toward technological maturity, they frequently circumvent the unstable operational limitations of a real-world post-disaster context, such as sporadic connectivity, high-volume rapid distribution, and field workers’ diverse levels of digital literacy. As a result, there is still a lack of empirical data on how well systems work in actual crisis situations, especially when it comes to field deployment, scalability under pressure, and operational usability. Table 2 summarizes these studies, which concentrate on assistance distribution (A.D.) and contain either prototype developments (AP.) or actual implementations, along with the platforms utilized.

Table 2. Use of Blockchain Technology in Disaster Management

Author	Years	A.D	AP.	Ethereum	Hyperledger
Ghani et al.	2025	✓	✓	✓	
Sarumathi et al.	2025	✓	✓	✓	
Srivatsa et al.	2024	✓	X		
Darmawan et al.	2024	✓	X		
Shiozaki & Hasegawa	2024		✓		✓
Lathkar et al.	2024		✓	✓	
Parıldar et al.	2023		✓	✓	
Kolhatkar et al.	2023		✓		
Das et al.	2022		✓	✓	
Shan et al.	2022	✓	X		
Kaur et al.	2022	✓	X		
Hunt & Zhuang	2022	✓	X		
Bhat et al.	2021		✓		✓
Demir et al.	2020	✓	X		

Studies in the literature highlight the theoretical advantages of blockchain technology in disaster management, particularly in terms of transparency, coordination, and information integrity. However, most existing research is limited to simulation environments, laboratory prototypes, or conceptual models that do not fully capture the complexity of real disaster operations. As a result, critical operational constraints such as infrastructure disruptions, coordination difficulties, and field-level uncertainties remain insufficiently addressed in empirical contexts. Although numerous blockchain-based frameworks have been proposed for aid and donation distribution, their effects on key operational performance indicators (KPIs)—such as delivery accuracy, duplicate delivery prevention, verification time, and data integrity—have not been adequately quantified. This reflects a persistent gap in field-based implementation and operational evaluation of blockchain applications under real disaster conditions. To address this limitation, this study implements a blockchain-based aid distribution system in a real disaster environment (Hatay, 2023 earthquakes). The proposed system enables end-to-end traceability, automation, and verification of aid processes under actual operational constraints. Unlike simulation-based studies, this research provides evidence from a field-based implementation of the proposed blockchain-supported workflow.

2.4. Research Gap and Contribution

Existing research predominantly utilizes simulation-based evaluations to quantify blockchain's benefits. This study diverges from the current body of work by providing field-based implementation evidence from the Hatay earthquake (2023) recovery phase. By demonstrating the blockchain-supported aid distribution workflow in a real post-disaster setting and complementing the implementation with expert-based assessments, this research moves beyond conceptual modeling into the realm of field-based proof-of-concept implementation.

3. Methodology

Post-disaster humanitarian aid processes require rapid response, effective coordination, and reliable information management. However, issues such as lack of transparency, inefficient resource utilization, and logistical disruptions necessitate the adoption of innovative technologies that ensure secure and verifiable data flow. In this context, blockchain technology (Demir et al., 2020), widely

associated with trust, transparency, and traceability, provides a suitable infrastructure for improving post-disaster operations. Distributed ledger technology ensures data integrity by enabling all transactions to be recorded and verified across a decentralized network. These properties—transparency, immutability, and verifiability—are critical for accountability in humanitarian aid systems.

3.1. Research Design

This study adopts an applied case study design conducted in a container city in Hatay following the 2023 Kahramanmaraş earthquakes. The methodology consists of three sequential stages (Figure 1):

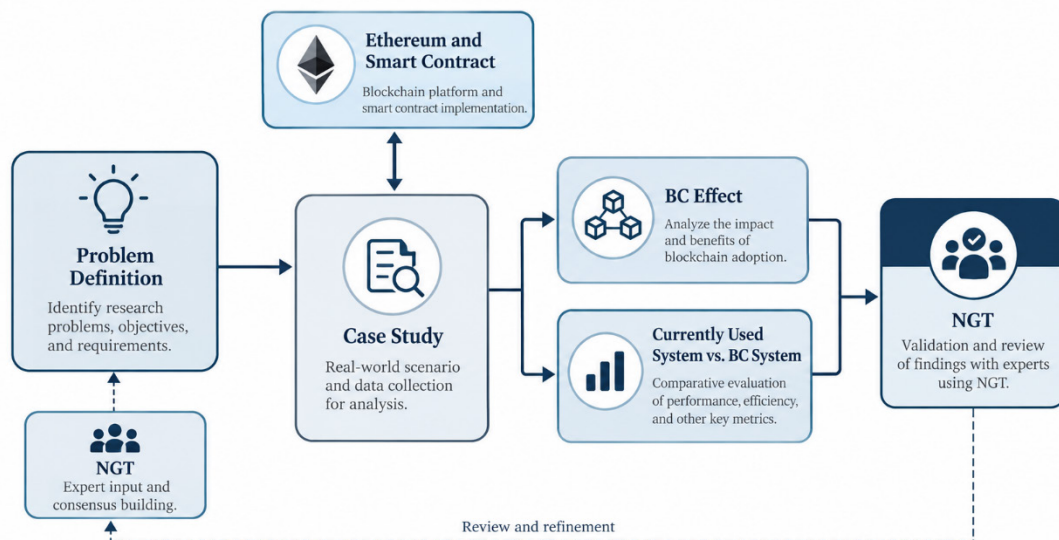


Figure 1. Research Methodology.

1. First Stage (Problem Definition): Fundamental operational problems encountered in traditional aid distribution processes were identified using the Nominal Group Technique (NGT).

Nominal Group Technique (NGT) is a structured method used to generate ideas, solve problems, and achieve group consensus through a facilitated decision-making process (Thao, 2023). In this study, NGT was employed to identify the requirements of traditional aid distribution systems and to assess the feasibility of a blockchain-based alternative. The method provides a formalized consensus mechanism that ensures equal participation by integrating independent judgments while minimizing the influence of dominant individuals or group dynamics on decision outcomes (Delbecq & Van de Ven, 1971; Van de Ven & Delbecq, 1974). Compared to traditional focus group methods, NGT offers advantages such as balanced participation, reduced power asymmetry, and the production of structured and actionable outputs suitable for implementation-oriented research designs (McMillan, King, & Tully, 2016; Rankin et al., 2016). The NGT process consists of four stages, as shown in Figure 2: (1) generating ideas, (2) recording ideas, (3) discussing ideas, and finally (4) voting on ideas (McMillan et al., 2016; Rose et al., 2025; Sauers-Ford et al., 2019). The nominal group technique has also been described as an effective means of developing structured group consensus (Harvey & Holmes, 2012).

NGT has also been applied to expert-led problem identification and prioritization in operationally complex settings, including barriers to sustainability-oriented innovation in manufacturing (Brandão, Fontana, Silva, & da Silva, 2025), maintenance implementation (Mustafa et al., 2025), regulatory recommendations (Car et al., 2025), and service-delivery decentralization (Oliveros et al., 2025). These studies serve as cross-sector methodological examples, not as empirical evidence about blockchain effectiveness in disaster relief.

Nominal Group Technique (NGT) Process

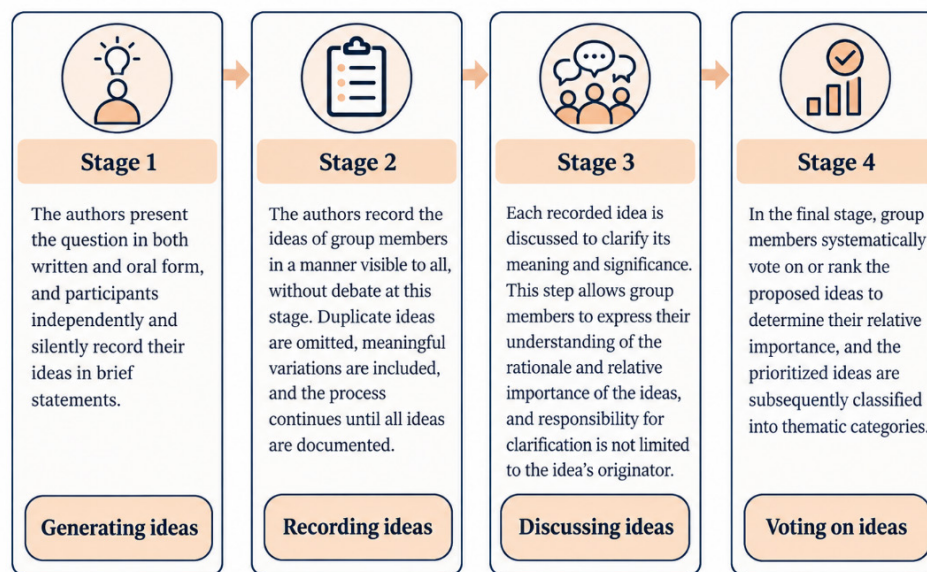


Figure 2. The Nominal Group Technique (NGT) process comprises the following stages:

4. Second Stage (Case Study)

The developed blockchain-based system has been integrated into the field; the processes of collecting and reporting distribution data have been carried out through a case study.

5. Third Stage (Validating the Results by NGT)

The data obtained were evaluated in terms of the functionality of the implemented system, and its perceived operational contributions were assessed using NGT sessions. This structure enables the study to not only present a technical prototype, but also to demonstrate its field-based implementation and complement the technical findings with expert-based assessments in a real post-disaster environment.

5.1. System Requirements and Technological Infrastructure

The fundamental characteristics of blockchain—transparency, efficiency, security, accountability, and direct transfer principles—have directly shaped the requirements of the developed system. The verifiable recording of each step in the distribution process, the package-level duplicate-delivery controls, and the backward traceability of the process flow form the backbone of the methodological design.

A Decentralized Application (DApp) running on the Ethereum blockchain has been developed to reliably record humanitarian aid transactions. The core technologies used in the system are as follows: Solidity is the programming language used for Ethereum smart contracts; a technical introduction is provided by Bauer (2022).

Smart Contracts (Solidity): It automates the execution, verification, and recording of assistance-related processes.

Ethers.js: It has enabled interaction between the blockchain and the user interface.

MetaMask: It has been used for wallet and transaction management.

Sepolia Testnet: It has provided a public and low-cost testing environment. These technologies were chosen due to the power of the open-source ecosystem, low cost, and the ability of field personnel to adapt to the system with minimal training. The use of the Sepolia test network has enabled field testing of blockchain transactions without incurring the costs associated with a production Ethereum deployment.

5.2. Data Collection and Operational Analysis

During the development process, system requirements were analyzed, smart contracts were programmed, and user-friendly interfaces were designed. The immutable nature of the blockchain ensures that every transaction is protected from unauthorized interference and verified. The data generated by the system consists of delivery timestamps, package-recipient matches, container numbers, and verification logs.

Through these data:

- Package-level duplicate delivery controls were implemented through the smart-contract logic,
- The delivery process was recorded through blockchain timestamps,
- The system workflow was examined in terms of reducing reliance on manual record-keeping,
- Distribution records were made traceable and retrospectively verifiable.

6. Application

6.1. Determining Operational Evaluation Dimensions with NGT

During the expert selection process for the NGT application, invitations were sent to 15 institutional representatives actively involved in post-earthquake humanitarian operations following the February 6 earthquakes. Based on the responses received a panel of six experts specializing in disaster management and humanitarian logistics was established. The selection criteria were based on direct involvement in field operations and experience in post-disaster humanitarian coordination. In addition, both sectoral and academic competencies relevant to evaluating the integration of traditional aid distribution processes with the proposed blockchain-based model were considered. The participant profile is presented in Table 3.

Table 3. Determination of the expert group

Number of Experts	Institution / Field of Expertise	Experience / Job Description
2	AFAD (Disaster and Emergency Management Authority) Field Personnel	Distribution processes in operations management
1	Ministry of Family and Social Services	Disaster emergency social assistance processes
2	NGO Representative	Humanitarian aid field activities
1	Academic / Logistics Expert	Humanitarian logistics and operations management

The NGT session was conducted face-to-face with experts meeting the inclusion criteria at a predetermined time and location and followed a four-stage structure. In the first stage (Generating Ideas), participants independently listed operational challenges encountered in humanitarian aid processes following the February 6 earthquakes. In the second stage (Recording Ideas), each participant shared their responses sequentially, while discussion was restricted to minimize bias and prevent

dominance effects (Humphrey-Murto, Varpio, Gonsalves, & Wood, 2017). In the third stage (Discussing Ideas), experts identified common themes and consolidated overlapping issues, which were subsequently organized using movable cards for thematic structuring. In the final stage (Voting on Ideas), instead of a traditional ranking procedure, a consensus-based approach was adopted. Participants emphasized that the identified issues were interrelated and more appropriately addressed through thematic grouping rather than individual ranking for intervention planning purposes. Accordingly, operational challenges were consolidated through a structured consensus process. In the evaluation phase, experts were presented with a standardized form based on operational evaluation dimensions reported in the literature (Table 4), enabling a structured expert-based comparison between traditional and blockchain-supported aid distribution systems.

Applications of NGT in intervention planning have also been documented in vocational rehabilitation, hypertension management, psychosocial support, and adolescent behavioral interventions (de Dios Perez et al., 2025; Kichou et al., 2025; Ling, Syed Abdullah, & Saleh, 2025; Mbedzi, van der Wath, & Moagi, 2025). These studies illustrate the structured identification and discussion of stakeholder priorities across fields; they are not used to infer operational outcomes for the humanitarian system evaluated here.

Table 4. Operational Dimensions Used in the Expert Assessment

Indicator Title	Blockchain Feature Supported in the Literature (CSF)	Contribution of Blockchain	References
1. Verification Time	Enhanced Transaction Speed and Scalability	Provides higher throughput and sufficient scalability, enabling faster verification processes compared to conventional systems.	Taher, Ameen, and Ahmed (2024), Haque et al. (2024), Kumar, Phani, Chilamkurti, Saurabh, and Ratten (2024), Coretti, Fitzi, Kiayias, Panagiotakos, and Russell (2025)
2. Duplicate Delivery Rate	Immutability and Security	Prevents duplicate package deliveries and record inconsistencies through a shared, tamper-proof ledger.	Antsipava, Strycharz, van Reijmersdal, and van Noort (2024), Duan, Onyeaka, and Pang (2024), Karaduman & Gülhas (2025), Nwani (2025)
3. Data Integrity	Enhanced Security and Immutability	Ensures data integrity and confidentiality through immutable record-keeping mechanisms.	Maariz, Wiputra, and Armanto (2024), Musthafa & Bargavi (2024)
4. Auditability	Increased Auditability	Strengthens audit assurance through immutable records, improving performance monitoring and accountability.	Al-Naseri (2023), Harakeh, El Diri, Lambrinoudakis, and Tsileponis (2024), Zhang, Ma, and Meng (2025).
5. Delivery Accuracy	Traceability	Enhances tracking of missing or end-of-life (EOL) products within supply chains, supporting operational and environmental performance.	Mansoor, Helmy, Sekhon, and Ally (2023; Xiao, Sun, Chang, Lu, and Jiang (2024); Rahman, Yii, Masli, and Voon (2024)
6. Transparency Perception	Improved Visibility	Increases transparency and traceability across the supply chain, improving overall system visibility.	Khairunnisa, Christiani, and Prawiyogi (2024), Rahman et al. (2024), Nwani (2025)
7. Personnel Workload	Cost and Resource Efficiency / Disintermediation	Improves operational efficiency and resource utilization by reducing intermediaries (disintermediation).	Han, Shiwakoti, and Chen (2024), Ktari, Frikha, Hamdi, and Hamam (2024), Nagy (2025)
8. Record Discrepancy Rate	Immutability and Security	Prevents record inconsistencies and guarantees data accuracy through immutable ledger structures.	Abubakar, Liu, and Gilliard (2023), Piesciorovsky, Hahn, Borges Hink, and Werth (2024), Sivaprakash et al. (2024)

6.2. Case Description

Hatay was one of the provinces most severely affected by the February 6, 2023 earthquakes, with extensive loss of life and severe infrastructure damage. Critical services such as electricity, water, communication, and transportation were largely disrupted, leading to widespread displacement and urgent humanitarian needs. Following the disaster, container cities were established by AFAD, TOKİ, NGOs, and international organizations to address shelter needs. Aid distribution, coordinated mainly by AFAD and NGOs such as the Turkish Red Crescent, included essential supplies. However, disrupted logistics, weak coordination, and limited information flow resulted in delays and unequal distribution. More than two years later, Hatay still hosts over 200,000 people in container settlements (AFAD). While basic needs are now partially addressed through the “Esen Card” system, humanitarian dependency continues. Ramadan further increases the importance of aid delivery due to its social and cultural significance. In this context, blockchain-based systems offer a potential solution for ensuring transparency and traceability in aid distribution, improving accountability and beneficiary verification.

6.3. Adaptation of Information Technology in the Distribution of Ramadan Food Packages in Hatay

During Ramadan and Eid al-Fitr, food distribution was implemented using an Ethereum-based blockchain system to ensure end-to-end traceability. The system was field-tested on 9 April 2025 as a limited proof-of-concept implementation. The proof-of-concept comprised five food-package delivery transactions recorded on the Sepolia test network. Each package was assigned a unique QR code, and key delivery information (time, location, and synthetically generated recipient data) was recorded on-chain. Smart contracts enabled secure and immutable storage of distribution records, ensuring that the recorded transactions were verifiable and tamper-proof. This enabled the technical testing of traceability, accountability, and transaction-verification functions within the proposed aid distribution workflow. All activities were conducted by authorized institutions, allowing retrospective verification by both aid organizations and supervising authorities. Each transaction was automatically time-stamped, and QR-based scans and delivery confirmations were logged. These records formed the basis for technical verification and post-distribution auditing. Because the implementation was designed to test workflow functionality rather than operational performance, staffing, rejected duplicate attempts, failed transactions, system errors, and deployment-duration metrics were not systematically recorded.



Figure 3. Aid Distribution Process

Figure 4 presents the general working principle of the designed system. As shown in Figure 3, the beneficiaries and the aid packages to be distributed are recorded on the blockchain through a smart contract triggered by the application layer developed in this study and operated by the charity organization.

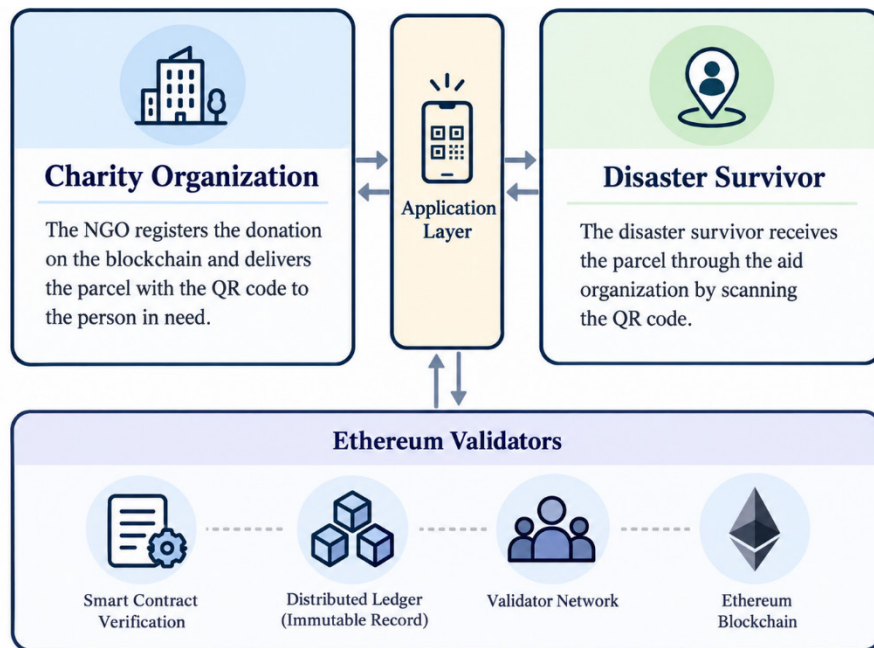


Figure 4. Architectural design of the study

In Figure 5, synthetically generated beneficiary information, including name, surname, phone number, and identification number fields, is encrypted using the AES-GCM algorithm during the aid registration process and subsequently recorded on the blockchain. During the encryption process, a random salt and Initialization Vector (IV) were generated for each user, and the encryption key was derived using the PBKDF2 (Password-Based Key Derivation Function 2) algorithm. A unique ID, generated by the application specifically for each user, was added to the blockchain as plaintext, and all aid distributions were linked through this ID. The encrypted values stored on the network can only be decrypted using the AES key; however, the encrypted on-chain values themselves remain publicly retrievable on Sepolia.

For the field-based proof-of-concept, no real beneficiary names, telephone numbers, or national identification numbers were stored on the public Sepolia test network; instead, synthetic data were used to test the registration and verification workflow. The encryption mechanism was incorporated as a technical safeguard, but the present study does not claim that encryption alone establishes full compliance with KVKK or GDPR requirements.

Figure 5. Create Disaster Victim UI

In Figure 6, the distribution of packages to beneficiaries was carried out through the interface, and the packages were recorded on the blockchain. Similarly to the beneficiary registration screen, a unique ID number was generated and added to the blockchain. This registered ID number was converted into a QR code and displayed on the interface. Additionally, the QR code was printed and physically affixed to the package, thereby establishing a physical link between the package and the QR code.

Decentralized Disaster Aid Distribution App

Create Disaster Victim | **Create Aid Package** | Associate Disaster Victim & Package | Delivery

Create Aid Package

Title:

Category:

Weight (kg):

Expiration Date:

Create

Aid Packages List

Package-1
UID: AP-m9a0z9t-
a9442e1c-52fd-4da1-b84b-...
Category: Food
Weight: 20.0 kg
Expiration Date: 23.05.2025

Package-2
UID: AP-m9a13gop-
2ab9f0ed-d825-4106-bec3-...
Category: Food
Weight: 20.0 kg
Expiration Date: 23.05.2025

Package-3
UID: AP-m9a13xmj-
6ea77664-4568-413b-645b-...
Category: Food
Weight: 20.0 kg
Expiration Date: 23.05.2025

Package-4
UID: AP-m9a14e50-
da3f9989-dbc3-42b3-8e52-...
Category: Food
Weight: 20.0 kg
Expiration Date: 23.05.2025

Package-5
UID: AP-m9a15u6-
fe13cd40-c83a-4122-b3f8-...
Category: Food
Weight: 20.0 kg
Expiration Date: 23.05.2025

Figure 6. Create Aid Package UI

In Figure 7, the system matches the registered beneficiary and packages, and this matching information is added to the blockchain to create a traceable record of the association. The QR code contains three data elements: Victim ID, Package ID, and Association Date.

Decentralized Disaster Aid Distribution App

Create Disaster Victim | Create Aid Package | **Associate Disaster Victim & Package** | Delivery

Associate Disaster Victim & Aid Package

Disaster Victim:

Aid Package:

Associate

Associated Packages List

**Victim ID: DV-m9y9t9g-8106ac8-4e79-
4688-a6c3-c1f6c2400077**
**Package ID: AP-m9a0z9t-a9442e1c-52fd-
4da1-b84b-4d2d1018f276**
Association Date: 09.04.2025 17:47:00

**Victim ID: DV-m9y9t9g-c9e9f5ee-31d3-
4868-bca8-36c039a78fcd**
**Package ID: AP-m9a13gop-2ab9f0ed-d825-
4106-bec3-7ca44176a41a**
Association Date: 09.04.2025 17:47:24

**Victim ID: DV-m9y9t9g-1164750-50c5-
4d72-43a2-51c52b5145ed**
**Package ID: AP-m9a13xmj-6ea77664-4568-
413b-645b-5c98235a4d25**
Association Date: 09.04.2025 17:47:48

**Victim ID: DV-m9y9t9g-34c97b93-6203-
4162-8444-a563c58e1daa**
**Package ID: AP-m9a15u6-fe13cd40-c83a-
4122-b3f8-a83034408afa**
Association Date: 09.04.2025 17:49:24

Figure 7. Associate Disaster Victim- Aid Package UI

In Figure 8, the QR codes belonging to the beneficiaries and the packages were scanned, and the matching was verified through the interface shown in Figure 4 to ensure the delivery of the aid packages. The distributed packages were listed on the screen along with the beneficiary ID and package ID numbers. Additionally, a function was coded in the smart contract to prevent the same package identifier from being recorded as delivered more than once.

Decentralized Disaster Aid Distribution App

Create Disaster Victim Create Aid Package Associate Disaster Victim & Package **Delivery**

Delivery

Victim ID

Package ID

Deliver

Delivery List

Victim ID: DV-m99y8f6-8106aac8-4e79-4658-adcb-c31fe5240007
Package ID: AP-m9a0z6t-a9442e1c-52f6-4da1-b84b-d42610189276
Delivery Date: 09.04.2025 17:54:12

Victim ID: DV-m99y99qt-d5e5f5ae-31d3-48e9-bc49-3b0390e7b5cd
Package ID: AP-m9a13gop-2ab9f0ed-db25-4106-bec3-7ca4417b641a
Delivery Date: 09.04.2025 17:55:00

Victim ID: DV-m99y9thq-116d4750-50c6-4d72-a3a2-b1c52e5145ed
Package ID: AP-m9a13xmj-6ea77664-4568-413b-845b-5c9823d5ad25
Delivery Date: 09.04.2025 18:01:36

Victim ID: DV-m99yam2t-cbf7717b-6933-4d93-bd74-9dc8e91a3a1e
Package ID: AP-m9a14e50-da3f8989-dbc3-42b3-8e52-1a00fba88b5
Delivery Date: 09.04.2025 18:05:48

Victim ID: DV-m99yb83f-34c97b93-5203-4162-84e4-a563c5be1daa
Package ID: AP-m9a15ul6-fe13cd40-c83a-4122-b3f9-aa83044bfefa
Delivery Date: 09.04.2025 18:10:48

Figure 8. Delivery UI

Figure 9 shows the transaction hash information related to the distribution process. Thanks to the immutable blockchain structure, it is possible to track which aid was distributed to which disaster victim and on what date.

The interfaces were designed to be simple and suitable for field conditions, enabling volunteer staff to use the system after brief training sessions. This design supported the practical use of the prototype during the field demonstration; however, operational delay reduction was not directly measured in this study.

Transactions

Internal Transactions

Token Transfers (ERC-20)

Contract

Events

Latest 5 from a total of 5 transactions

Download Page Data

	Transaction Hash	Method	Block	Age	From	To	Amount	Txn Fee
	0x41698fa71f0...	0x3bfd95f1	8084765	4 days ago	0xac364C2d...9651a0393	IN 0x398944F5...ded4d944E	0 ETH	0.00062541
	0xb811097221...	0x3bfd95f1	8084741	4 days ago	0xac364C2d...9651a0393	IN 0x398944F5...ded4d944E	0 ETH	0.00049936
	0x354be542c4...	0x3bfd95f1	8084722	4 days ago	0xac364C2d...9651a0393	IN 0x398944F5...ded4d944E	0 ETH	0.00039668
	0x4eefab7f3f9...	0x3bfd95f1	8084690	4 days ago	0xac364C2d...9651a0393	IN 0x398944F5...ded4d944E	0 ETH	0.00035767
	0xe79436fd15b...	0x3bfd95f1	8084686	4 days ago	0xac364C2d...9651a0393	IN 0x398944F5...ded4d944E	0 ETH	0.00039082

[Download: CSV Export]

Figure 9. Sepolia Testnet Transactions

In Figure 9, the distributed aid transactions are tracked on the Sepolia testnet by monitoring their transaction hash values, which remain immutable and verifiable.

Table 5. Deliveries Transaction Hash.

No	Transaction Hash
1	0x41698fa71f056a120b9928c42470fc6d11cae8425a9ac9e630711c2144fb7f4e
2	0xb81109722172e3aa5a60cf3e39971f3bcc45a88c748efec82f37d2d0ef561d64
3	0x354be542c4b0c09b0f4cabbd532a6219e99d19b0483716b480da6910272c8b28
4	0x4eefab7f3f92a073d8d7e1d0cc569a5cbe6121c1077a1be6ccbd22ef306878f3
5	0xe79436fd15b1dcf9f02fd7f8a148378282000c05645f99104962476bf4c71211

The transaction hash values shown in Table 5 demonstrate that each distribution transaction can be independently verified, providing technical evidence of the traceability and independent verifi-

ability of the recorded transactions. Table 5 presents the five delivery transaction hashes recorded during the limited proof-of-concept demonstration.

6.4. Verification of Findings Using the Nominal Group Technique (NGT)

At this stage, the findings of the study were validated using the Nominal Group Technique (NGT). Accordingly, an online NGT session was conducted to review the findings obtained from the field implementation and the expert-based operational assessment. Hugé and Mukherjee (2018) emphasize that virtual environments provide an effective and reliable setting for expert-based validation processes.

The operational indicators and case study outputs were presented to the same six-member expert panel that participated in the initial NGT stage in a structured online meeting. Using the same panel provided continuity between the identification of operational problems and the subsequent assessment of the proposed solution, allowing the experts to evaluate the system in relation to the issues they had initially identified. Experts were selected based on their field experience in disaster management and humanitarian logistics.

The NGT process followed four structured stages. In the first stage, experts independently evaluated the findings. In the second stage, each expert presented their views sequentially, ensuring equal participation. In the third stage, collective discussion was conducted to clarify and compare viewpoints. In the final stage, experts reviewed and reached consensus on the final set of findings based on expert judgment.

Conventional and modified NGT approaches have also been used to elicit and prioritize expert-informed strategies in education, including character education, teachers' technological self-efficacy, and teaching activities for the 4C skills (Ramly, Masnan, Awang, & Menon, 2025; Subramaniam, Ismail, & Ahmad, 2025; Zakaria, Hanri, Noer, Triana, & Widyastuti, 2025). These examples illustrate NGT as a structured process for synthesizing expert input rather than providing independent validation of the present blockchain prototype.

No numerical rating scale or statistical aggregation was used in the final qualitative assessment. Consensus was operationally defined as the absence of substantive objections following the structured discussion. During the session, experts examined the classification and interrelationships of operational factors and evaluated whether any items required modification, reclassification, or removal. Consensus was reached through structured discussion, and no substantive objections were raised regarding the identified operational dimensions or their interpretation.

The integration of individual judgments through structured discussion ensured content validity and consensus, which is a key strength of NGT (Rankin et al., 2016). Consistent with Hugé and Mukherjee (2018), the online implementation proved effective for validating complex analytical outputs. Overall, the findings were supported by the expert panel as a consistent interpretation of the field-based proof-of-concept based on expert consensus.

7. Discussion

This study demonstrates the real-world integration of blockchain technology into post-disaster humanitarian aid and examines its technical feasibility and perceived operational contributions under field conditions. While existing literature emphasizes blockchain's potential to enhance transparency, traceability, and reliability in disaster relief, most contributions remain theoretical (Demir et al., 2020; Shevtekar & Raut, 2023) or conceptual frameworks without empirical validation (Jain & Simha, 2018; Patil & Kadam, 2022). Prior studies also indicate that intermediaries in donation systems increase corruption risks, while immutable records can mitigate these issues (Saraswat et al., 2022; Srivatsa et al., 2024).

The main contribution of this study is the field-based demonstration of a blockchain-supported aid distribution workflow in a real post-disaster environment. In Hatay, following the 2023 earthquakes, aid distribution was implemented using an Ethereum-based system under AFAD coordination. QR-coded packages enabled traceable and tamper-proof monitoring of distribution events. This implementation provides practical support for the potential of blockchain to strengthen traceability, verifiability, and accountability (Adediran et al., 2024; Demir et al., 2020; Shevtekar & Raut, 2023). Although global initiatives such as AidChain and Binance Charity exist, this study differs as one of the first field-implemented, locally deployed blockchain systems tested under real disaster conditions. However, the limited proof-of-concept design does not establish system robustness or large-scale operational performance under infrastructure constraints and operational uncertainty. The implementation should also be considered within the broader operational context of disaster response, where technological tools interact with institutional capacity, field personnel, coordination mechanisms, and infrastructure vulnerabilities. Previous disaster-response research has emphasized that organizational, informational, resource-related, and operational weaknesses can affect response capacity, while preparedness, interoperability, and coordination among institutional and community-level actors remain critical for effective disaster management (Cvetković, 2025; Cvetković, Tanasić, Renner, Rokvić, & Beriša, 2024; Cvetković et al., 2025). Similarly, Masaba, Aryatwijuka, Ntayi, and Bagire (2025) highlight the central role of coordination among humanitarian organizations in supporting effective disaster response. Accordingly, blockchain should be viewed as a supporting tool within the wider disaster-response system rather than as a standalone solution to operational challenges.

7.1. Benefits

Blockchain provides a decentralized, immutable, and transparent structure that shifts trust from institutional actors to cryptographic verification. In this study, blockchain enabled traceable recording of aid flows, supported digital beneficiary–package association, and ensured a verifiable audit trail. These features have the potential to support accountability, reduce opportunities for record manipulation, and strengthen information sharing among humanitarian actors (Hunt & Zhuang, 2022). Operationally, the system incorporated technical mechanisms for package-level duplicate control, transaction verification, and traceability. Blockchain-based logging provided a traceable record that may support resource allocation, distribution planning, and last-mile visibility; however, these operational effects were not directly measured in the present study.

7.2. Challenges

Despite its benefits, several challenges emerged:

Technical Challenges

1. Disaster environments involve stochastic, dynamic, and multi-stakeholder structures, making blockchain integration complex.
2. Infrastructure damage, fluctuating needs, and unstable communication systems complicate real-time blockchain operations.
3. Data protection regulations and ambiguity regarding data ownership can limit implementation. Although synthetic data were used in the present proof-of-concept, deployment with real personal data would require additional consideration of data minimization, key management, access control, retention, and erasure-related requirements under applicable data-protection frameworks. Privacy challenges in private blockchain networks have been discussed by Ncube, Dlodlo, and Terzoli (2020).

4. Scalability remains a major concern in large-scale crises. Because the present implementation used the Sepolia test network, the study does not evaluate production-level transaction costs, network congestion, throughput, or reliability under large-scale humanitarian operations.
5. Infrastructure costs and energy requirements can be burdensome in resource-constrained environments.

Adoption Challenges

1. Limited technological literacy among field personnel.
2. Difficulty integrating blockchain with existing aid systems.
3. Role inconsistencies across agencies and NGOs.
4. Limited communication infrastructure and interoperability issues.

7.3. Expert-Based Assessment of the Blockchain-Supported Distribution System

At this stage, the perceived operational contributions of the traditional aid distribution system and the blockchain-supported system were compared based on expert assessments obtained under the Nominal Group Technique (NGT) framework. Table 6 summarizes the qualitative comparative judgments of the expert panel. These assessments were not derived from direct operational measurements or benchmark testing and should therefore be interpreted as expert perceptions of the potential contribution of the proposed system.

Table 6. Qualitative Expert-Based Comparison of Traditional and Blockchain-Supported Aid Distribution Workflows

Operational Dimension	Traditional Workflow	Blockchain-Supported Workflow	Expert Assessment
Verification	Primarily manual verification	QR-supported digital verification	Experts considered QR-based verification potentially useful for facilitating the verification process.
Duplicate Package Delivery Control	Dependent mainly on manual records	Smart-contract-supported package-level control	Experts considered automated package-level checks an additional safeguard against repeated recording of the same package delivery.
Data Integrity	Records may depend on centralized/manual data handling	Immutable blockchain-based transaction records	Experts associated immutable records with stronger data integrity and consistency.
Auditability	Retrospective verification may depend on institutional records	Transaction hashes allow independent verification of recorded transactions	Experts considered independent verification a key advantage of the proposed workflow.
Delivery Accuracy	Dependent on manual beneficiary–package matching	QR- and ID-supported beneficiary–package association	Experts perceived digital association as potentially reducing matching errors.
Transparency	Limited by fragmented or institution-specific records	Blockchain records provide traceable transaction histories	Experts associated the blockchain-supported workflow with greater process visibility.
Personnel Workload	Greater reliance on manual record-keeping	Digital recording and QR-supported processing	Experts perceived the system as having the potential to reduce some manual recording tasks.
Record Consistency	Manual records may be vulnerable to discrepancies	Blockchain-based records provide a common immutable record	Experts considered this structure potentially useful for reducing record inconsistencies.

As shown in Table 6, expert evaluations indicated that the blockchain-supported workflow was perceived to offer potential advantages over the traditional workflow across the assessed operational dimensions. In particular, data integrity, auditability, traceability, and package-level duplicate control were identified by the experts as notable potential contributions of the proposed system. These findings reflect structured expert judgment and should not be interpreted as statistically measured performance gains or as evidence of superiority based on direct operational benchmarking. RQ 1. In a disaster area, how might blockchain integration reduce conventional operational inefficiencies such as aid duplication and human entry errors?

The findings indicate that the proposed system provides technical mechanisms that may help address operational inefficiencies such as duplicate package recording, inconsistencies in beneficiary records, identity mismatches, and missing timestamp information through the integration of QR-based identification and smart contract validation mechanisms. These mechanisms were designed to reduce reliance on manual verification and to limit opportunities for human-induced recording errors. RQ 2. How does the system support data integrity, verifiability, and traceability during last-mile distribution?

The integration of time-stamped blockchain transactions and hash-based verification supported process traceability and auditability. Each aid transaction was immutably recorded, enabling retrospective verification of distribution events. While these features support data integrity at the system level, their effectiveness depends on correct data input at the operational interface layer.

RQ 3. In terms of operational planning and resource allocation, what potential advantages does the created framework provide to field staff and decision-makers?

From an operational perspective, the system provides a digital record of distribution activities and may reduce reliance on manual record-keeping processes. In addition, the package-level duplicate control and improved record consistency may support more informed decision-making in resource allocation processes. Taken together, these findings suggest that blockchain-supported aid distribution systems may offer potential advantages in terms of traceability, record integrity, and accountability; however, direct comparative performance testing is required before conclusions can be drawn regarding operational efficiency or superiority over conventional systems. 5.4. Limitations

This study has several limitations that should be considered when interpreting the findings. First, the field implementation was conducted as a limited proof-of-concept involving five recorded delivery transactions rather than as a large-scale operational deployment. Accordingly, the study demonstrates the technical feasibility and traceability of the proposed blockchain-supported workflow but does not establish its performance under high-volume humanitarian operations.

Second, operational outcomes such as verification time, personnel workload, delivery accuracy, duplicate prevention rates, and record discrepancies were not directly benchmarked against the conventional distribution system. The comparative findings presented in this study therefore reflect expert assessments of the potential operational contributions of the proposed system rather than objectively measured performance gains.

Third, the same six-member expert panel participated in both the initial problem-identification stage and the subsequent validation stage. This continuity provided an important advantage by allowing the experts who initially identified the operational challenges to evaluate the proposed solution within the same contextual framework. However, the use of the same panel may also introduce a degree of confirmation bias, and future studies could strengthen external validation by incorporating an independent expert group.

Finally, the prototype was implemented on the Sepolia test network. Although this environment was suitable for demonstrating blockchain functionality in the field, the present study does not evaluate production-level transaction costs, network congestion, throughput, or scalability under large-scale disaster-response conditions. Future research should therefore examine the system using larger operational samples and direct comparative performance measurements in production-oriented environments.

8. Conclusion

This study presents a field-based proof-of-concept of the integration of blockchain technology into humanitarian aid distribution in a real post-disaster setting. Aid packages distributed by AFAD in a Hatay container city were tracked via an Ethereum-based system using QR codes assigned to each beneficiary. This implementation demonstrates the technical feasibility of creating tamper-proof, timestamped, and independently verifiable records of aid deliveries.

While the literature provides many conceptual and architectural proposals, real-world applications remain scarce. This study fills an important gap by offering field-based evidence of the feasibility of a QR-integrated blockchain workflow for supporting traceability, verifiability, and accountability in humanitarian logistics. However, the technology still faces limitations related to system adoption, data entry accuracy, infrastructure costs, and integration challenges. Moreover, because the implementation was conducted as a limited proof-of-concept and operational performance was not directly benchmarked against the conventional system, the findings should not be interpreted as evidence of overall performance superiority.

Future research should focus on:

- testing similar systems across multiple NGOs or regions,
- comparing blockchain-supported and traditional distribution workflows, using directly measured operational indicators,
- incorporating biometric verification to strengthen identity validation,
- integrating AI-based analytics to improve resource allocation and demand forecasting,
- evaluating operational performance using measurable indicators such as delivery accuracy, duplicate prevention rate, and time efficiency.

By addressing these directions, blockchain technology may evolve from a promising conceptual tool into a robust operational component of humanitarian aid systems.

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Ethics: This study did not involve any procedures requiring approval from an institutional ethics committee. Throughout the research process, the principles outlined in the Declaration of Helsinki as well as relevant national and international ethical standards were strictly followed. Expert participation was voluntary, and informed consent was obtained after participants were informed about the purpose and procedures of the study. Confidentiality of personal information was ensured, and participants were reminded that they could withdraw from the study at any time without any consequences. No real beneficiary personal data were used in the field-based proof-of-concept; synthetically generated beneficiary information was used for testing the system workflow.

9. References

1. Abubakar, A. A., Liu, J., & Gilliard, E. (2023). An efficient blockchain-based approach to improve the accuracy of intrusion detection systems. *Electronics Letters*, 59(18), e12888. doi:10.1049/ell2.12888
2. Adediran, F. E., Okunade, B. A., Daraojimba, R. E., Adewusi, O. E., Odulaja, B. A., & Igbokwe, J. C. (2024). Blockchain for social good: A review of applications in humanitarian aid and social initiatives. *International Journal of Science and Research Archive*, 11(1), 1203–1216. doi:10.30574/ijs-ra.2024.11.1.0184

3. Ahmed, I., Fumimoto, K., Nakano, T., & Tran, T. H. (2024). Blockchain-empowered decentralized philanthropic charity for social good. *Sustainability*, 16(1), 210. doi:10.3390/su16010210
4. AidChain. (n.d.). *AidChain*. Retrieved February 25, 2025, from <https://www.aidchain.co/>
5. Al-Naseri, N. (2023). Enhancing transparency: Blockchain's contribution to auditability. *Journal of AI-Assisted Scientific Discovery*, 3(1), 762–783. <https://scienceacadpress.com/index.php/jaasd/article/view/277>
6. Antsipava, D., Strycharz, J., van Reijmersdal, E. A., & van Noort, G. (2024). What drives blockchain technology adoption in the online advertising ecosystem? An interview study into stakeholders' perspectives. *Journal of Business Research*, 171, 114381. doi:10.1016/j.jbusres.2023.114381
7. Arun, N., & Mathiyalagan, R. (2021). Authentication and identity validation blockchain application. *Journal of Physics: Conference Series*, 1979(1), 012017. doi:10.1088/1742-6596/1979/1/012017
8. Barger, A., Ilina, O., Zemtsov, A., & Tagirova, K. (2022). Trustful charity foundation platform based on Hyperledger Fabric. In *2022 IEEE International Conference on Omni-Layer Intelligent Systems (COINS)*. IEEE. doi:10.1109/COINS54846.2022.9854995
9. Bauer, D. P. (2022). Solidity. In *Getting started with Ethereum: A step-by-step guide to becoming a blockchain developer* (pp. 13–16). Berkeley, CA: Apress. doi:10.1007/978-1-4842-8045-4_2
10. Bhat, V. G., Pranaav, H. P., Mini, S., & Tosh, D. (2021). Blockchain-centric resource management system for disaster response and relief. In *2021 11th International Conference on Cloud Computing, Data Science & Engineering (Confluence)* (pp. 540–545). IEEE. doi:10.1109/Confluence51648.2021.9377059
11. Binance Charity. (n.d.). *Binance Charity*. Retrieved February 27, 2025, from <https://www.binance.charity/>
12. BitHope. (n.d.). *BitHope*. Retrieved February 26, 2025, from <https://bithope.org/>
13. Boz, U. (2025). Kahramanmaraş merkezli depremin insan kaynakları sürecine etkisi: Hatay örneği. *Disiplinlerarası Yenilik Araştırmaları Dergisi*, 5(1), 30–39. doi:10.56723/dyad.1428947
14. Brandão, S. C. G., Fontana, M. E., Silva, W. D. O., & da Silva, G. L. (2025). Drivers and barriers of sustainability-oriented innovations in Brazilian denim treatment facilities: An expert-driven decision support. *Humanities and Social Sciences Communications*, 12, 679. doi:10.1057/s41599-025-05006-4
15. Car, E., Barbier, L., Schwarzenberger, I., Huys, I., Simoens, S., & Vulto, A. G. (2025). Toward regulatory convergence and streamlined biosimilar development: Recommendations from an international qualitative study. *BioDrugs*, 39(6), 943–955. doi:10.1007/s40259-025-00746-w
16. Casino, F., Kanakaris, V., Dasaklis, T. K., Moschuris, S., & Rachaniotis, N. P. (2019). Modeling food supply chain traceability based on blockchain technology. *IFAC-PapersOnLine*, 52(13), 2728–2733. doi:10.1016/j.ifacol.2019.11.620
17. Chen, L., Hendalianpour, A., Feylizadeh, M., & Xu, H. (2023). Factors affecting the use of Blockchain technology in humanitarian supply chain: A novel fuzzy large-scale Group-DEMATEL. *Group Decision and Negotiation*, 32, 359–394. doi:10.1007/s10726-022-09811-z
18. Chen, X., He, S., Sun, L., Zheng, Y., & Wu, C. Q. (2024). A survey of consortium blockchain and its applications. *Cryptography*, 8(2), 12. doi:10.3390/cryptography8020012
19. CoinMarketCap. (n.d.). *CharityDAO*. Retrieved February 24, 2025, from <https://coinmarketcap.com/currencies/charitydao/#About>
20. Coretti, S., Fitzi, M., Kiayias, A., Panagiotakos, G., & Russell, A. (2025). High-throughput permissionless blockchain consensus under realistic network assumptions. In *Annual International Cryptology Conference* (pp. 69–100). Cham, Switzerland: Springer. doi:10.1007/978-3-032-01878-6_3
21. Cvetković, V. M., Tanasić, J., Renner, R., Rokvić, V., & Beriša, H. (2024). Comprehensive risk analysis of emergency medical response systems in Serbian healthcare: Assessing systemic vulnerabilities in disaster preparedness and response. *Healthcare*, 12(19), 1962. doi:10.3390/healthcare12191962

22. Cvetković, V. M., Aleksov, B., Renner, R., Gačić, J., Ivanov, A., & Milašinović, S. (2025). Community-based disaster risk reduction: Overcoming barriers to build stronger communities. *International Journal of Disaster Risk Management*, 7(2), 113–129. doi:10.18485/ijdrm.2025.7.2.7
23. Cvetković, V. M. (2025). First responders in the Western Balkans: Strengthening capacities and preparedness for a resilient future. *International Journal of Disaster Risk Management*, 7(2), 361–384. doi:10.18485/ijdrm.2025.7.2.19
24. Darmawan, B., Okitasari, H., Dwiyaniti, V., Pratama, P. Y., & Haritman, E. (2024). Preliminary research: Blockchain system design for post-disaster management in Indonesia. *Journal of Engineering Science and Technology*, 19(4), 1268–1279.
25. Das, N., Basu, S., & Bit, S. (2022). ReliefChain: A blockchain-leveraged post-disaster relief allocation system over smartphone-based DTN. *Peer-to-Peer Networking and Applications*, 15, 2603–2618. doi:10.1007/s12083-022-01366-9
26. de Dios Perez, B., Senior, C., das Nair, R., Kendrick, D., Evangelou, N., Newsome, I., & Radford, K. (2025). Key outcomes for a vocational rehabilitation intervention for people with multiple sclerosis: A nominal group technique study. *Health Expectations*, 28(2), e70265. doi:10.1111/hex.70265
27. Delbecq, A. L., & Van de Ven, A. H. (1971). A group process model for problem identification and program planning. *The Journal of Applied Behavioral Science*, 7(4), 466–492. doi:10.1177/002188637100700404
28. Demir, M., Turetken, O., & Ferworn, A. (2020). Blockchain-based transparent disaster relief delivery assurance. In *2020 IEEE International Systems Conference (SysCon)* (pp. 1–8). IEEE. doi:10.1109/SysCon47679.2020.9275915
29. Demir, M., Turetken, O., Ferworn, A., & Kargar, M. (2023). A blockchain-based system for aid delivery: Concept development, data modeling, and validation. *Journal of Database Management*, 34, 1–35. doi:10.4018/jdm.321757
30. Dennison, M. O., & Coldwell, D. A. L. (2025). Exploring the concept of strategy as practice in national disaster risk reduction: The case of Botswana. *International Journal of Disaster Risk Reduction*, 120, 105339. doi:10.1016/j.ijdr.2025.105339
31. Duan, K., Onyeaka, H., & Pang, G. (2024). Leveraging blockchain to tackle food fraud: Innovations and obstacles. *Journal of Agriculture and Food Research*, 18, 101429. doi:10.1016/j.jafr.2024.101429
32. Duan, K., Onyeaka, H., Pang, G., & Meng, Z. (2024). Pioneering food safety: Blockchain's integration in supply chain surveillance. *Journal of Agriculture and Food Research*, 18, 101281. doi:10.1016/j.jafr.2024.101281
33. Dubey, R., Gunasekaran, A., Bryde, D., Dwivedi, Y., & Papadopoulos, T. (2020). Blockchain technology for enhancing swift-trust, collaboration and resilience within a humanitarian supply chain setting. *International Journal of Production Research*, 58, 3381–3398. doi:10.1080/00207543.2020.1722860
34. Dubey, R., Gunasekaran, A., & Foropon, C. R. H. (2024). Improving information alignment and coordination in humanitarian supply chain through blockchain technology. *Journal of Enterprise Information Management*, 37(3), 805–827. doi:10.1108/JEIM-07-2022-0251
35. Duruel, M. (2023). Afetlerde göçmen olmak: 6 Şubat depremi Hatay örneği. *Mukaddime*, 14(2), 227–255. doi:10.19059/mukaddime.1381750
36. Food and Agriculture Organization of the United Nations. (2013). *SAVE FOOD: Seeking end to loss and waste of food along production chain*. <https://www.fao.org/partnerships/container/news-article/es/c/210839/>
37. Gao, X., Chen, Z., Huang, G., & Hezam, I. M. (2024). Blockchain-enabled safeguard mechanism in SCP-based relief supply chain designs in response to long-term disasters. *IEEE Access*, 12, 133054–133066. doi:10.1109/ACCESS.2024.3457609
38. Ghani, A., Zinedine, A., & El Mohajir, M. (2025). Eghatha: A blockchain-based system to enhance disaster preparedness. *Computers*, 14(10), 405. doi:10.3390/computers14100405
39. The Giving Block. (n.d.). *The Giving Block*. Retrieved February 26, 2025, from <https://thegiving-block.com/>

40. Gopal, G., & Garcia, A. (2021). Blockchain applications in humanitarian logistics. *Journal of Supply Chain Management, Logistics and Procurement*, 3(4), 399–411. doi:10.69554/nzcw7059
41. Halkiopoulou, C., Antonopoulou, H., & Kostopoulos, N. (2023). Utilizing blockchain technology in various applications to secure data flows: A comprehensive analysis. *Technium: Romanian Journal of Applied Sciences and Technology*, 11, 44–55. doi:10.47577/technium.v11i.9132
42. Han, H., Shiwakoti, R. K., & Chen, W. (2024). Unlocking enterprise blockchain adoption: A R3 Corda case study. *Journal of General Management*. Advance online publication. doi:10.1177/03063070241292701
43. Hanspal, M. S., & Behera, B. (2024). Role of emerging technology in disaster management in India: An overview. *International Journal of Disaster Risk Management*, 6(2), 133–148. doi:10.18485/ijdrm.2024.6.2.9
44. Haque, E. U., Abbasi, W., Almogren, A., Choi, J., Altameem, A., Rehman, A. U., & Hamam, H. (2024). Performance enhancement in blockchain based IoT data sharing using lightweight consensus algorithm. *Scientific Reports*, 14, 26561. doi:10.1038/s41598-024-77706-x
45. Harakeh, M., El Diri, M., Lambrinoudakis, C., & Tsileponis, N. (2024). The impact of blockchain adoption on corporate investment efficiency. *Economics Letters*, 236, 111603. doi:10.1016/j.econlet.2024.111603
46. Harvey, N., & Holmes, C. A. (2012). Nominal group technique: An effective method for obtaining group consensus. *International Journal of Nursing Practice*, 18(2), 188–194. doi:10.1111/j.1440-172X.2012.02017.x
47. Haryani, S., Matharu, S. K., Nagar, C., & Verma, A. (2024). Detailed analysis of advancements in cryptocurrency with blockchain's optimization on fintech. In *2024 IEEE 4th International Conference on ICT in Business Industry & Government (ICTBIG)* (pp. 1–5). IEEE. doi:10.1109/ICTBIG64922.2024.10911718
48. He, B., Feng, T., Fang, J., Liu, C., & Su, C. (2024). A secure and efficient charitable donation system based on Ethereum blockchain and searchable encryption. *IEEE Transactions on Consumer Electronics*, 70(1), 263–276. doi:10.1109/TCE.2023.3323356
49. Hoque, T., Nijhum, M. C., Kafi, A., & Siyam, M. H. (2024). Decentralized charity network architecture with Hyperledger Fabric blockchain. In *2024 27th International Conference on Computer and Information Technology (ICCIT)* (pp. 221–226). IEEE. doi:10.1109/ICCIT64611.2024.11022437
50. Hugé, J., & Mukherjee, N. (2018). The nominal group technique in ecology & conservation: Application and challenges. *Methods in Ecology and Evolution*, 9(1). doi:10.1111/2041-210X.12831
51. Humphrey-Murto, S., Varpio, L., Gonsalves, C., & Wood, T. J. (2017). Using consensus group methods such as delphi and nominal group in medical education research. *Medical Teacher*, 39(1), 14–19. doi:10.1080/0142159X.2017.1245856
52. Hunt, K., & Zhuang, J. (2022). Blockchain for disaster management. In *Big data and blockchain for service operations management* (pp. 253–269). Cham, Switzerland: Springer. doi:10.1007/978-3-030-87304-2_10
53. Hunt, K., Narayanan, A., & Zhuang, J. (2022). Blockchain in humanitarian operations management: A review of research and practice. *Socio-Economic Planning Sciences*, 80, 101175. doi:10.1016/j.seps.2021.101175
54. Jadhav, S., Mohite, S., & Pise, N. (2025). Blockchain technology-based Crypto-Go-Charity for scholarship donation tracking platform. *Web Intelligence*, 23(3), 374–394. doi:10.1177/24056456251320120
55. Jain, S., & Simha, R. (2018). Blockchain for the common good: A digital currency for citizen philanthropy and social entrepreneurship. In *2018 IEEE International Conference on Internet of Things (iThings) and Related Conferences*. IEEE. doi:10.1109/Cybermatics_2018.2018.00238
56. Jha, P. K., Priya, S., Chandrakar, K., & Pradhan, A. (2024). Blockchain-enabled supply chain transparency and smart contracts for efficient humanitarian aid operations in NGO. In *2024 5th International Conference for Emerging Technology (INCET)* (pp. 1–6). IEEE. doi:10.1109/INCET61516.2024.10592900

57. Karaduman, Ö., & Gülhas, G. (2025). Blockchain-enabled supply chain management: A review of security, traceability, and data integrity amid the evolving systemic demand. *Applied Sciences*, 15(9), 5168. doi:10.3390/app15095168
58. Karale, P. B. (2025). Blockchain-based document verification: A comprehensive review. *International Journal of Advanced Research in Computer Science*, 16(1). doi:10.26483/ijarcs.v16i1.7183
59. Kaur, M., Kaur, P. D., & Sood, S. K. (2022). BIoT (blockchain-based IoT) framework for disaster management. In *2022 12th International Conference on Cloud Computing, Data Science & Engineering (Confluence)* (pp. 318–323). IEEE. doi:10.1109/Confluence52989.2022.9734193
60. Khairunnisa, N., Christiani, F., & Prawiyogi, A. G. (2024). Supply chain transparency: Exploring blockchain solutions for enhanced traceability and efficiency. *Blockchain Frontier Technology*, 4(1), 15–22. doi:10.34306/bfront.v4i1.569
61. Khalil, I., Aziz, O., & Asif, N. (2021). Blockchain and its implementation for charitable organizations. In *2021 International Conference on Innovative Computing (ICIC)*. IEEE. doi:10.1109/ICIC53490.2021.9692944
62. Khan, M., Imtiaz, S., Parvaiz, G., Hussain, A., & Bae, J. (2021). Integration of internet-of-Things with Blockchain technology to enhance humanitarian logistics performance. *IEEE Access*, 9, 25422–25436. doi:10.1109/access.2021.3054771
63. Kichou, B., Bouraghda, A., Lahmar, H. M. A., Amara, S., Aoudia, Y., Benchabi, Y., . . . Chettibi, M. (2025). The role of single-pill ACE inhibitor/CCB combination for hypertension: An Algerian view via the nominal group technique. *Future Cardiology*, 21(3), 155–166. doi:10.1080/14796678.2025.2465218
64. Kolhatkar, D., Jain, O., Patil, S., Shelke, P., Mirajkar, R., & Wawage, P. (2023). Blockchain applications in disaster management systems. In *2023 4th International Conference for Emerging Technology (INCET)* (pp. 1–7). IEEE. doi:10.1109/INCET57972.2023.10170452
65. Ktari, J., Frikha, T., Hamdi, M., & Hamam, H. (2024). Enhancing blockchain consensus with FPGA: Accelerating implementation for efficiency. *IEEE Access*, 12, 44773–44785. doi:10.1109/ACCESS.2024.3379374
66. Kumar, D., Phani, B. V., Chilamkurti, N., Saurabh, S., & Ratten, V. (2024). A taxonomy of blockchain technology application and adoption by small and medium-sized enterprises. *Entrepreneurial Business and Economics Review*, 12(3), 141–160. doi:10.15678/EBER.2024.120308
67. Kumari, S., Dixit, T., Prakash, P., & Sharma, V. (2022). Public fund care tracking system based on blockchain. In *2022 2nd Asian Conference on Innovation in Technology (ASIANCON)*. IEEE. doi:10.1109/ASIANCON55314.2022.9908651
68. L'Hermitte, C., & Nair, N.-K. C. (2021). A blockchain-enabled framework for sharing logistics resources during emergency operations. *Disasters*, 45(3), 527–554. doi:10.1111/disa.12436
69. Lathkar, M., Deshmukh, P., Patil, A., & Shelke, P. (2024). Increasing donation transparency in disaster relief: A blockchain-based solution. In *2024 ASU International Conference in Emerging Technologies for Sustainability and Intelligent Systems (ICETSYS)*. IEEE. doi:10.1109/ICETSYS61505.2024.10459402
70. Lee, Y. (2023). An in depth analysis of Blockchain technology and its potential industrial applications. *Journal of Machine and Computing*, 3(4), 534–544. doi:10.53759/7669/jmc202303045
71. Ling, K. G., Syed Abdullah, S. M., & Saleh, Z. (2025). Intervention for adolescent gaming addiction using nominal group technique. *Environment-Behaviour Proceedings Journal*, 10(SI24), 17–23. doi:10.21834/e-bpj.v10iSI24.6355
72. Maariz, A., Wiputra, M. A., & Armanto, M. R. D. (2024). Blockchain technology: Revolutionizing data integrity and security in digital environments. *International Transactions on Education Technology (ITEE)*, 2(2), 92–98. doi:10.33050/itee.v2i2.435
73. Mahajan, D., & Kadam, S. (2019). A survey paper on blockchain technology. *International Journal for Research in Applied Science and Engineering Technology*, 7(5), 3564–3569. doi:10.22214/ijra-set.2019.5584

74. Makkar, H. P., & Costa, C. (2020). Potential blockchain applications in animal production and health sector. *CABI Reviews*, 15, 035. doi:10.1079/PAVSNNR202015035
75. Mansoor, A. H. H., Helmy, A., Sekhon, B., & Ally, T. A. (2023). Deployment of blockchain technology traceable from farm to table: A conceptual framework for national agricultural and food industry. *Journal of Emerging Technologies and Innovative Research*, 10(2). <https://www.jetir.org/papers/JETIR2302344.pdf>
76. Masaba, A. K., Aryatwijuka, W., Ntayi, J. M., & Bagire, V. (2025). Network structure in disaster response: The mediating role of coordination within a humanitarian organizational network in Uganda. *International Journal of Disaster Risk Management*, 7(1), 39–54. doi:10.18485/ijdrm.2025.7.1.3
77. Mbedzi, T. E., van der Wath, A. E., & Moagi, M. M. (2025). Psychosocial interventions for families caring for mental health care users: A nominal group technique. *Journal of Psychiatric and Mental Health Nursing*, 32(5), 1131–1141. doi:10.1111/jpm.70008
78. McIsaac, J., Brulle, J., Burg, J., Tarnacki, G., Sullivan, C., & Wassel, R. (2019). Blockchain technology for disaster and refugee relief operations [Conference poster abstract]. *Prehospital and Disaster Medicine*, 34(S1), s106. doi:10.1017/S1049023X1900222X
79. McMillan, S. S., King, M., & Tully, M. P. (2016). How to use the nominal group and Delphi techniques. *International Journal of Clinical Pharmacy*, 38(3), 655–662. doi:10.1007/s11096-016-0257-x
80. Mincewicz, W. (2022). The potential of using blockchain technology in human life: Examples of implementation. *Online Journal Modelling the New Europe*, (40), 78–97. doi:10.24193/OJMNE.2022.40.04
81. Mir, S. R. U., Kalaji, Y. A. A., & Ahmad, R. W. (2023). Blockchain-based system for end-to-end donations monitoring. In *2023 24th International Arab Conference on Information Technology (ACIT)* (pp. 1–5). IEEE. doi:10.1109/ACIT58888.2023.10453793
82. Mustafa, M. S. S., Sumarwati, S., Rahman, M. A. A., Zakaria, A. F., Damanhuri, A. A. M., Subri, U. S., & Ahmad, A. M. (2025). Exploring issues and problems towards implementing heating, ventilation and air conditioning (HVAC) maintenance in the Malaysian oil and gas industry. *International Journal Of Academic Research In Business And Social Sciences*, 15(1), 1713–1728. doi:10.6007/IJARBS/v15-i1/24657
83. Musthafa, N., & Bargavi, S. M. (2024). Blockchain integration in cyber security: Strengthening defenses and ensuring data integrity. *International Journal of Innovative Research in Science, Engineering and Technology*, 13(5), 8023–8027. doi:10.15680/IJIRSET.2024.1305236
84. Muthukumar, S., & Meenakshi, C. (2025). Developing a secured voteing sysytem using blockchain trechnology. *International Journal of Latest Technology in Engineering, Management & Applied Science*, 14(4), 600–605. doi:10.51583/IJLTEMAS.2025.140400066
85. Nagy, P. (2025). The role of blockchain technology in improving efficiency and reducing costs in companies: A systematic literature review. *Economy and Finance*, 12(2), 237–268. doi:10.33908/EF.2025.2.5
86. Nakamoto, S. (2008). *Bitcoin: A peer-to-peer electronic cash system*. <https://bitcoin.org/bitcoin.pdf>
87. Nazareth, P., Sathyaprakash, T., Shetty, S. S., & Poojary, S. S. (2025). Blockchain integration in IoT: A comprehensive review of security, algorithms, and applications. In *2025 9th International Conference on Electronics, Communication and Aerospace Technology (ICECA)* (pp. 668–673). IEEE. doi:10.1109/ICECA66444.2025.11383536
88. Ncube, T., Dlodlo, N., & Terzoli, A. (2020). Private blockchain networks: A solution for data privacy. In *2020 2nd International Multidisciplinary Information Technology and Engineering Conference (IMITEC)* (pp. 1–8). IEEE. doi:10.1109/IMITEC50163.2020.9334132
89. Nwani, S. (2025). Evaluating the impact of blockchain technology on supply chain transparency and traceability. *Global Journal of Accounting and Business Research*, 3(6), 1065–1093. doi:10.51594/gjabr.v3i6.149
90. Oliveros, D., Konda, K. A., Madden, L. M., Montenegro-Idrogo, J. J., Tafur Quintanilla, K. T., Sosa Barbarán, K., . . . Altice, F. L. (2025). Using nominal group technique to identify and prioritize barriers to decentralizing HIV care to primary health centers in lima, peru. *BMC Health Services*

Research, 25(1), 466. doi:10.1186/s12913-025-12618-8

91. Partigöç, N. S., & Dinçer, C. (2025). Afet tecrübesi üzerinden toplanma alanlarının işlevselliğinin iurdelenmesi: Hatay iuli örneği. *PLANARCH-Design and Planning Research*, 9(1), 187–201. doi:10.54864/planarch.1476607
92. Parıldar, B., Sayin, D., Türkzeybek, F. Z., Küçüköz, O., & Erten, Y. M. (2023). Helpchain: A block-chain-based disaster management system. In *2023 4th International Informatics and Software Engineering Conference (IISEC)* (pp. 1–5). IEEE. doi:10.1109/IISEC59749.2023.10391032
93. Patil, D., & Kadam, A. (2022). Charity donation system based on blockchain technology. *International Journal of Research Publication and Reviews*, 3(5), 3073–3077. <https://ijrpr.com/uploads/V3IS-SUE5/IJRPR4254.pdf>
94. Piesciorovsky, E. C., Hahn, G., Borges Hink, R., & Werth, A. (2024). Total power factor smart contract with cyber grid guard using distributed ledger technology for electrical utility grid with customer-owned wind farm. *Electronics*, 13(20), 4055. doi:10.3390/electronics13204055
95. Rahman, S. M. M., Yii, K. J., Masli, E. K., & Voon, M. L. (2024). The blockchain in the banking industry: A systematic review and bibliometric analysis. *Cogent Business & Management*, 11(1), 2407681. doi:10.1080/23311975.2024.2407681
96. Rai, H., Srivastava, A. K., Rai, S., & Pattanashetti, D. (2024). Blockchain-powered transparency: Tracking and disseminating donations for disaster-stricken regions. In *Futuristic trends in artificial intelligence* (pp. 1–15). IIP Series. doi:10.58532/V3BGAI10P1CH1
97. Ramly, N. A., Masnan, A. H., Awang, A., & Menon, N. (2025). Teaching strategies for shaping children's character: A study using the nominal group technique. *Environment-Behaviour Proceedings Journal*, 10(SI24), 153–159. doi:10.21834/e-bpj.v10iSI24.6383
98. Rankin, N. M., McGregor, D., Butow, P. N., White, K., Phillips, J. L., Young, J. M., . . . Shaw, T. (2016). Adapting the nominal group technique for priority setting of evidence-practice gaps in implementation science. *BMC Medical Research Methodology*, 16, 110. doi:10.1186/s12874-016-0210-7
99. Reddy, S. S., & Manjunath, D. R. (2024). Enhancing data security and traceability in supply chain management using blockchain technology. *Journal of Cyber Security in Computer System*, 3(3), 11–24. doi:10.46610/jcscs.2024.v03i03.002
100. Rejeb, A., & Rejeb, K. (2020). Blockchain and supply chain sustainability. *LogForum*, 16(3), 363–372. doi:10.17270/J.LOG.2020.467
101. Rodríguez-Espíndola, O., Chowdhury, S., Beltagui, A., & Albores, P. (2020). The potential of emergent disruptive technologies for humanitarian supply chains: The integration of blockchain, artificial intelligence and 3D printing. *International Journal of Production Research*, 58, 4610–4630. doi:10.1080/00207543.2020.1761565
102. Rose, C., Shearer, E., Woller, I., Foster, A., Ashenburg, N., Kim, I., & Newberry, J. (2025). Identifying high-priority ethical challenges for precision emergency medicine: Nominal group study. *JMIR Formative Research*, 9(1), e68371. doi:10.2196/68371
103. Saberi, S., Kouhizadeh, M., Sarkis, J., & Shen, L. (2019). Blockchain technology and its relationships to sustainable supply chain management. *International Journal of Production Research*, 57(7), 2117–2135. doi:10.1080/00207543.2018.1533261
104. Saleh, H., Avdoshin, S., & Dzhonov, A. (2019). Platform for tracking donations of charitable foundations based on blockchain technology. In *2019 Actual Problems of Systems and Software Engineering (APSSE)* (pp. 182–187). IEEE. doi:10.1109/APSSE47353.2019.00031
105. Sammer, M., Seong, K., Olvera, N., Gronseth, S. L., Anderson-Fletcher, E., Jiao, J., . . . Kakadiaris, I. A. (2024). AI-FEED: Prototyping an AI-powered platform for the food charity ecosystem. *International Journal of Computational Intelligence Systems*, 17(1), Article 259. doi:10.1007/s44196-024-00656-9
106. Saraswat, D., Patel, F., Bhattacharya, P., Verma, A., Tanwar, S., & Sharma, R. (2022). UpHaaR: Blockchain-based charity donation scheme to handle financial irregularities. *Journal of Information Security and Applications*, 68, 103245. doi:10.1016/j.jisa.2022.103245

107. Sarumathi, S., Johny, J., Mol, L., Khandare, M., & Keerthi, V. (2025). BECP: Blockchain enabled charity process framework for effective donation management during disasters. *International Research Journal of Multidisciplinary Scope*, 6(2), 516–532. doi:10.47857/irjms.2025.v06i02.03133
108. Sauers-Ford, H. S., Hamline, M. Y., Tzimenatos, L., McKnight, H., Hamilton, C. M., McKennan, M. G., & Rosenthal, J. L. (2019). You don't know what you don't know: Using nominal group technique to identify and prioritize education topics for regional hospitals. *Hospital Pediatrics*, 9(4), 300–304. doi:10.1542/hpeds.2018-0217
109. Shaheen, E., Hamed, M. A., Zaghloul, W., Al Mostafa, E., El Sharkawy, A., Mahmoud, A., & Attiya, G. (2021). A track donation system using blockchain. In *2021 International Conference on Electronic Engineering (ICEEM)* (pp. 1–7). IEEE. doi:10.1109/ICEEM52022.2021.9480649
110. Shan, H., Liu, Y., Shi, J., & Zhang, Y. (2022). Blockchain application in emergency materials distribution under disaster: An architectural design and investigation. In *The International Conference on Natural Computation, Fuzzy Systems and Knowledge Discovery* (pp. 1034–1044). Cham, Switzerland: Springer. doi:10.1007/978-3-031-20738-9_113
111. Shevtekar, S., & Raut, A. (2023). Fundraising tracking system for NGOs using blockchain. *International Journal for Research in Applied Science & Engineering Technology*. doi:10.22214/ijra-set.2023.51520
112. Shiozaki, Y., & Hasegawa, H. (2024). Fair distribution of supplies through a disaster information sharing system utilizing blockchain. In *2024 IEEE 13th Global Conference on Consumer Electronics (GCCE)* (pp. 904–907). IEEE. doi:10.1109/GCCE62371.2024.10761012
113. Shynar, Y., Seitenov, A., Kenzhegarina, A., Kenzhetayev, A., Kemel, A., Ualiyev, N., . . . Sakhipov, A. (2025). Comprehensive analysis of blockchain technology in the healthcare sector and its security implications. *International Journal of E-Health and Medical Communications*, 16(1), 1–45. doi:10.4018/IJEHMC.372423
114. Singh, A., Rajak, R., Mistry, H., & Raut, P. (2020). Aid, charity and donation tracking system using blockchain. In *2020 4th International Conference on Trends in Electronics and Informatics (ICOEI)* (pp. 457–462). IEEE. doi:10.1109/ICOEI48184.2020.9143001
115. Sivaprakash, P., Charaan, R. D., Ithayan, J. V., Sankar, M., Chithambaramani, R., & Marichamy, D. (2024). IPFS-based blockchain enabled system for secure data storage and access in health-care. In *2024 Second International Conference on Intelligent Cyber Physical Systems and Internet of Things (ICoICI)* (pp. 203–208). IEEE. doi:10.1109/ICoICI62503.2024.10696438
116. Srivatsa, A., Thammaiah, A., MV, L. K., D, R., & AP, S. (2024). Secure data transmission in power systems using blockchain technology. *International Journal of Electrical and Computer Engineering*, 14(6), 6170–6181. doi:10.11591/ijece.v14i6.pp6170-6181
117. Subramaniam, S., Ismail, A., & Ahmad, N. S. (2025). Prioritizing strategies to enhance teachers' technological self-Efficacy: A nominal group technique approach. *Environment-Behaviour Proceedings Journal*, 10(SI24), 275–281. doi:10.21834/e-bpj.v10iSI24.6395
118. Suganthi, S., Beena, T. L. A., Sumathi, D., & Poongodi, T. (2021). Blockchain. In *Blockchain, internet of things, and artificial intelligence* (pp. 1–21). Boca Raton, FL: Chapman & Hall/CRC. doi:10.1201/9780429352898-2
119. Suthar, T. R., Suryawanshi, O. K., & Gavane, A. B. (2019). The agriculture blockchain: An overview. *Journal of Emerging Technologies and Innovative Research*, 6(6), 597–602. <https://www.jetir.org/papers/JETIR1908B76.pdf>
120. Taher, S. S., Ameen, S. Y., & Ahmed, J. A. (2024). Enhancing blockchain scalability with snake optimization algorithm: A novel approach. *Frontiers in Blockchain*, 7, 1361659. doi:10.3389/fbloc.2024.1361659
121. Tapia, A. H., Bajpai, K., Jansen, B. J., Yen, J., & Giles, L. (2011). Seeking the trustworthy tweet: Can microblogged data fit the information needs of disaster response and humanitarian relief organizations? In *Proceedings of the International Conference on Information Systems for Crisis Response and Management (ISCRAM)*. https://www.bernardjjansen.com/uploads/2/4/1/8/24188166/seeking_the_trustworthy_tweet.pdf
122. Thao, P. P. H. (2023). Language awareness and nominal group technique in effective group

- collaboration. *Journal of Knowledge Learning and Science Technology*, 2(2), 81–88. doi:10.60087/jklst.vol2.n2.p.88
123. Treiblmaier, H., & Rejeb, A. (2023). Exploring blockchain for disaster prevention and relief: A comprehensive framework based on industry case studies. *Journal of Business Logistics*, 44(4), 550–582. doi:10.1111/jbl.12345
124. Uikey, D., Brarskar, R., & Ahirwar, M. (2024). A blockchain-based digital notary system provides reliable and tamper-proof timestamping and verification services for digital documents: A review. *International Journal for Multidisciplinary Research*, 6(2). doi:10.36948/ijfmr.2024.v06i02.17429
125. Van de Ven, A. H., & Delbecq, A. L. (1974). The effectiveness of nominal, Delphi, and interacting group decision making processes. *Academy of Management Journal*, 17(4), 605–621. doi:10.5465/255641
126. Van Wassenhove, L. N. (2006). Humanitarian aid logistics: Supply chain management in high gear. *Journal of the Operational Research Society*, 57(5), 475–489. doi:10.1057/palgrave.jors.2602125
127. Wu, H., & Zhu, X. (2020). Developing a reliable service system of charity donation during the covid-19 outbreak. *IEEE Access*, 8, 154848–154860. doi:10.1109/access.2020.3017654
128. Xiao, L., Sun, W., Chang, S., Lu, C., & Jiang, R. (2024). Research on the construction of a blockchain-based industrial product full life cycle information traceability system. *Applied Sciences*, 14(11), 4569. doi:10.3390/app14114569
129. Yang, J., Bi, H., Liang, Z., Zhou, H., & Yang, H. (2020). A survey on blockchain: Architecture, applications, challenges, and future trends. In *2020 International Conferences on Internet of Things and Related IEEE Conferences* (pp. 749–754). IEEE. doi:10.1109/iThings-GreenCom-CPSCoM-SmartData-Cybermatics50389.2020.00129
130. Zakaria, M. I., Hanri, C., Noer, S. H., Triana, M., & Widyastuti, W. (2025). 4C skills teaching activities for mathematics teachers: Application of modified nominal group technique. *Journal of Education and Learning (EduLearn)*, 19(2), 626–633. doi:10.11591/edulearn.v19i2.22337
131. Zhang, L., Ma, X., & Liu, Y. (2022). *SoK: Blockchain decentralization* [Preprint]. arXiv. doi:10.48550/arXiv.2205.04256
132. Zhang, Y., Ma, Z., & Meng, J. (2025). Auditing in the blockchain: A literature review. *Frontiers in Blockchain*, 8, 1549729. doi:10.3389/fbloc.2025.1549729

