Humanitarian Logistics Performance Improvement Model using Blockchain Approach

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Abstract

Disasters, both human-made and natural, have bleak characteristics to upheaval lives. Disaster response requires multidimensional efforts and multidisciplinary teams. The humanitarian supply chain is responsible for managing the pre-disaster and post-disaster movement of goods, funds, information, and humans. This paper will explore managerial interventions possible in disaster response from a supply chain management perspective. Paper will describe issues with information management of disaster relief operations. Paper proposes a novel framework for integrating blockchain technology, internet of things (IoT), social media analytics and advanced optimization algorithm to determine the relief action plan. The integration is sought to make the relief work self-regulated, encrypted, efficient, decentralized, responsive, agile and foolproof. The proposed framework may reduce the turnaround time of fund, improve resource distribution, and enhances reliability. The designed framework can also support the integration of blockchain platform with IoT sensors, smart devices and autonomous equipment's. It will facilitate better interagency coordination, express decision making and wide adaptability or interoperability.

Keywords
Humanitarian Supply Chain, blockchain, framework, decision support system, IoT.

1. Introduction

Humanitarian supply chain (HSC) received much attention in the past two decades due to increased disasters and uncertainty in managing disaster operations. 2004 Tsunami of Indian Ocean and Haiti earthquake of 2010 presents a grim picture of disaster relief works. Earlier natural disasters used to perceive as a frequent low occurrence with a

high number of incidences. However, low-frequency phenomenon is also gradually decreasing due to increased environmental changes such as global warming, urbanization and deforestation. A clear indication of increased natural disasters is hurricanes in Central America, earthquakes in Japan, heatwaves in India. Response to disasters is challenging. A cloudburst of 2013 at Uttrakhand poses managerial challenges for relief operation due to blocked pathways, destroyed communication channels and unpreparedness of disaster management authorities. The cost associated with these events also poses significant operational complexities.

The HSC defined as "the process of evacuating people from disaster-stricken areas to safe places and planning, implementing and controlling the efficient, cost-effective flows of goods, meanwhile collecting related information from the point of supply to the point of consumption to alleviate the sufferings of vulnerable people" (Habib *et al.*, 2016). HSC involves higher risks, a very high uncertainty level, urgency and time pressure, making operations complex, multidisciplinary and chaotic (Soosay and Hyland, 2015). Supply chain involves the flow of goods, money, humans and information along the product life cycle, which is now operating in a more dynamic environment. Significant activity in HSC consists of the rapid flow of personnel, victims, and components mentioned above of the supply chain. In HSC, fund and material flow unidirectionally from donors and aid agencies to humanitarian organizations (HO). However, information flow becomes multipolar with plural stakeholders creating and distributing information useful for others. HSC becomes an altogether different problem, with minimal opportunity to forecast the demand, end customer being the donors; however, goods receivers are victims and short lifespan of the chain. The chaotically formed network requires rapid adaptability. This network efficiency depends on the timely dispersal and the authenticity of information, the reachability of personnel and capability of relief agency to use the information. Information is the backbone of every operation. It is comparable to the house's foundation upon which every other operation success depends, If the foundation is weak, the house crashes. The information must be accurate, reliable, and within reach of HOs at the appropriate time. Sometimes information system solely determines the success of relief operation. Information flow becomes crucial at the times of disaster; however, agencies strive to produce tangible products and neglect the building of information system (Oloruntoba and Gray, 2006). Ergun et al., (2014), pointed out the integration of multiple humanitarian organizations using IT tools. Safety and security of sensitive victim data is another critical issue that had not received enough attention from the HSC stakeholder (Thylin and Duarte, 2019). Several instances of victims data misuse have been reported in the literature (Khan *et al.*, 2019). These issues generated the need for a safe, secure, reliable, transparent, and robust information management system for disaster operations.

HO manages data in different ways. Some HO with a significant base of donor and large operations have proprietary software system developed to suit their needs. These software systems have dedicated data architecture to support decision making and operation planning. Functional aspects of these systems have sufficient capacity to manage the individual operation effectively. These systems have delivered intended functions and facilitate the effective relief work and created problems like data interoperability, high maintenance cost, data consistency and data redundancy. One major issue with such a system is the tendency to make poor decisions due to the inability to share data among HO. Cross-network data sharing becomes a desirable feature due to the presence of multiple no of HO. However, the lack of provision to share data and incapability to handle, the data make the operation fail to realize its full potential.

Integration of stakeholder of commercial organizations started with the introduction of quality management principals around 1970s-80s, ERP software made it possible to integrate the stakeholder along the value creation chain. The system fulfilled the intended objective by optimizing operations at multiple levels. HOs can also leverage IT advances in improving their operational capabilities. Blockchain has been proposed as a potential solution for the above-mentioned data-related issues. Several authors proposed blockchain utilization in the different supply chains for information management, tracking and tracing, smart contracting, automation, and others (Dobrovnik *et al.*, 2018; Kersten *et al.*, 2017; Nakasumi, 2017; Shardeo *et al.*, 2020). Literature has also accessed the application of blockchain in the humanitarian domain and described the benefits of technology adoption (Baharmand and Comes, 2019; Coppi and Fast, 2019; Dubey *et al.*, 2020; Seyedsayamdost and Vanderwal, 2020). The number of literature highlights that the humanitarian domain will observe an increased application of blockchain technology.

1.1 Purpose:

The purpose of this paper is to understand and present a framework to exploit the benefits of blockchain technology for effective management of relief operations. This paper attempts to minimize the complexities involved in decision making with humanitarian logistics by proposing a framework for information management of HSC.

1.2 Research Background:

Nakamoto, (2008) proposed blockchain technology for the digital transaction in 2007. Since then, various cryptocurrency (Bitcoin, Ethereum, Litecoin) based on blockchain technology has been launched and successfully used worldwide. Blockchain also used by some firms for supply chain management, smart contracts, identity management and digital voting. The ecosystem for blockchain technology is in a nascent stage and will evolve. Several researchers have addressed and proposed blockchain technology's potential application (Dobrovnik et al., 2018; Patil et al., 2020; Saberi et al., 2019; Shardeo et al., 2020). It appears to be promising in future towards transcending the manner of handling digital data.

We review HSC related literature mentioning the critical issues and technological applications in the network. Research began with the idea of understanding the relief operation attributes. Literature-based on field surveys and case studies explored the possible field of improvement to enhance operations efficiency.

2. Literature review

As Van Wassenhove, (2006) said, disaster relief is 80% logistics and needs comprehensive management. Procurement, sorting, transport and distribution became the critical operations of HSC. Detailed planning of Supply chain operations becomes difficult and require much more flexibility, adaptability, responsiveness, and agility. Humanitarian aid cycle starts from the onset of disaster to the recover and preventive actions for the future. HSC demands the formation of the big supply chain network in a very short lifespan. These networks termed as hastily developed network by Tatham and Kovács, (2010), the author attempted to identify trust issue among the HSC networks.

Coordination is the most concerning issue in supply chain management. The primary objective of the commercial organization is the maximization of profit. This profit maximization is achieved by determining the appropriate capacity level and pricing strategy. Tomlin, (2000) propose multiple pricing strategies to achieve coordination between manufacturer and supplier. Coordination among HSC stakeholders poses various problems since humanitarian organizations cannot quantitively measure the profit and make the strategies keeping qualitative targets. Coordination among stakeholders depends heavily on the trust created in a short time. Altay and Labonte, (2014) Analyzed the Haiti earthquake and proposed an integrated complexity-information flow impediment framework for system effectiveness. Authors propose to remain agile and adaptive, be demand or need-driven instead of supply-driven, focus on value-added activities and develop an accommodative approach. Authors conclude by favouring the need of a good information management system for effective coordination. Fontainha, et al, (2017) Proposes a taxonomy for stakeholder management model of public-private- people relationship for relief operation. Author enhanced the stakeholder management conceptual model by analyzing types of relationship (vertical /horizontal and centralized/decentralized). Paper highlighted the need for better interagency coordination, cooperation, collaboration and integration among stakeholder. Patil et al., (2020) recommend adopting blockchain for improvement in the performance of HSC. An article emphasizing the need of HSC to learn from commercial supply chain concluded that HSC literature should focus towards demand visibility, requirement determination, information management, relief activity coordination, relief action planning and developing trust in the chain (Day *et al.*, 2012). Familiarity and awareness are two components for creating trust among organizations.

Size of organizations directly affects the capability of organizations to participate in coordination activities. International relief agencies are connected by one umbrella organization that facilitates horizontal coordination to share resources (Balcik *et al.*, 2010). UNJLC is the one organization established in 2002 to facilitate inter-agency coordination. Another coordination framework proposed in 2005 named logistics cluster under WFP. However, these organizations are failed to integrate local NGOs due to language and cultural barriers. Balcik et al., (2010) mentioned that coordination with smaller organizations has positive and negative effects. Coordination activities positively affect resource utilization, cost and time efficiency but increase bureaucracy and decrease flexibility.

In the best of our knowledge, a framework with the decision support system had never been proposed earlier. Limited literature did talk about the supply chain framework (Yu et al., 2015). But they lack a holistic view of providing DSS for HSC. An appropriate framework for humanitarian work must incorporate multiple decision-makers enriching actions of each other by concurrently making action plans to reach a maximum number of victims, in the minimum

time possible with the least possible amount of resources. Next section will discuss the learnings from commercial SCM and explore the opportunity to reduce the issues of HSC. We attempt to define the HSC operation in this section briefly. HSC concerns with the flow of food, shelter, medicines, personnel and relief/rescue equipment. Food, shelter, and medicines are three categories of items that need to have inflow. Information originates from multiple sources, received and utilized at numerous points to provide the said three materials to victims.

2.1 Commercial supply chain concepts need to be redesign:

The HSC has been learning from the commercial supply chain despite differences, but few characteristics made a clear distinction and managed very efficiently by commercial supply chain leaders. Humanitarian operation requires to redesign these concepts incorporating strategic and tactical knowledge used in defining these concepts.

- Long term objectives.
- Coordinated functions.
- Strategic planning.
- Synergy among goals and approach.
- Adaptability at field level (Agile supply chain).

2.2 Issues in the HSC

Literature attempted to identify the barriers of HSC using theoretical case studies, imperial tools (Kabra and Ramesh, 2015). This paper highlight some of them to understand the HSC complexities.

- Multiple agencies focus on only immediate relief, restoring normal life, and long-term sustainable livelihood receives less attention. Immediate relief work losses the opportunity to act towards sustainable actions.
- Unstable nature of funding: since targeted customers are victims but focused, and direct customers are multiple aid agencies, the flow of fund become somewhat unpredictable. Media attention and social media trend determine the sustainability/flow of fund.
- Flexibility: Disaster-stricken areas have dynamic characteristics in time and space dimensions, victims needs and ability to respond both become highly uncertain. The cost of failing to counter this uncertainty have losses regarding human lives. Flexibility required is much higher in the HSC than the commercial supply chain.
- Sensitive and accurate need assessment: HSC operations, planning and managing activities are done on an urgent basis, Good quality of information can improve the operation efficiency. Data related to material quantity and location, stranded people, blocked pathways required for drafting an appropriate operation plan.
- Adaptability: The existing infrastructure becomes inoperational in disaster-stricken areas. However, relief work requires logistics planning such that equipment efficiently deployed, dismantled and moved very frequently. Stakeholders of HSC must be adaptable for effective operations.
- Shortage of skilled staff: Relief work is demanding both regarding physical labour and emotions. Relief workers or volunteers exhaust very rapidly and burn out due to the traumatic environment.
- Multiple stakeholders: Aligning numerous agencies for coordinated work become extremely difficult since each agency has a different work culture, interest, belief and functional behaviour.
- Transaction time: Donations from international donors sometimes stuck in exchange or takes too much time for clearance and reach to HO/affected regions.
- Information Quality: HO struggles with an accuracy of information. In recent years fake information for shadows agendas is surfacing to hamper the operations. Compromise in relief work due to falsified data or tampered data can result in loss of lives and time.
- Tracking: Fright of HO are hybrid, and tracking becomes difficult in the affected field. Some material requires specific environmental conditions. Monitoring of logistics conditions needs to be insured.

Information flow is an essential part of the supply chain. Multiple stakeholders coming into the network with rapid speed bring number of complexities. Typical information flow in disaster relief work is presented in figure no 1. Blue color arrows reflect the one-way communication, and saffron color reflect two-way communication.

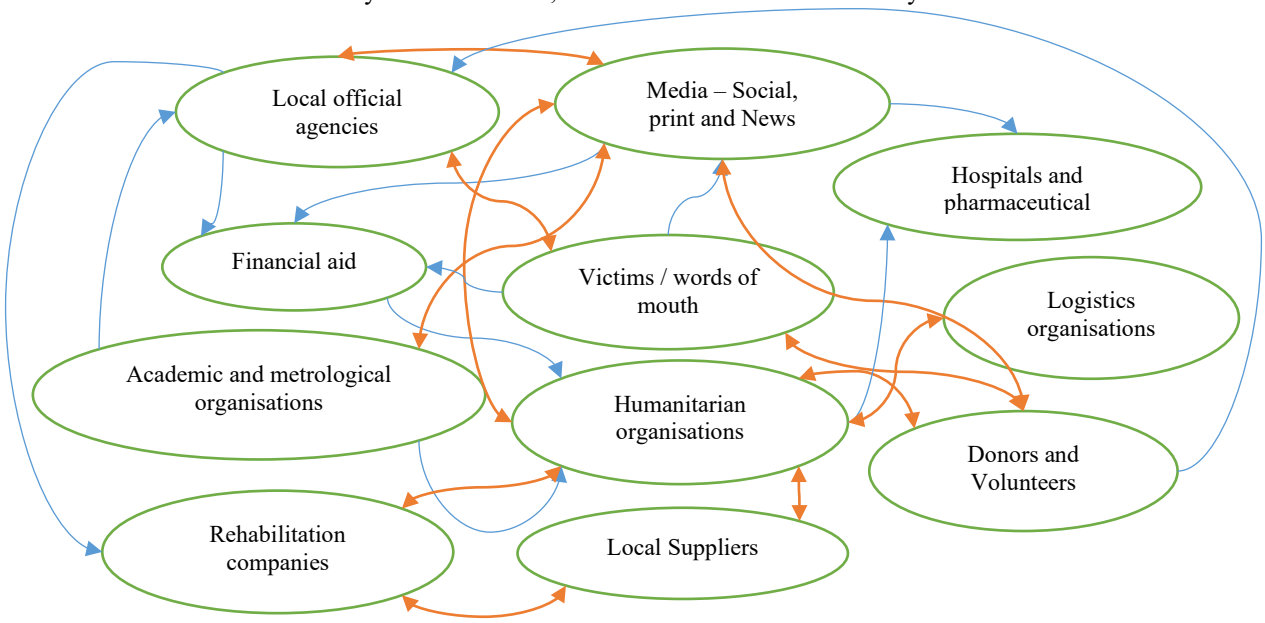

Figure 1: Information flow in HSC

2.3 Decision support system (DSS) requirement in context of HSC:

In this section, an attempt has been made to describes the decision-making process of HO. HO relies heavily on the regional stakeholders for information which is used in the creation of the network. The creation of network further hinders due to lack of infrastructure and other aftereffect of disaster event. Thus, to avoid the operational failure, information management should be robust. In practice, planning is performed for the current disaster by HOs. Majority of HO focus on the immediate relief and ignore the data collection process. However, the first few days of information, which is most important lost in the wake of the crisis. DSS needs to learn from previous disasters so that it can cater to future disaster more efficiently.

DSS for HO have following key requirement pertaining to information systems.

1. Tracking personnel for appropriate deployment
2. The reliable and robust information management system
3. Learning capabilities
4. Interoperability's
5. Fast, permanent and flexible system
6. Tracking goods in the logistics process
7. Monitoring storage and transport environment

3. Blockchain-based system for HSC decision support

We present an improvement model to existing supply chain management of the disaster. Our model incorporates blockchain, IoT, IOV and social media analytics to accord better coordination among relief operators. Our model is the extension of the model proposed by (Yang *et al.*, 2011) with a blockchain layer to bring the connectivity among different stakeholders. In this paper, the author used wireless communication, active and passive tag to have a unified information system for resource tracking and monitoring. Zigbee devices are used to make a temporary personal network.

3.1 Conceptual Framework and Measures

Blockchain: Blockchain provides an open, decentralized database. Cryptocurrency-Bitcoin is the first to utilize the blockchain system. Blockchain provides and facilitates multiple financial services such as value transfer, financing, asset acknowledgement, reduced settlement times, real-time tracking of transactions, ledger databases, information protection, and smart contracts. It can create digital footprinting of relief material, donations, personnel.

Internet of value: Information flow received a significant boost after the internet revolution. Information flow becomes fast and reliable with the risk of tampering. However, fund flows still struggles with multiple stakeholders, regulations, and reliability. In the era of global manufacturing, international transactions need to be settled as fast as information flow. Internet of value provides a secure solution to communicate funds, votes, stocks, machine commands, and codes.

Internet of things: Internet of things is the ubiquitous group of sensors and devices connected to the internet and continuously share the data. Literature is full of working case studies and applications describing the role of IoT in the supply chain. Integration of IoT with blockchain is still needed to be analyzed.

Media: Both formal media (television and print media) and free media (social media, oral communication) play a significant role in bringing donations and developing an opinion/perception regarding the crisis scale. Media also play role in motivating the volunteers and field workers. Our model will access the media orientation towards the crisis to determine the adaptability of operation.

Stakeholder: The commercial supply chain has a private set of stakeholders interacting with limited customers. However, humanitarian logistics involves both local and international population, multiple agencies and stranded victims.

3.2 Humanitarian logistics framework:

Relief operations require the coordinated efforts of multiple dissimilar agencies. Each agency is unique regarding its operation, culture, expertise, hierarchy, and design. They have their own work culture, religious belief, and motivations. We segmented differences agencies into three groups.

- International organizations. (UN, MSF)
- Local government agencies.
- Regional agencies (NGOs, media)

Big organizations such as UNDP, WFP bring standard expertise applicable for most locations but require local and regional agencies information for effective operations. Various organizations have their own predefined set of suppliers and logistics providers. The focus should shift to using local providers so that rehabilitation and resettlement operations receive economic support.

We propose bringing all the information into one shared network of a distributed ledger using the blockchain networks. In our proposed system organizations create their blockchain database that caters to an organization's supply chain. Then multiple blockchain networks are connected to share the information through a blockchain of blockchains. Figure 2 illustrates the network we are proposing. The network is trying to highlight the critical stakeholder in the existing supply chain. In the proposed framework, the sharing of information will be utilized for making distributed action plans considering the expertise of organizations. For example, a local NGO can better estimate alternative routes that might be unavailable in government databases and international organizations. Alternatively, an international organization can help decide priorities while drafting an action plan to avoid the disaster chain. Effective relief operations require tactical know-how of prominent international organizations. Disaster interacts with multiple subsystems. It may cause by one system but in the chain of events, communicate with multiple subsystems and bring a chain of disaster. For example, chances of spreading infection, plague becomes higher after the flood.

The model proposed by Yang et al., (2011) considers unavailability of existing information infrastructure. It proposes a Zigbee network created using a mash of Zigbee modules and RFID sensors deploy a temporary robust information

network in the affected area. Our framework can use the proposed model to gather the data from sensors and transmit to the Blockchain network.

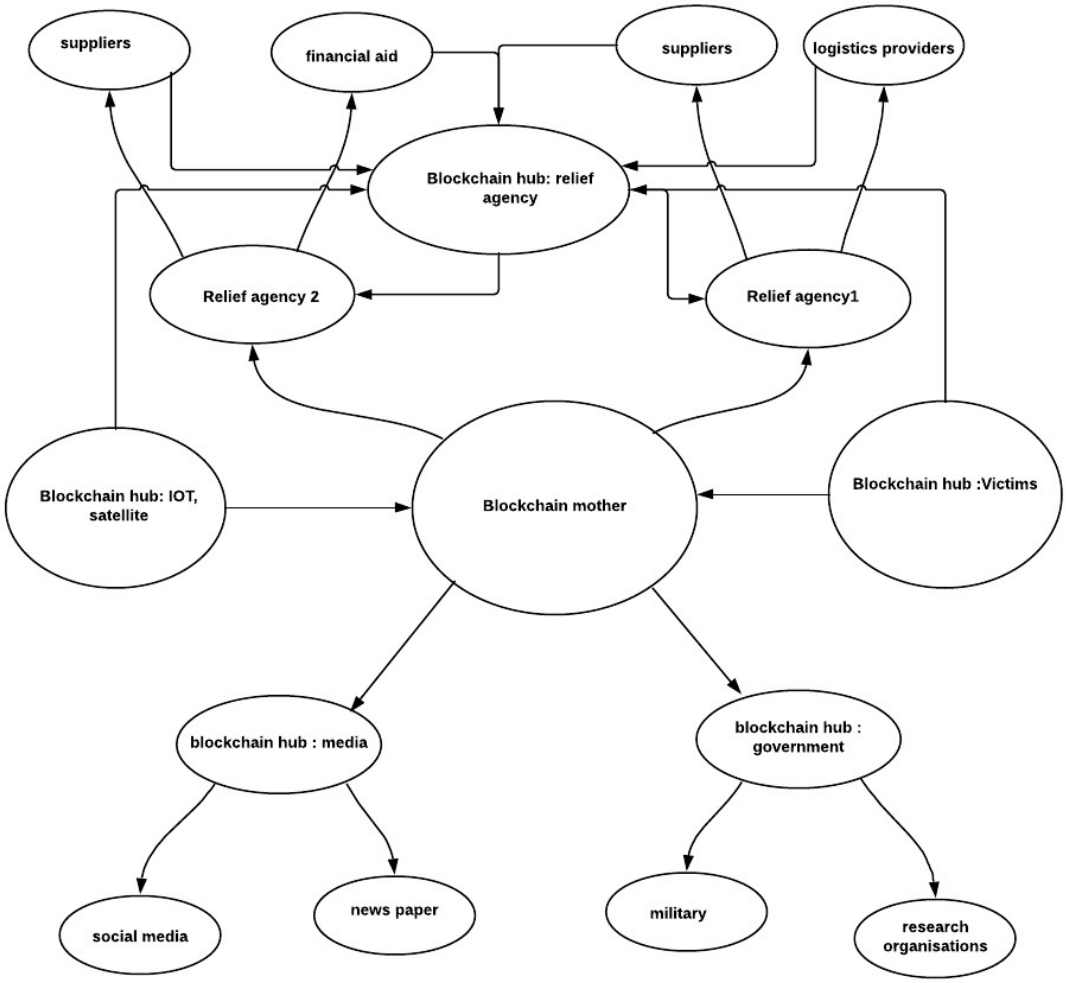

Figure 2: Proposed blockchain network for HSC

Our framework attempts to connect all the stakeholders for faster decision making, transaction settlement, and real-time monitoring. We designed it to be transparent and decentralized information system. Figure 3 shows the proposed framework of HSC decision support system using the blockchain information management system. It incorporates the information received from multiple stakeholders and quantitative analysis to optimize the relief operations. The proposed framework will work as an information sharing as well as a decision support system. Since all the data related to disaster exist in the blockchain network, the data of all the action plans for relief work done by any agency can be retrieved from the blockchain network and can use to make new action plans. Also, agencies can share an action plan for better coordination. The coordinated action plan can be designed, verify and implement together through our proposed framework. Figure 4 presents a decision-making process through the blockchain framework. Data acquisition from multiple sources ensures credibility and remove the risk of malicious input. For example, here authority's priorities actions based on the malicious input of workers who colluded with privileged people of disaster-stricken areas and some victims are left out (Sruthisagar, 2015). The system must ensure the fair and equal delivery of relief work. A blockchain-based DSS can access social media to ensure the reachability of every victim. If social media trend shows no of people suffering are more in some areas, then humanitarian agencies can implement efficiently priorities action plan. Action plans designed through framework can ensure maximum impacts and optimize the distribution of relief material through various checks and balances.

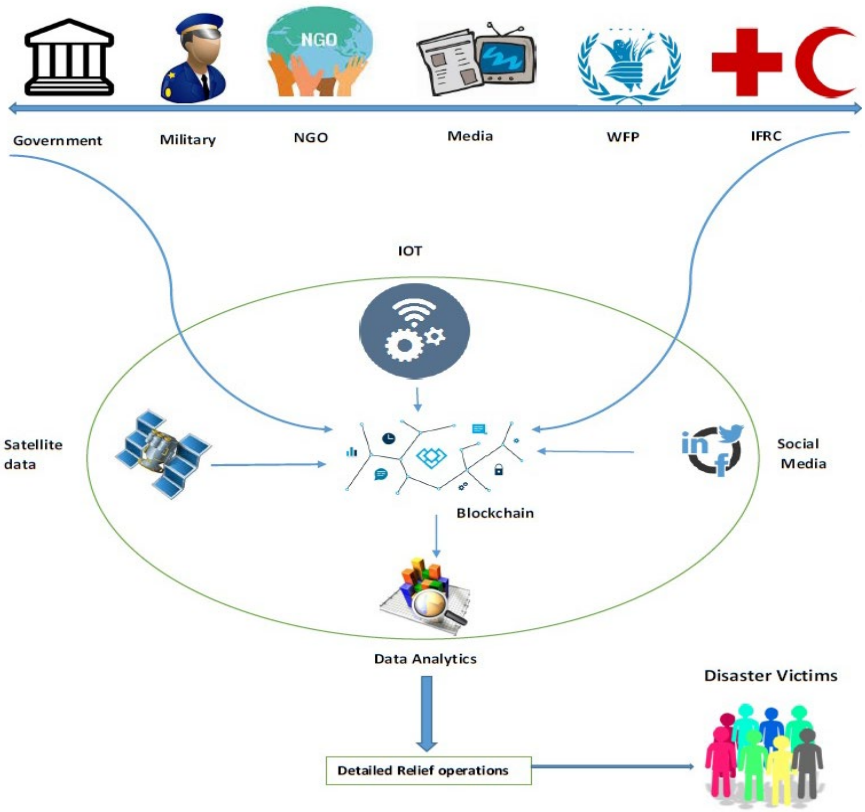

Figure 3: Developed DSS for HSC

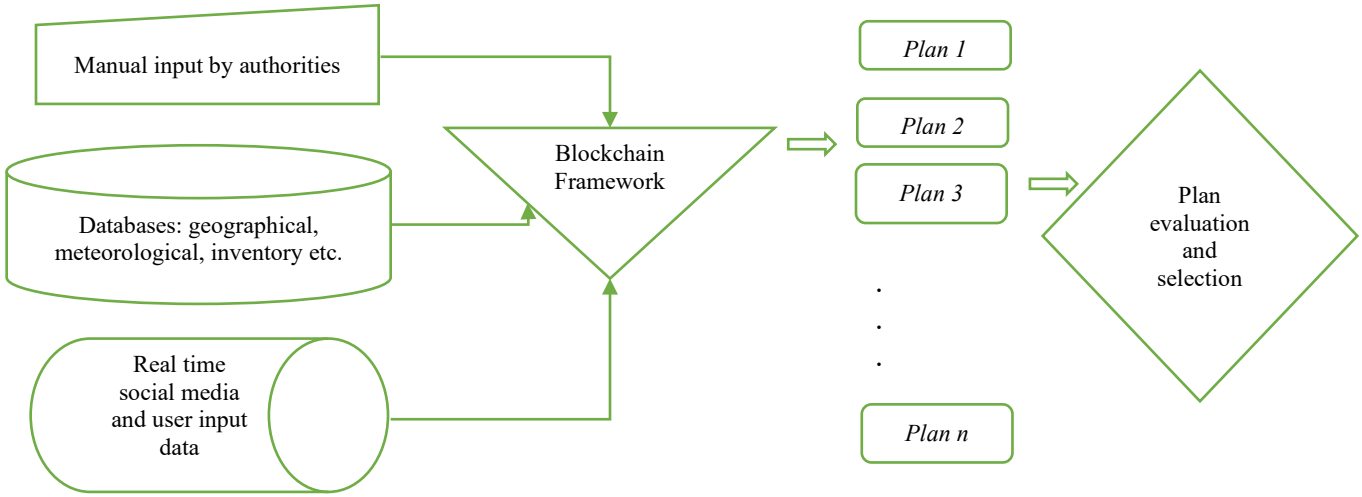

Figure 4: Decision making process in HSC

Why blockchain for transfer of value:

- Transparent: Auditing becomes very easy and can be traced back to inception in the blockchain-based framework. The process will motivate Stakeholders to follow beneficial mutual agreements.
- Processing of fund transfer will become more efficient and reliable.
- Security: the network will be encrypted and altering in the whole network will be a tedious task.

- Accessibility: A blockchain-based network will be globally accepted and much faster than a centralized bank system. Donors across the world can easily contribute to relief work.
- Decentralized: Blockchain system facilitates the exchange without any oversight. Two parties can mutually decide and exchange anonymously.

Relief work will receive the donation without any malicious motivation and obligation. The framework will help in maintaining the nature of relief work as impartial, transparent and humane.

4. Discussion

This section presents a detailed discussion about the proposed framework and key insights derived from the study. Our proposed framework facilitates the multi-agency collaboration for coordinated operations by facilitating the information exchange system based on Blockchain platform. Information can do wonders for humanitarian relief work. However, information is as useful as the ability to make its sense. Information overload and the inability to gather and analyze the data can lead to overwork and humanitarian personnel fatigue. Framework sought to minimize personnel fatigue with data related activities and make relief operations more effective. The proposed framework needs to be further improved, considering the data filtration process. An assessment process for data suitability needs to be integrated with DSS. A DSS must have learning capabilities since the logistic system for each disaster is unique. The proposed framework will support the learning from previous disasters. Key benefits of the proposed framework are given below.

Information Management: Blockchain framework lowers the cost of keeping the data since each organization manages its databases. More established organizations manage to use the well-established tool. However, local and small organizations rely on excel sheet (Widera *et al.*, 2015). A decentralized database available to everyone can lower the cost and speed of information management, and both the credibility and reliability of data increases.

Disaster Victim Identification: Integration of blockchain framework with a government-citizen database can quickly facilitate the identification of victims. The framework will reduce the efforts of following the paper trail.

Transaction settlement: Smart contract facilitates the automatic approval of transactions based on mutual agreements. Humanitarian logistics operations demand accountability, and the blockchain-based system can ensure that relief work impacts without any centralized oversight. Both International and regional transaction settlement are possible using such a network. The framework can also facilitate crowdfunding and ensures the appropriate utilization of funds.

Supply chain monitoring: The proposed system will bring visibility and monitoring ability, with the capability to learn from previous missions. It will reduce bottleneck along the supply chain. Food and medicines require appropriate environment for storage and transportation. The blockchain monitoring system will ensure the specific conditions are being maintained.

Decision support system: Blockchain can work as the backbone of the decision support system. Different sources of data need to collaborate for effective planning of humanitarian operations. The proposed framework removes duplication of efforts in developing the information network by different HO.

The proposed framework may counter few issues which are discussed here. A key issue may arise of the fair and just distribution of resources to HOs. Further, HOs may have conflicting views on the assigned tasks. This can work as a potential barrier to DSS adoption. Future research needs to integrate a performance measurement system and priority matrixes in the DSS to counters these issues. Further, the cost of integrating blockchain with IoT and decision support system across the whole supply chain system requires synergy among stakeholders and substantial financial investment. This can only be insured with donors' sensitization and increasing awareness about the blockchain technology among stakeholders. The same has also been supported by (Patil, Shardeo, Dwivedi, *et al.*, 2020). The author also discussed in detail the issues with the blockchain implementation in HSC. ROI of blockchain implementation in the HSC may pose realization issue, which will be difficult to estimate. Donor agencies need to redefine their focus from immediate relief to a holistic support system. This support further strengthens the donation mechanism by ensuring data availability. Data availability can be utilized for better assessment and reporting; this

may increase the HSC stakeholders focus from immediate relief work to sustainable livelihood building. A key insight derived from the study is that HSC stakeholders also need to be cautious while using social media data since it can be a significant source of unverified data and may lead to non-value activities**.**

5. Conclusion

Paper presents a decision support system and information framework for relief work operations and disaster management. Several dimensions of proposed frameworks are discussed in the study. The paper is conceptual and only represents a brief overview of what can be developed as a foolproof system for easy and readily available data platform for HOs and HSC stakeholders. A key limitation of this study is that the constraints associated with the conceptual stage of the paper. Practical aspects of implementing such a framework can be presented after experimenting in the real-life scenario or after piloting with the proposed framework. A few pilot studies exist where HOs and donors adopted a blockchain-based information management system. However, coordination based on the blockchain does not exist. Thus, this paper may motivate future researchers to experiment with the coordination platform based on the blockchain system. Our future work will incorporate the laboratory trial of blockchain and IOT based HSC network. We will analyze the framework capability to draft the relief action plan and coordination capabilities.

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Biographies

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