

## LEVERAGING BLOCKCHAIN FOR SMART CITY RESILIENCE: STRENGTHENING PREVENTION AND CIVIL PROTECTION SYSTEMS

DOI: 10.26341/issn.2241-4002-2024-3b-2-T02074

### **Dimitrios Christodoulou**

*Ph.D, Department of Planning and Regional Development, School of Engineering, University of Thessaly, Greece.*

[dimischris@gmail.com](mailto:dimischris@gmail.com)

### **Dimitrios Kalergis**

*Assistant Professor, Department of Planning and Regional Development, School of Engineering, University of Thessaly, Greece.*

[dkalergis@uth.gr](mailto:dkalergis@uth.gr)

### **Abstract**

*Cities today present a growing need for risk management of complex crises and disasters, often caused by natural hazards or human-induced (i.e. climate change, violent population dislocation, etc.). In any case of an urban threat, civil protection faces two critical aspects: a) the level of readiness and prevention and b) the ability to coordinate actions and necessary responses to those demanding urban crises.*

*This paper aims to address those two aspects by using Blockchain technology presenting a theoretical framework suggesting an automated and decentralized database system that shares vital information to civil protection agents. A central objective of this technology is to minimize human errors, when handling critical data, and consequently assist in any decision-making process of a threatening urban condition.*

*More precisely, the framework suggests an information flow and communication system based on "smart contracts" that will represent a coordinating basis of all involved agents and services, before, during and following an urban crisis. The suggested decentralized application (DApp) and conceptual model correlate with the current literature review on urban risk management and Blockchain technology and present a functional four stages - scenarios according to the current institutional framework of civil protection in Greece.*

**Keywords:** *Urban resilience, risk management, blockchain,*

## **1. Introduction**

Modern cities face an escalating demand for advanced risk management mechanisms to address diverse crises and disasters, often stemming from natural or social factors like climate change and population displacements. In critical scenarios, civil protection grapples with two crucial challenges: a) enhancing preparedness and prevention, and b) efficiently coordinating operations and responding to crises.

Urban crises, being unpredictable and challenging, strain management mechanisms to their limits, necessitating immediate and organized responses. Blockchain technology, or the "chain of blocks" (Lalenis et al., 2018), emerges as a solution for preventing and addressing urban crises. It provides an automated and decentralized database system for vital information in civil protection, aiming to eliminate human errors that may delay critical data extraction

and sharing. This is particularly vital for well-informed decision-making during times of urgency.

In the context of smart city resilience, the proposed application involves creating a system to address threats to life, public health, and citizens' real estate. Specifically, the suggested approach establishes an information flow and communication system based on Blockchain technologies, specifically "smart contracts." These contracts coordinate all involved entities and services before and during an urban crisis. The decentralized implementation and conceptual model are rooted in an extensive literature review on disaster management in relation to Blockchain technology. The proposed system model covers various use cases in situations before, during, and after catastrophic events and aligns with a four-phase action system based on the existing institutional framework (N3013/2002, Y.A. 1299/2003 - Official Gazette 423/B' 10.4.2003).

## **2. Urban Disaster Management: A Blockchain Perspective**

Urban centers today grapple with increasing exposure to intense natural disasters, including fires, floods, and earthquakes, causing profound effects on communities and local economies. Notable instances in Greece, such as the 2007 forest fires, the 2017 floods in Mandra, and the 2018 Mati fire, underscore the urgency for robust disaster management strategies. Additionally, extreme weather events in 2019 and subsequent crises like the COVID-19 pandemic further emphasize the need for effective response mechanisms.

Post-disaster, diverse entities, including voluntary organizations, aid groups, NGOs, collaborate with local governments, the General Secretariat of Civil Protection, residents, and corporate entities to mitigate the impact of disasters. However, operational challenges abound, encompassing coordination issues, inadequate resource utilization, inefficiencies in business rescue plans, communication gaps, transparency concerns, and a lack of trust. The complexity and chaos in managing catastrophic events, as described by Sakurai & Murayama (2019), necessitate a comprehensive, timely, and effective approach to recording, processing, storing, and disseminating information.

To develop an integrated and effective response to urban crises, a collaborative solution based on enhanced connectivity, transparency, and trust is imperative. Leveraging technological advancements in areas such as organization, communication, interoperability, immediacy, continuous updates, and data extraction and processing becomes a critical parameter. Blockchain technology, specifically the "chain of blocks" (Blockchain) (Lalenis et al., 2018), emerges as a core technology capable of orchestrating various applications.

Blockchain facilitates value exchange within a network through a user-trusted, decentralized system, eliminating the need for intermediaries. The decentralized structure, utilizing peer-to-peer networks, ensures data immutability and consensus through a continuous, growing data structure. Mining, based on Proof-of-Work (PoW), verifies transactions and adds them to the Blockchain, ensuring the integrity of the data. Smart contracts, a crucial element, automate and enforce pre-defined agreement terms, enhancing decentralized automation.

Utilizing Blockchain technology in disaster management provides significant advantages, including:

- Creation of immutable data, resistant to modification once recorded.
- Identity management for organizations and teams, ensuring certified competence for relief activities.
- Secure sharing and management of Personally Identifiable Information (PII) in compliance with privacy/GDPR regulations.
- Monitoring and visibility of supplies from warehouse receipt to final recipient delivery.

- High accessibility through devices like smartphones, recording requests for help from any location.
- Decentralized FOAM location service network usage for geographical recording in challenging scenarios.

### **3. Blockchain Applications in Crisis Response: A Comprehensive Overview**

Blockchain applications have permeated various technological realms, ushering in both opportunities and challenges (Culha, 2020). In the realm of emergency management, Blockchain technology has found multifaceted applications, including resource production, storage, deployment, and the tracking of supplies during crisis scenarios.

Below are noteworthy instances of Crisis Response Blockchain Applications, derived from bibliographic research:

Enhancing Trust and Transparency: Baharmand and Comes (2019) explored the utilization of smart contracts to enhance trust and transparency between humanitarian organizations and logistics service providers.

Aid Resource Sharing: L'Hermitte and Nair (2020) developed a Blockchain-based aid resource-sharing system, fostering interaction and trust among emergency responders and commercial organizations.

Medical Resource Sharing: Liu H and Liu Y (2021) introduced a Blockchain-based mechanism to significantly increase the degree of medical resource sharing, especially relevant in emergencies.

COVID-19 Response: The "Boya Medical Chain," a public welfare platform developed by BOYA REGCHAIN based on Blockchain, played a crucial role in the transparent management of medical material donations during the COVID-19 pandemic (Li, 2020).

Decentralized Trust Management: Samir et al. (2019) proposed a Blockchain-based decentralized trust management framework to facilitate collaborative anonymous disaster relief, particularly in infrastructure-supported scenarios.

Resilience in Urban Settings: Lalenis and Ruchinskaya (2018) emphasized the use of Blockchain technology to enhance resilience at all levels in urban settings, improving the coordination of emergency and evacuation services.

Disaster Recovery and Reconstruction: Nawari and Ravindran (2019) analyzed the potential application of Blockchain in disaster recovery and reconstruction, proposing a new blockchain integration and transfer framework to simplify the post-disaster reconstruction process.

Supply Chain Resilience: Aranda et al. (2019) and Balcik et al. (2010) highlighted how decentralized trust cooperation can enhance the resilience of supply chains in disaster scenarios.

While Blockchain technology holds significant potential in natural disaster response, its direct application throughout the emergency management process is limited. Few international studies have explored the possibility of enabling Blockchain as a collaborative multi-stakeholder emergency management mechanism. This research endeavors to establish a theoretical coupling mechanism between Blockchain and cooperative multi-agent emergency management, presenting a model based on Blockchain technology for multi-stakeholder cooperation in emergency management. Suggestions for future improvements are also anticipated.

#### **4. Operation of a Decentralized Emergency Management Application**

The envisioned decentralized application establishes a comprehensive framework for the operation and coordination of involved entities, drawing inspiration from proposed use cases developed by Sobha and Sridevi (2019) and Siemon et al. (2020). At its core, this application creates a unified Emergency Communication & Information System tailored to a crisis management plan for affected areas, orchestrating actions among involved parties and citizens. The primary entities involved in managing a catastrophic event include state bodies (local government and General Secretariat of Civil Protection), security bodies (fire brigade, police, army, etc.), M.K.O., investigation teams and rescue, transport infrastructure systems, energy and telecommunications suppliers, hospitals, rehabilitation centers, and the residents of an area.

The objectives of the proposed common management system utilizing Blockchain technology are as follows:

- Ensure interconnection among involved bodies.
- Establish a secure communication channel for emergency cases, ensuring data integrity and reliability for effective management and recovery.
- Facilitate quick and efficient response to emergencies.

Access to the common communication platform is restricted to authorized users to ensure both data security and reliability during transfer.

Through this decentralized application, the following functionalities will be achieved:

- Management of requests for assistance.
- Maintenance of a civil protection means database.
- Circulation of information regarding Civil Protection (PP) and its actions.
- Provision of information and data transfer security.

The decentralized database (universal/ledger) stores information across a network of distributed computers, diverging from a single central server. Consensus among the majority of network computers is required to determine the accuracy of the stored information, constituting a Risk Management Record. This record includes:

- Recording of all necessary actions related to identified risk factors.
- Documentation of material resources (financial, infrastructure, equipment and location, human resources, management, etc.) required for managing individual risk factors.
- Designation and authorization of Management Officers for each risk factor.

Beyond providing technical results, the proposed technological solution generates customized reports, offering each concerned party an up-to-date overview of risk factors or necessary controls under their responsibility. Uniform coded recording of management actions ensures information dissemination and essential monitoring of actions according to the contained schedules in the Risk Management Plan.

Interactions with the Blockchain network and data entry/retrieval are executed through Smart Contracts. A specific smart contract is proposed for activation and update phases of crisis management data, managing multiple other smart contracts and necessary licenses. Given the preference for a public permissionless Blockchain, user access to smart contracts is regulated hierarchically to ensure transparency and accountability. An Emergency Communication & Information system encompasses multiple use cases implemented as separate smart contracts, with a modular approach allowing activation individually or concurrently.

The proposed model encompasses four use cases aligned with the creation of a system of actions across four phases, as per FEK 423/10.04.2003. These Use Cases cover a spectrum of applications, ranging from information transmission to local authorities seeking help to the

effective response and resource utilization by local authorities in the aftermath of a natural disaster.

#### ***Use Case 1: System Activation and Update***

This scenario corresponds to the initial readiness phase (Code S), where the proposed Blockchain-based communication and information flow system is implemented. The goal is to establish an understanding among involved parties and make critical decisions. Within the decentralized application, the civil protection means are documented, and their adequacy and suitability are evaluated. In instances where the means are considered insufficient, the system offers the option to generate certificates for political requisition (if data is available) of means and services, ensuring the transparency of the process. Additionally, preparatory actions are executed, and civil protection levels are anticipated. Leveraging GPS systems and risk analysis programs, a digital risk map is generated, showcasing the level of risks. These geospatial data are stored in the decentralized network and are updated when significant changes are identified by the coordinating body throughout the phenomena's evolution. Accessible via the internet, these risk maps serve as an output of the proposed model and offer location services (e.g., proximity of users based on the evolution of phenomena) when accessed by devices supporting such services (e.g., mobile phones with GPS receivers, GLONASS, etc.).

#### ***Use Case 2: Early Warning Reception***

This use case is situated within PHASE 2 – Increased preparedness with Code A. In this phase, the crisis management center predicts the potential cause, occurrence, and intensity of a disaster, notifying relevant users. Users, in this context, represent interested parties collaborating through Blockchain technology. To receive an early warning, users need to register and authenticate through various communication channels, such as mobile phone numbers, email, social media accounts, or by creating a user account on the Blockchain platform.

To ensure a secure registration process, a "certificate issuing authority" (CIA) is introduced, serving the following roles:

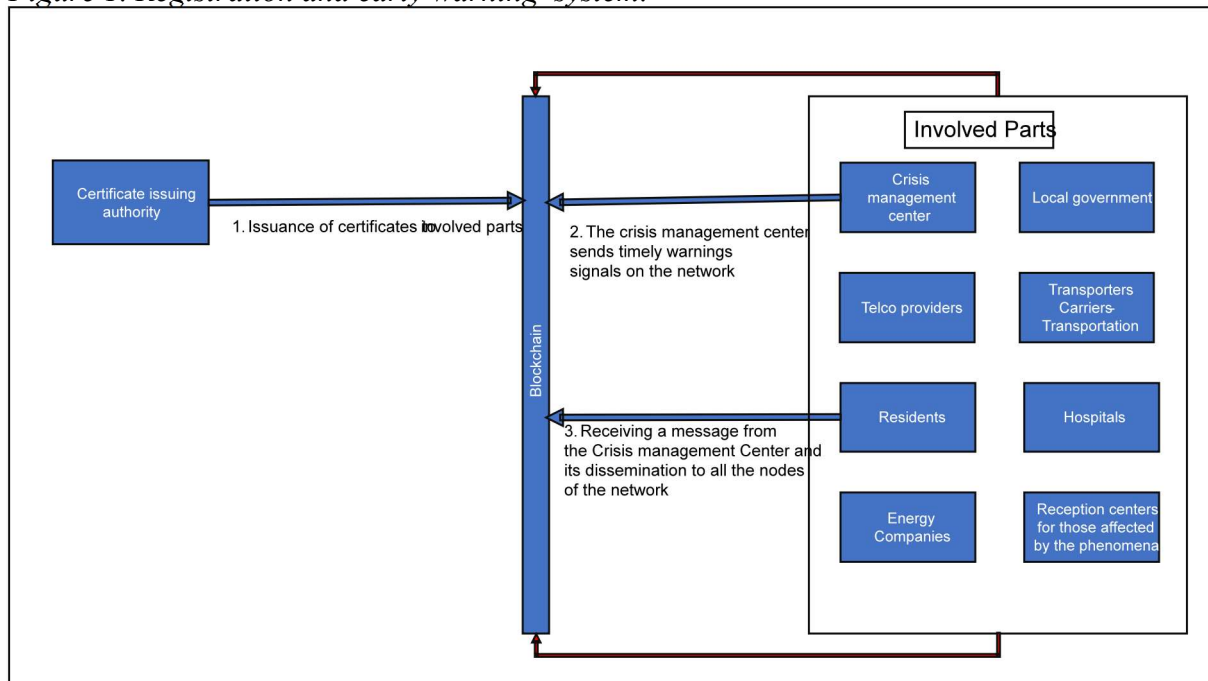
- **Verifying Agency Identity and Eligibility:** The CIA verifies an agency's identity, qualifications, and eligibility for certification, potentially through document checks, inspections, or compliance assessments.
- **Issuing Blockchain-Based Certificates:** After verification, the CIA issues a digital certificate, anchored on the blockchain for security and immutability. The issuing authority may be distributed among multiple nodes or require consensus within the network.

In the long term, the CIA may evolve into a more advanced role, acting as a Facilitator and Guarantor:

- **Enabling Self-Sovereign Identity (SSI):** The CIA facilitates agencies in creating self-sovereign identities on the blockchain, allowing them to issue their certificates independently.
- **Guaranteeing the Network:** While agencies issue their certificates, the CIA ensures the overall integrity of the network by setting standards, validating processes, and resolving disputes if needed.

Once the warning is transmitted to the Blockchain network, it undergoes identity verification with authorized users, such as rescue teams. Subsequently, the early warning information is disseminated across the network, reaching all users and enabling them to prepare and organize for disaster response. Figure 1 illustrates the proposed system and model for registration and early warning.

Figure 1. Registration and early warning system.



**Use Case 3: Resident Assistance Request in Crisis**

In this scenario, the established Blockchain-powered system is deployed to streamline and enhance the emergency response process during crises. Residents requiring assistance can send real-time distress signals through a mobile application seamlessly connected to the Blockchain network. All relevant stakeholders, including residents, local government, transporters, rescue teams, reception centers, energy companies, hospitals, and telecommunication providers, are registered and certified on the Blockchain network as per the prior Use Case. With transparent and secure information, there are no concerns about data consistency or integrity. Once the rescue operation concludes, the pertinent information is transmitted back to the network to validate the completion of the rescue operation, and the data is securely stored in the Blockchain with a timestamp.

**Use Case Steps:**

**1. Resident Sends Help Signal:**

A resident in distress uses a mobile application connected to the Blockchain network to send a help signal in real-time.

**2. Local Government Response:**

The local government, registered on the Blockchain, receives and acknowledges the help request. They initiate the emergency response protocol.

**3. Transporter Carriers Routing:**

Transporter carriers, connected to the Blockchain network, receive routing information to optimize the means of transport for efficient response to the resident's location.

**4. Rescue Teams Deployment:**

Certified rescue teams use the information on the Blockchain to locate and assist the residents who requested help.

**5. Reception Centers Update Information:**

Reception centers, responsible for managing those affected, update their databases with the latest information and upload the data to the Blockchain for transparency and coordination.

**6. Energy Companies Enhance Efficiency:**

Energy companies, integrated with the Blockchain, leverage the information to optimize the power grids during the crisis, ensuring a more efficient distribution of energy resources.

**7. Hospitals Serve and Record Information:**

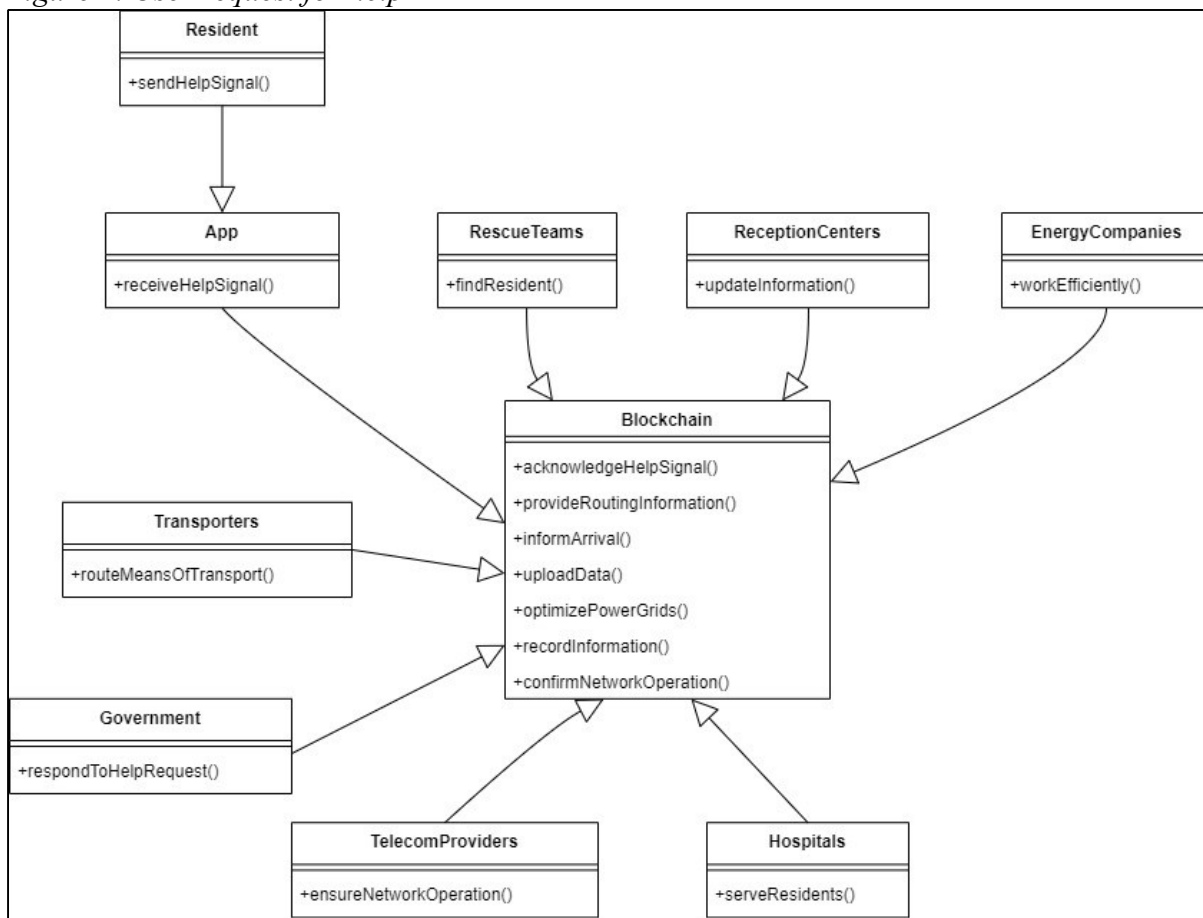
Hospitals, registered on the Blockchain, serve affected residents and record relevant information directly into the Blockchain network for secure and transparent data management.

**8. Telecommunication Providers Ensure Network Operation:**

Telecommunication providers, part of the Blockchain network, ensure the uninterrupted operation of networks, facilitating communication between all involved parties throughout the crisis.

The UML class diagram for rescue assistance is presented in more detail in Figure 2.

Figure 2. User request for help



**Use Case 4: Blockchain-Powered Disaster Recovery and Relief System**

This use case serves to demonstrate the utilization of blockchain technology to improve the effectiveness, transparency, and security of the disaster recovery and relief process. Through the incorporation of blockchain, the system endeavors to optimize information flow, enable precise damage assessment, and guarantee the transparent allocation of resources during the recovery phase.

**Components and Features:**

**1. Recording and Monitoring Damage Assessment:**

- Blockchain will be utilized to securely record and monitor the total damage incurred during the disaster response stage.

- All relevant information, including damage reports, resource utilization, and response actions, will be stored on the blockchain network in an immutable and transparent manner.

**2. Victim Certification:**

- Blockchain will enable the creation of victim certificates with accurate and verifiable information.
- The victim certificates will serve as a secure record of individuals affected by the disaster, providing a reliable source for relief agencies and government bodies to assess and prioritize aid distribution.

**3. Resource Tracking and Allocation:**

- The system will employ smart contracts on the blockchain to automate and secure the allocation of resources for the recovery process.
- Smart contracts will ensure that funds and resources are distributed based on predefined criteria, reducing the risk of mismanagement and ensuring efficient resource utilization.

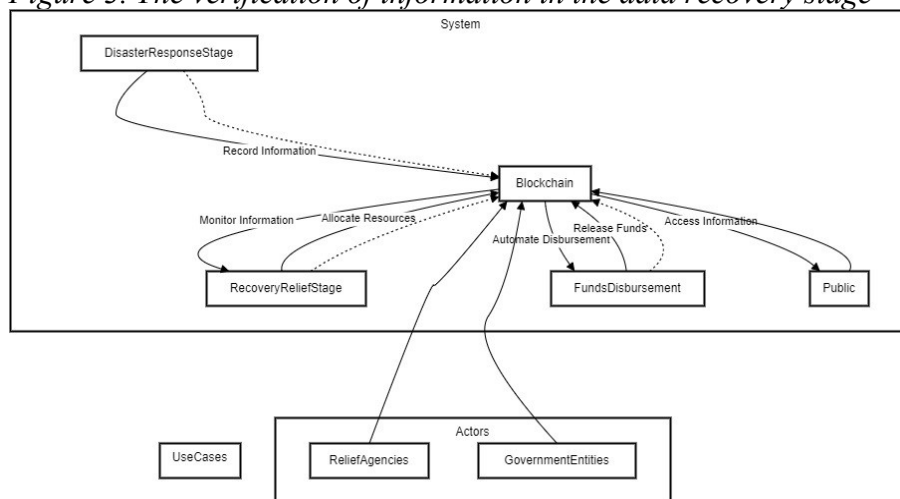
**4. Funds Disbursement for Recovery:**

- Blockchain's transparency and security features will be leveraged to facilitate the release of funds for the recovery process.
- Smart contracts can automate the disbursement process, ensuring that funds are allocated only to approved and validated initiatives, reducing the likelihood of fraud and corruption.

**5. Public Access to Information:**

- The decentralized nature of blockchain ensures that information related to the disaster recovery process is accessible to all stakeholders, including the public.
- This transparency fosters trust among citizens, relief organizations, and government entities, as they can independently verify the progress and effectiveness of the recovery efforts.

Figure 3. The verification of information in the data recovery stage



The effective realization of the aforementioned usage scenarios is not only essential but also a prerequisite for addressing various additional challenges that emerge during and after a disaster. These challenges encompass:

- **Supply Chain Issues (Logistics):** The 2010 earthquake in Haiti, despite substantial international aid, highlighted the inefficiency of efforts due to the lack of communication on a unified platform. This resulted in delays and the mismatch of

resources with demand. While this issue mirrors common supply chain problems, in the context of natural disasters, its implications extend significantly to human losses.

- **Identification of Evacuation Sites per the Xenokratis Plan:** Through the decentralized application, citizens and participating agencies in the rescue plan are informed about evacuation sites and the safe routes (routing) to reach them, derived from secure information distributed within the Blockchain network.
- **Locating the Nearest Reception Center for Affected Individuals:** Information is provided about nearby reception centers using location services (proximity), benefiting both citizens and rescue agencies.

Similar challenges include locating missing persons, determining the statistical impact, damage assessment, certificate issuance, protection against fraud in humanitarian aid distribution, etc. The use of Blockchain offers an efficient solution to these issues, minimizing delays and eliminating redundancy. Additionally, recording events via Blockchain at a secondary level contributes significantly in cases of major disasters, such as the Mati fire, facilitating the redevelopment of areas with a focus on urban resilience criteria.

#### **4. Limitations of the Proposed Application**

The application of Blockchain technology, while promising, does not offer a universal remedy for the challenges and inefficiencies in disaster response efforts. A crucial precondition for its effectiveness is the connection of all relevant parties managing an urban crisis to the same Blockchain network. The necessity for a common communication platform becomes more pronounced, especially when dealing with critical products like drugs and medical supplies. The proposed model acknowledges the need for a regulatory body overseeing the Blockchain network, introducing a potential conflict with Blockchain's fundamental philosophy of eliminating third parties and disintermediation.

Furthermore, the current state of Blockchain technology, originally designed for different purposes, demands further development for seamless integration into disaster management. This involves a central authority to supervise Blockchain participants and ensure authenticity, raising questions about the overseeing entity's identity. The possibility of an international aid organization or a European authority assumes significance for improved intervention and cooperation among Member States.

Additionally, concerns arise regarding the mandatory participation of entities in a specific Blockchain during a disaster. Staff training and infrastructure funding are pivotal factors for successful integration and operation within the network.

An ongoing concern involves the lack of standardization in integrating external factors into the system. Without a unified platform, organizations, individuals, or government bodies risk receiving incorrect or unreliable information, complicating the management of urban disasters.

Power supply and uninterrupted telecommunication coverage are prerequisites for using the technology effectively. Failure to meet these conditions can result in system crashes. Addressing telecommunication challenges, Ilbeigi et al. (2022) propose a fully decentralized emergency communication system based on Blockchain, enabling direct device-to-device (D2D) Wi-Fi Direct connections and information exchange through a routing algorithm.

The model faces challenges in sourcing risk assessment data from various external oracles. Ensuring clarity, reliability, and a robust scientific background in these data sources becomes crucial for effective disaster management.

Smart contracts, once deployed on the Blockchain network, are challenging to modify, demanding meticulous planning. In the context of managing catastrophic events, where

system failures can have life-threatening consequences, the reliability of smart contract code is paramount.

The adoption of Blockchain technology introduces a knowledge and usability challenge, as users need to be proficient in utilizing the technology, connecting to the network, and accessing reliable information.

Full deployment of Blockchain for disaster response remains a future prospect, with advancements such as strong AI and the Internet of Things expected to complement and enhance disaster response efforts. These technologies offer the potential for sophisticated data analysis, prediction, and preparation, ultimately strengthening urban resilience.

## **5. Concluding Remarks**

The envisioned model employing Blockchain technology for urban crisis response serves as an initial exploration in the realm of research. The imperative for urban resilience, coupled with the global impact of climate change, necessitates the development of effective tools capable of addressing crises. This Blockchain model focuses on the foundational considerations and potentialities for creating a unified data and information exchange system among involved entities and participants, including rescue teams, security forces, and local residents.

The application of Blockchain in risk analysis and management offers several advantages, including:

- Establishment of a decision-making system grounded in reliable information.
- Provision of direct and transparent access to crucial information and data for all stakeholders.
- Spatial and temporal identification of resources in an operational risk management plan during the course of an urban crisis.
- Ability to reassess the situation, enabling accurate predictions for various scenarios and objective strategies.

Blockchain technology, leveraging its features like distributed storage, decentralization, consensus algorithms, tamper protection, traceability, and smart contracts (particularly in automated risk response scenarios under specified conditions), can introduce innovation into emergency management mechanisms. Embracing a Blockchain-centric approach to disaster management helps safeguard valuable data from corruption, accelerates partnerships between relief agencies, ensures verified and timely communications during disaster development, optimizes resource allocation, and ensures secure access to pertinent data generated throughout response and recovery operations.

However, the efficacy of timely response hinges significantly on the design and structure of collaborative processes among involved entities. Consequently, meticulous planning at each stage, with a focus on smart contract coding, precedes the implementation of Blockchain technology.

In conclusion, the adoption of technological solutions, specifically Blockchain, for addressing major disasters does not equate to a wholly decentralized resolution eliminating the need for third-party involvement. In the context of urban resilience, an overseeing authority (conceptually termed the "Crisis Management Center" in our application model) remains essential for managing the data system and safeguarding the rights of involved and authorized users.

## References

- Acheson, N., Biggs, J. & Nguyen, H. (2018) 'How Bitcoin Mining Works'. CoinDesk. Available at: <https://www.coindesk.com/learn/how-bitcoin-mining-works-2> (8.11.23).
- Aranda, D. A., Fernández, L. M. M., & Stantchev, V. (2019) Integration of internet of things (IoT) and Blockchain to increase humanitarian aid supply chains performance. In 2019 5th International Conference on Transportation Information and Safety (ICTIS) (pp. 140-145). IEEE.
- Antonopoulos, A. M. (2014) *Mastering Bitcoin: Unlocking Digital Cryptocurrencies*. 1st ed.; O'Reilly Media, Inc.: Sebastopol, CA, USA.
- Baharmand, H. & Comes, T. (2019) 'Leveraging Partnerships with Logistics Service Providers in Humanitarian Supply Chains by Blockchain-Based Smart Contracts'. *IFAC-Pap.*, 52, 12–17.
- Balcik, B., Beamon, B. M., Krejci, C. C., Muramatsu, K. M., & Ramirez, M. (2010) 'Coordination in humanitarian relief chains: Practices, challenges and opportunities'. *International Journal of Production Economics*, 126(1), 22-34.
- Çulha, D. (2020) 'A random and transaction-positioned Blockchain'. *Comptes Rendus de l'Academie Bulgare des Sciences*. 73 (7) (2020) 915–925.
- Ilbeigi, M., Morteza, A., & Ehsani, R. (2022) 'An infrastructure-less emergency communication system: A Blockchain-based framework'. *J. Comput. Civ. Eng.*, 2022, 36(2): 04021041
- Lalenis, K. & Ruchinskaya, T. (2018) 'Building Urban Resilience of Public Places in Volos (Greece)'. Perspectives and possibilities of related contribution of digital tools., in *Proceedings of the IFoU 2018: Reframing Urban Resilience Implementation: Aligning Sustainability and Resilience*, Barcelona, 10–12 December 2018, MDPI: Basel, Switzerland, doi:10.3390/IFOU2018-05931
- Lalenis, K., Kalergis, D., Samourkasidou, E. & Zygouri, F. (2018) 'Blockchain & Urban Management: opportunities and perspectives towards a more democratic approach'. 5th Panhellenic Conference on Town Planning, Spatial Planning and Regional Development, Volos, 27-30 Sept. 2018.
- L'Hermitte, C., & Nair, N. C. (2021) 'A blockchain-enabled framework for sharing logistics resources during emergency operations'. *Disasters*, 45(3), 527–554. <https://doi.org/10.1111/disa.12436>
- Li, J. (2020) 'The application and development of Blockchain in the public industries'. *Frontiers* 5 (2020) 57–65.
- Liu, H. & Liu, Y. (2021) 'Construction of a medical resource sharing mechanism based on Blockchain technology: evidence from the medical resource imbalance of China'. *Healthcare* 9 (2021) 52.
- Nawari, N.O. & Ravindran, S. (2019) 'Blockchain and Building Information Modeling (BIM): Review and Applications in Post-Disaster Recovery'. *Buildings*, 9, 149.

- Sakurai, M., & Murayama, Y. (2019) 'Information technologies and disaster management – Benefits and issues'. *Progress in Disaster Science*, 2, 100012.
- Samir, E., Azab, M., & Jung, Y. (2019) 'Blockchain guided trustworthy interactions for distributed disaster management'. In 2019 IEEE 10th Annual Information Technology, Electronics and Mobile Communication Conference (IEMCON), British Columbia, Canada, Vancouver, 2019.
- Shen, C. & Pena-Mora, F. (2018) 'Blockchain for cities—A systematic literature review'. *IEEE Access*, 6, 76787–76819. [CrossRef]
- Siemon, C., Rueckel, D., & Krummy, B. (2020) 'Blockchain Technology for Emergency Response'. Paper presented at the 53rd Hawaii International Conference on System Sciences, Maui, Hawaii. (VHB\_3: C)
- Sobha, G. V. & Sridevi, P. (2019) Usecase of Blockchain in disaster management-a conceptual view. Greeley, Colorado: Aims Community College. Available at: <http://www.aims-international.org/aims17/17ACD/PDF/A374-Final.pdf> (8.11.23).
- Van Wassenhove, L. N. (2006) 'Humanitarian aid logistics: Supply chain management in high gear'. *Journal of the Operational Research Society*, 57(5), 475-489.
- Christodoulou, D. (2022) 'Creation of an algorithm for the operation of the Digital Land Bank, based on Blockchain technology'. Panhellenic Spatial Planning Conference, 2022, Volos - Greece.
- Wu, H., Li, Z., King, B., Ben Miled, Z., Wassick, J., & Tazelaar, J. (2017) 'A Distributed Ledger for Supply Chain Physical Distribution Visibility'. *Information*, 8(4), 137.