A blockchain technology for improving financial flows in humanitarian supply chains: benefits and challenges

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Abstract

Purpose – This study aims to determine how the applications of blockchain technology (BT) can play a crucial role in managing financial flows in the humanitarian supply chain (HSC) and what benefits and challenges are associated with BT in a humanitarian setting.

Design/methodology/approach – The present study used a qualitative research approach, incorporating a systematic literature review and conducting semi-structured interviews with 12 experts in the fields of humanitarian operations, supply chain management, fintech and information technology.

Findings – The findings show that the humanitarian sector has the potential to reap significant benefits from BT, including secure data exchange, efficient SCM, streamlined donor financing, cost-effective financial transactions, smooth digital cash flow management and the facilitation of cash programs and crowdfunding. Despite the promising prospects, this study also illuminated various challenges associated with the application of BT in the HSC. Key challenges identified include scalability issues, high cost and resource requirements, lack of network reliability, data privacy, supply chain integration, knowledge and training gaps, regulatory frameworks and ethical considerations. Moreover, the study highlighted the importance of implementing mitigation strategies to address the challenges effectively.

Research limitations/implications – The present study is confined to exploring the benefits, challenges and corresponding mitigation strategies. The research uses a semi-structured interview method as the primary research approach.

Originality/value – This study adds to the existing body of knowledge concerning BT and HSC by explaining the pivotal role of BT in improving the financial flow within HSC. Moreover, it addresses a notable research gap, as there is a scarcity of studies that holistically cover the expert perspectives on benefits, challenges and strategies related to blockchain applications for effective financial flows within humanitarian settings. Consequently, this study seeks to bridge this knowledge gap and provide valuable insights into this critical area.

Keywords Blockchain technology, Humanitarian supply chain management, Blockchain attributes, Humanitarian financing, Humanitarian operations

Paper type Research paper

1. Introduction

Organizations engaging in disaster relief activities face complex and difficult situations because of disasters and crises (Gunasekaran *et al.*, 2018). Natural calamities are increasingly influencing people's lives. For example, earthquakes and tsunamis claimed the lives of most of the 10,373 individuals who died in 2018, while adverse weather impacted over 61.7 million population (UNISDR, 2019). These incidents show that the volatility in our environmental, social and economic systems is increasing faster than many organizations and societies can handle. As a result, in recent years, most developing economies have been either purposefully constructed or evolved to run efficiently and successfully in predictable and stable circumstances (Ivanov and Dolgui, 2019; Zhang *et al.*, 2019). Despite extensive planning, various natural catastrophes have resulted in the potential loss of life and property, as well as several lessons gained that have led to a paradigm change in how post-disaster relief efforts are controlled.

In 2019, humanitarian reports revealed that more than 100 million people globally needed assistance, a figure that has risen to roughly 120 million in 2020 (GHA, 2020). Continuous development of the humanitarian supply chain (HSC) is crucial in meeting these needs. The HSC is a:

> Network of humanitarian organizations, their suppliers, and logistics partners that are involved in a variety of processes and activities that result in value in the form of supplies, services/cash in the hands of affected communities via upstream and downstream linkages (Kovacs and Spens, 2009).

Given the large number of humanitarian relief participants involved in post-disaster relief efforts, a major challenge is the lack of collaboration (Chen *et al.*, 2023; Dubey *et al.*, 2019; Moshtari, 2016; Negi, 2022; Negi and Negi, 2021) and high levels of

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corruption (Dwivedi *et al.*, 2018; Islam and Walkerden, 2017) among these humanitarian organizations. In the humanitarian setting, crowdsourcing, cash programs, donor financing and data sharing have long posed significant difficulties (Behl and Dutta, 2020; Mejia *et al.*, 2019). Recent studies demonstrate that HSC continues to suffer from an absence of trust and transparency, resulting in duplication of effort and operational inefficiencies (Besiou and Van Wassenhove, 2020). While humanitarian organizations face increasing pressure to improve the traceability of relief supplies, donors and governments have consistently demanded verifiable outcomes and improved information sharing among humanitarian players. Furthermore, a lack of trust in HSC impairs the effectiveness of disaster relief operations and may result in donor cash being withheld or in the imposition of complicated audit procedures (Behl and Dutta, 2019b; Piotrowicz, 2018).

Due to a lack of transparency in funding and multiple scandals around the world, the humanitarian aid sector has generated severe issues about trust and faith in charities. Additionally, the high administrative fees and the high cost of sending donations internationally have played a significant role in the decline in charitable activity. Time is also critical: traditional banking systems impose large costs for cash transfers, particularly cross-border transfers, and these procedures can take weeks, even during a response operation (Ruzafa, 2020). Donation management and payment distribution are inherently risky activities that might result in malpractice and fraud. Human Rights Watch (in its 2017 report) is concerned about the lack of transparency concerning donor funding (Rau, 2017). Fundraising difficulties and donor unavailability have been identified as serious impediments to HSC management (Behl and Dutta, 2019b; Behl and Dutta, 2020; Kovacs and Moshtari, 2019; Petrudi *et al.*, 2020).

According to the United Nations Office for the Coordination of Humanitarian Affairs (UN OCHA), increasing transparency, accountability and reporting among donors is essential for building trust in initiatives and sustaining donor engagement (Salazar *et al.*, 2015). As a result, there is an urgent need to enhance the traceability and transparency of funds used in disaster assistance networks (Dubey *et al.*, 2020; Mejia *et al.*, 2019). To address these issues, humanitarian players are increasingly demanding that disaster relief supply chains be made more resilient using developing technology (Chen *et al.*, 2019; Chen *et al.*, 2023; Dubey *et al.*, 2019; Izadi *et al.*, 2023; Ko and Verity, 2016). Despite increased efforts to address organizational capability and coordination misalignment concerns, there is minimum research on how to better align IT capacities and coordination among humanitarian players (Dubey *et al.*, 2021a, 2021b; Dubey *et al.*, 2022a; Stieglitz *et al.*, 2022).

The term blockchain technology (BT) (also known as distributed ledger technology) has become a major buzzword in today's era, and its applications and deployments have exploded in popularity in current times. Recent studies indicate that interest in using blockchain in the context of operations and supply chain management (SCM) is growing (Chowdhury *et al.*, 2023; Dubey *et al.*, 2022a; Hunt *et al.*, 2022; Izadi *et al.*, 2023; Lim *et al.*, 2021; Magd *et al.*, 2023; Negi, 2023; Prashar *et al.*, 2020; Queiroz *et al.*, 2020). This technology is believed to have the ability to change not only the financial industry but also a wide variety of other businesses due to its ability to operate without the interference of middlemen or central authority. Since BT has the potential to improve transparency, trust, traceability, data security and data immutability, it has garnered interest from academics and professionals from a variety of industries (Chowdhury *et al.*, 2023; Dubey *et al.*, 2022b; Izadi *et al.*, 2023; Magd *et al.*, 2023; Negi, 2023; Prashar *et al.*, 2020; Zheng *et al.*, 2021). Blockchain investment is accelerating and is predicted to achieve US$176bn by 2025, as per KPMG (2018). This technology has been increasingly recognized as a valuable tool for enhancing efficiency and productivity, with its potential to store information, manage records and facilitate payments. This transformative role of BT in HSC has garnered significant attention over the last five years (Hunt *et al.*, 2022; Lim *et al.*, 2021; Wamba, 2020). Although the use of BT in the humanitarian sector is still in its infancy, donors and government entities are increasingly calling for greater relationships of trust and collaborations among different humanitarian stakeholders to enhance the traceability and transparency of disaster funds and information exchanges flow in HSC (Chen *et al.*, 2023; Dubey *et al.*, 2020; Dubey *et al.*, 2021a, 2021b; Dubey *et al.*, 2022b; Hunt *et al.*, 2022; Izadi *et al.*, 2023; Negi, 2022). Thus, this study aims to determine how the implementation of BT can play a crucial role in managing financial flows in the HSC setting. The study sets out to address the following research questions:

RQ1. How can BT be used to improve financial flows in an HSC?

RQ2. What are the benefits of integrating BT into the HSC management?

RQ3. What are the challenges in implementing BT in the HSC, and what effective strategies can be used to mitigate these challenges?

This study adds to the body of knowledge on BT and HSC by explaining how BT contributes to the improved financial flow of HSC through blockchain attributes such as real-time information sharing, security, transparency and traceability. This study is intended to serve as guidelines for possible use within the humanitarian community. Academics and practitioners may use this study as a starting point for further research and discussion.

The rest of the article is structured into five sections. Section 2 provides a literature review on the subject, while the methodology is outlined in Section 3. In Section 4, the findings on applications, benefits, associated challenges and corresponding mitigation strategies are covered. Section 5 presents the discussion and contribution of the study. Finally, Section 6 concludes the article, including limitations and the future scope of the study.

2. Literature review

This section presents a review of the literature on financial flows in HSC, BT and the benefits and challenges associated with BT within HSCs.

2.1 Financial flows in humanitarian supply chain

The HSC plays a crucial role in disaster response and relief efforts, encompassing the efficient flow of goods, information and financial resources (Kovacs and Spens, 2009). Financial

flows within the HSC refer to the movement of funds, donations, grants and other financial resources from donors to beneficiaries, including intermediary organizations and relief agencies. It involves a distinct structure, originating from upstream donors and reaching downstream beneficiaries (Habib *et al.*, 2016). Donors act as the primary source of financial resources, emphasizing the significance of efficient fund management (Behl and Dutta, 2020). The downstream flow involves intermediary organizations, relief agencies and local partners, ensuring resources are strategically allocated to address the needs of affected populations (Habib *et al.*, 2016).

HSCs, as relief-oriented and nonprofit networks, differ from conventional industrial supply chains in strategic objectives, performance metrics and partner dynamics (Balcik and Beamon, 2008). They face increased risks, unpredictability and time constraints due to the nature of humanitarian crises (Soosay and Hyland, 2015). Despite the unidirectional movement of funds from donors to beneficiaries, challenges such as unpredictable demand and time constraints contribute to the intricate dynamics of financial management within the HSC (Behl and Dutta, 2019b; Oloruntoba and Gray, 2009).

The effective management of financial flows within the HSC is critical for delivering timely and efficient aid to affected populations during emergencies. However, addressing the challenges associated with improving financial flows in HSCs requires further research and analysis (Behl and Dutta, 2020).

2.2 Blockchain technology and transformation of financial flows

Blockchain technology, a distributed ledger system, facilitates verified communication and real-time data sharing among network members (Kumar *et al.*, 2019). Initially associated with Bitcoin, blockchain extends its capabilities to establish direct networks between organizations, minimizing reliance on intermediaries and reducing potential errors and transaction costs (Crosby *et al.*, 2016; Esmaeilian *et al.*, 2020; Kuijpers, 2018).

The decentralized and transparent nature of blockchain enhances the traceability and accountability of financial transactions (Piscini *et al.*, 2017; Prashar *et al.*, 2020). Its trust and transparency capabilities, manifested through secure and unchangeable transaction records, enhance control over exchange activities and generate trust among network members (Beck *et al.*, 2016; Hawlitschek *et al.*, 2018; Karamchandani *et al.*, 2021). The blockchain database, comprised of a continually evolving sequence of timestamped blocks containing recorded data, provides a visual representation of the technology's structure (refer to Figure 1), which in turn facilitates better financial flows management by offering transparency, security and efficiency in recording and tracking financial transactions. It stores and shares vital information, like transaction logs and safety records, ensuring control over exchanges. Additionally, it generates trust via secure and unchangeable transaction records with cryptographic signatures, traceable to network members (Hawlitschek *et al.*, 2020).

2.3 Benefits of blockchain applications

The literature presents a multifaceted view of the benefits associated with the integration of BT in HSCs. Baharmand *et al.* (2021); Dubey *et al.* (2022b); Khadke and Parkhi (2020); and Privett (2014) underscore the capacity of BT to address challenges related to visibility and data availability in HSCs through its distributed and verifiable data source. However, Stathakis (2019) cautions that while BT offers transparency, challenges such as scalability and interoperability must be addressed to realize its full potential.

Moreover, the literature reflects a growing trend among institutions, including governments and international organizations, toward considering BT for various applications within humanitarian operations, such as digital identification solutions and transparent funding methods (Stathakis, 2019).

The literature also presents compelling arguments regarding the advantages of BT adoption. Dubey *et al.* (2020) emphasize BT's potential to reduce transaction costs and streamline the flow of disaster relief supplies, information and funds. Similarly, Kenny (2017) and Poorterman (2017) demonstrate BT's effectiveness in combating fraud and corruption in humanitarian donations. Ruzafa (2020) emphasizes the elimination of third-party intermediaries as a key advantage of BT adoption in HSCs, potentially mitigating the risks of fraudulent activities. Charitable organizations are particularly enthusiastic about BT due to its potential for substantial cost savings in transactions and the automation of SCM and contractual arrangements through smart contracts (Zwitter and Boisse-Despiaux, 2018).

BT is suggested as a potential solution to enhance traceability, trust and transparency throughout supply chains, mitigating information-sharing difficulties (Cole *et al.*, 2019; Kovacs and Spens, 2009; Kouhizadeh and Sarkis, 2018; Kshetri, 2018; Queiroz *et al.*, 2020; Wang *et al.*, 2019a). Moreover, studies by Dubey *et al.* (2020) and Salazar *et al.* (2015) advocate for BT to improve transparency, accountability and reporting, thereby fostering trust among donors, project initiators and funding beneficiaries.

ODI (2015) acknowledges the concept of digital cash within cash management programs, suggesting that BT facilitates visible, compatible, cost-effective and secure digital currency transfers, ensuring traceability from the supporter to the beneficiary while maintaining privacy. Similar sentiments are echoed by Currion (2015) and Ko and Verity (2016).

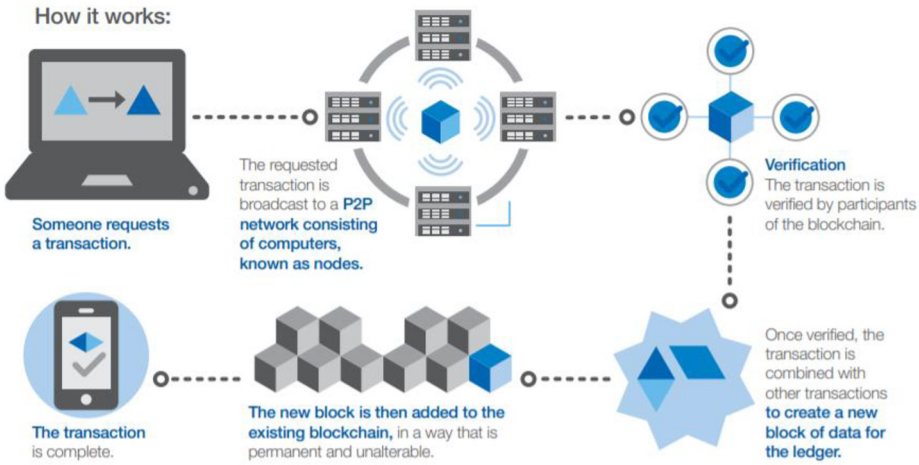
From the perspective of HSCs, the literature identifies various drivers for blockchain adoption, including improving visibility, accountability and fostering partnerships with logistics service providers (Baharmand and Comes, 2019; Baharmand *et al.*, 2021; Chowdhury *et al.*, 2023). However, critical evaluation is necessary to assess the practical implications and complexities associated with integrating BT into existing supply chain systems. Suggestions to integrate BT with emerging technologies such as artificial intelligence and the internet of things highlight the potential for synergies but also underscore the need for careful planning and execution to realize the full benefits (Dubey *et al.*, 2022a; Khan *et al.*, 2021; Rodriguez-Espindola *et al.*, 2020).

2.4 Challenges in implementing blockchain technology

Blockchain technology has been publicized as a transformative tool with the potential to revolutionize HSCs, promising enhanced transparency, accountability and efficiency. The literature review synthesizes findings from key studies to delve into the challenges associated with implementing BT in HSCs.

The literature reveals a myriad of challenges faced by humanitarian organizations venturing into blockchain applications. Budgetary constraints, top management

Figure 1 A look at blockchain technology



Source: World Economic Forum (2018)

commitment, institutional compatibility and technology readiness emerge as significant barriers to BT adoption in HSCs (Baharmand and Comes, 2019; Patil *et al.*, 2021). In addition, issues such as technical complexity, infrastructure suitability and legal considerations further complicate the adoption process (Patil *et al.*, 2021).

The requirement for reliable internet access, as highlighted by Swan (2015), underscores the unsuitability of BT for locations with inadequate infrastructure. Moreover, studies consistently underscore the limited understanding of BT among humanitarian organizations, alongside significant hurdles in personnel training (Baharmand *et al.*, 2021; Coppi and Fast, 2019; Sahebi *et al.*, 2020). Sahebi *et al.* (2020) identify additional barriers, including effective validations, sustainability costs, integration difficulties with legacy systems and scalability concerns. The scalability issue, emphasized by Baharmand *et al.* (2021) and Khadke and Parkhi (2020), further highlights the current limitations of BT due to the absence of essential algorithms and advancements.

Technical difficulties, cost complexities, security concerns, ownership disputes, data privacy concerns and funding challenges pose significant hurdles to BT adoption (Patil *et al.*, 2021; Kafeel *et al.*, 2023; Khadke and Parkhi, 2020). The transition from legacy systems to blockchain is recognized as a time- and resource-intensive process, intensifying the complexity of adoption (Baharmand *et al.*, 2021; Khadke and Parkhi, 2020; Sahebi *et al.*, 2020).

Downstream challenges, including a lack of technological and human resources, low engagement levels, governance framework absence, standardization gaps and implementation-related issues, further impede BT adoption (Coppi, 2020). Governance frameworks are consistently identified as crucial barriers in various studies (Baharmand and Comes, 2019; Baharmand *et al.*, 2021; Coppi, 2020; Patil *et al.*, 2021; Sahebi *et al.*, 2020). Moreover, the slower evolution of social, legislative and regulatory frameworks for blockchain, including privacy standards, presents an additional challenge (Ko and Verity, 2016).

The literature extensively explores the benefits of blockchain applications in HSCs, yet it reveals a gap regarding the specific advantages of BT in facilitating financial flows within HSCs. While optimism exists for BT adoption, critical analysis emphasizes a complex landscape where opportunities must be balanced with challenges. Further research and practical implementations are crucial to fully harness BT's potential in HSCs.

In addition, while challenges associated with blockchain applications in HSCs are highlighted, a significant gap exists in the literature regarding the specific barriers hindering BT adoption for improving financial flows within HSCs. These challenges underscore the diverse obstacles requiring attention for successful BT adoption in HSCs. Consequently, this study aims to identify mitigation strategies to overcome challenges and bridge this gap in the literature.

In summary, while the literature provides comprehensive discussions on both the benefits and challenges of implementing BT in HSCs, it stresses the need for further research and strategic approaches to navigate the complex landscape of blockchain adoption in improving financial flows in humanitarian contexts. Addressing the benefits and challenges of BT in managing financial flows in HSCs allows stakeholders to capitalize on blockchain's potential in humanitarian aid financial management, paving the way for a more resilient and transparent HSC ecosystem.

3. Methodology

The research adopted a qualitative, exploratory design to investigate the study's research questions. To address the initial research question concerning blockchain's role in improving financial flows within an HSC, a comprehensive literature review was conducted using a systematic literature review (SLR) methodology, with findings presented narratively. Subsequently, semi-structured interviews were used to gather data from diverse participants to address the remaining research questions (RQ2 and RQ3). While the primary aim of the study is to explore and gain insights into the phenomena under investigation, it also incorporates a descriptive aspect to provide clarity on key findings and observations.

3.1 Systematic literature review

The SLR approach in this study follows the guidelines proposed by Tranfield *et al.* (2003) to ensure a structured and rigorous review process.

- *Planning:* The SLR investigates how BT is used in managing financial flows within HSCs. It focuses on understanding BT implementation, benefits and challenges within humanitarian operations;
- *Search strategy-identification of databases:* Academic databases, such as Scopus and Web of Science, were chosen based on their use in previous reviews (Behl and Dutta, 2019a; Galindo and Batta, 2013; Negi and Negi, 2021; Saad *et al.*, 2022). Relevant literature was identified using carefully selected search terms and keywords;
- *Search strategy-search terms and syntax:* The keywords such as "blockchain technology," "humanitarian supply chain" and "humanitarian financial aid" were used in the first phase. Thereafter, search strings were constructed to combine search terms effectively, where different keyword combinations were used to increase search scope and reach such as "blockchain" and "humanitarian supply chain," "humanitarian supply chain" and "financial flows," "benefits of blockchain" and "humanitarian supply chain," "challenges of blockchain" and "humanitarian supply chain," "humanitarian supply chain" and "financial flows" and so on. The search syntax was adapted to ensure comprehensive coverage of relevant literature. During the search process, a total of 320 papers were identified from the selected databases;
- *Search strategy-search data range:* The search encompassed a specified time frame between 2015 and 2023 to include recent publications while considering seminal works in the field. This timeframe was chosen based on the significant proliferation of research on blockchain in HSCs during the specified period (Hunt *et al.*, 2022);
- *Selection criteria-inclusion and exclusion of the study:* Inclusion criteria encompassed publications focusing on the application of BT within HSCs and studies addressing financial flow management within humanitarian operations, which included aspects such as fund distribution, transparency and accountability. Inclusion criteria for selecting sources primarily focused on peer-reviewed articles, with some consideration given to papers in conference proceedings and chapters indexed in Scopus, provided they met certain criteria (Saunders *et al.*, 2012; Tranfield *et al.*, 2003). In addition, only English-language publications were included to ensure accessibility and consistency in language. Conversely, exclusion criteria involved publications unrelated to BT in HSCs, as well as studies outside the scope of research questions. These selection criteria were applied rigorously during the screening process to ensure the relevance and quality of the included studies;
- *Screening process – initial screening and full-text screening:* The screening process consisted of two stages, initial screening and full-text screening. During the initial screening phase, titles and abstracts of retrieved records were carefully evaluated to identify potentially relevant studies. After the initial screening based on titles and abstracts, 165 papers were selected for full-text screening. Records that did not meet the predefined inclusion criteria were promptly excluded from further consideration. Most of the excluded papers mainly focused on technical aspects of BT rather than HSCs. Subsequently, in the full-text screening stage, the full texts of selected studies were retrieved and thoroughly examined against the inclusion criteria. Following full-text screening, 100 papers were excluded based on the predefined inclusion and exclusion criteria, resulting in 65 papers being included in the final analysis. This systematic approach helped to systematically filter and identify studies that aligned with the objectives, thereby ensuring the relevance and quality of the included literature in addressing the focus of the SLR;
- *Data extraction:* Relevant information from included studies, such as study characteristics and key findings related to financial flow management in HSCs, was systematically extracted using a standardized data extraction form; and
- *Data synthesis and reporting:* Extracted data were synthesized into a coherent narrative, providing an overview of the current state of literature and highlighting key findings, gaps and areas for further research. The findings are reported, presenting a comprehensive analysis of the integration of BT in managing financial flows within HSCs with their benefits and challenges.

Several prestigious journals are cited to conclude this study, including *Manufacturing and Service Operations Management*, *International Journal of Logistics Research and Applications*, *International Journal of Information Management, Blockchain, Law and Governance*, *International Journal of Production Research*, *International Journal of Production Economics*, *Journal of Enterprise Information Management*, *Electronic Commerce Research and Applications*, *International Journal of Disaster Risk Reduction*, *European Journal of Operational Research*, *International Journal of Physical Distribution and Logistics Management*, *Decision Sciences*, *Production and Operations Management and Journal of Humanitarian Logistics and Supply Chain Management*, among others, thereby grounding its conclusions in established academic discourse. This meticulous methodology contributes to the robustness and reliability of the study's findings, providing valuable insights for both academic and practical considerations within the field.

3.2 Primary data collection (semi-structured interviews)

The qualitative research design of this study was chosen to intricately explore the perspectives of experts in the field, with semi-structured interviews identified as the most fitting method for this purpose. The phenomenological approach was selected because it offers a robust framework for understanding and interpreting the lived experiences and perspectives of individuals within a specific context (Creswell, 2013). Phenomenology aligns well with the study's objectives, which aim to explore the benefits of applying BT in HSC operations and the challenges faced during its implementation. By adopting a phenomenological lens, this study seeks to uncover the subtle meanings and insights embedded within participants' experiences, shedding light on the complexities of

managing financial flows within HSC operations during emergencies.

Theoretical underpinnings for this research draw upon several relevant theories within the fields of SCM, IT and organizational behavior. Specifically, the Diffusion of Innovations theory by Rogers (2003) is particularly pertinent to this study, providing useful insights into the adoption of BT in SCM and helping organizations understand the process of how new technologies, like blockchain, are adopted and diffused among supply chain stakeholders (Agi and Jha, 2022). Moreover, while the Diffusion of Innovations theory has been extensively applied in studies concerning blockchain in the supply chain domain (Agi and Jha, 2022; Karamchandani *et al.*, 2021), its framework also offers valuable insights into the adoption and spread of innovations within humanitarian organizations, aiding in the identification of barriers and strategies for overcoming them.

Interviews were chosen as the primary data collection method due to their ability to delve deeper into experiential dimensions and extract context-specific insights (Creswell, 2013). Aligned with the study's exploratory and descriptive nature, this approach seeks to unveil novel insights beyond the existing literature, contributing to a holistic understanding of the subject matter (Patton, 2015).

The chosen method proved optimal for its ability to facilitate an in-depth investigation into participants' experiences in the field. Emphasizing the shared experience of a diverse group of participants, the semi-structured nature of the interviews enriched the overall study (Creswell and Poth, 2017; Dolczewski, 2022; Yadav, 2022). In addition, several studies (e.g. Agi and Jha, 2022; Baharmand *et al.*, 2021; Chaudhuri *et al.*, 2023; Karamchandani *et al.*, 2021; Pattanayak *et al.*, 2023; Wang *et al.*, 2019b) have used semi-structured interviews with industry experts to gather information on the similar research topic and to develop a better understanding of the research area.

A judgmental sampling method was used to deliberately select respondents based on their expertise in the field (Creswell and Creswell, 2017), aligning with the recommendation of Cavana *et al.* (2008, p. 137) regarding the effectiveness of non-probability methods for swiftly extracting quality information. The judgmental sampling approach aimed at achieving data saturation and collecting comprehensive information until the absence of novel essential insights was perceived (Miles and Huberman, 1994).

A total of 12 experts in the fields of humanitarian operations, SCM, fintech and IT were interviewed online via Microsoft Teams and Google Meet to gather in-depth information using a standardized interview guide (see Appendix). The details of the interview participants are presented in Table 1.

The study's selection of 12 interviews, with three evaluators in each field, and the rationale behind reaching saturation align with established qualitative research principles (Miles and Huberman, 1994), emphasizing theoretical saturation over a rigid sample size (Guest *et al.*, 2006). This approach allows for a diverse range of perspectives and expertise to be considered, enhancing the reliability and validity of the findings through expert consensus (Patton, 2015). Such an approach prioritizes achieving data saturation rather than conforming to a predetermined interview count, reinforcing methodological rigor within qualitative research methodologies (Given, 2008).

Ethical considerations were paramount throughout the data collection process. The participants were assured of their anonymity, and all other ethical guidelines for research involving human participants were strictly adhered to, ensuring voluntary participation, informed consent and confidentiality of responses. The interview responses were meticulously recorded using an auto-transcription option and lasted between 35 and 50 min, with an average duration of 40 min.

Following the collection of interview data, a systematic approach to coding was adopted. The qualitative analysis involved the identification of recurring themes, patterns and meaningful insights within the transcribed responses. The study's findings are then presented based on the analyzed output.

4. Findings

This section presents the study's outcomes, integrating insights from a SLR for RQ1, and from semi-structured interviews with a diverse pool of experts for RQ2 and RQ3.

Within this segment, insights are provided regarding the applications of BT to improve financial flows within the humanitarian context (RQ1), explain the benefits of using blockchain applications for financial flow management within HSC (RQ2) and examine the challenges of blockchain applications in an HSC setting, accompanied by viable mitigation strategies (RQ3).

4.1 Application of blockchain technology to improve financial flows in humanitarian supply chain

This section presents the potential of BT in transforming financial flows and operational efficiency within humanitarian operations. Recognized as a disruptive force capable of reshaping global industries and supply chains, scholars have extensively explored its implications (Agi and Jha, 2022; Chaudhuri *et al.*, 2023; Dolgui *et al.*, 2019; Karamchandani *et al.*, 2021; Kewell *et al.*, 2017; Min, 2019; Pattanayak *et al.*, 2023; Queiroz and Wamba, 2019; Saberi *et al.*, 2019; van Hoek, 2020; Wang *et al.*, 2019ab; Zhu and Kouhizadeh, 2019; Zhu *et al.*, 2019). BT facilitates secure financial transactions within supply chain networks by utilizing a digital decentralized ledger that is resistant to tampering or unauthorized access (Piscini *et al.*, 2017). This impenetrable ledger ensures the integrity of dealings between multiple entities involved in supply chain operations. Supported by research from Dobrovnik *et al.* (2018), Kersten *et al.* (2017), Khan *et al.* (2021), Nakasumi (2017), Prashar *et al.* (2020) and Shardeo *et al.* (2020), the value of BT in revolutionizing supply chain operations across different sectors becomes apparent.

Transitioning from theoretical frameworks to practical applications, BT exhibits promise in HSCs (Aranda *et al.*, 2019; Baharmand and Comes, 2019; Baharmand *et al.*, 2021; Chen *et al.*, 2023; Coppi, 2020; Dubey *et al.*, 2020; Dubey *et al.*, 2022b; Hunt *et al.*, 2022; Izadi *et al.*, 2023; Khadke and Parkhi, 2020; Khan *et al.*, 2021; L'Hermitte and Nair, 2020; Ozdemir *et al.*, 2021; Patil *et al.*, 2021; Ramadurai and Bhatia, 2019; Rodriguez-Espindola *et al.*, 2020; Sahebi *et al.*, 2020; Zwitter and Boisse-Despiaux, 2018). The BT's applications in

Table 1 Interviews details

Interview ID	Experience (yrs.)	Participant area	Qualification	Type of organization	Region	Frequency ($n = 12$)	%
F1	7	Fintech	PhD	Technology firm	Asia	3	25
F2	8		MBA	Fintech startup	North America		
F3	4		MA	Financial institution	Asia		
H1	20	Humanitarian operations	MSc	NGO	Africa	3	25
H2	22		MA	Government aid agencies	Asia		
H3	15		PhD	NGO	Europe		
I1	6	IT	MCA	Technology firm	Asia	3	25
I2	12		MTech	Technology firm	Africa		
I3	14		MSc	Consulting firm	Asia		
S1	10	Supply chain	PhD	Academics	Europe	3	25
S2	12		MSc	Logistics company	Asia		
S3	15		MBA	Consulting firm	South America		

Source: Author's work

HSC operations include tracking relief funding, preventing corruption and implementing smart contracts, all contributing to trust, transparency, traceability, human error risk mitigation and improving efficiency of fund distribution throughout the HSCs (Aranda *et al.*, 2019; Baharmand *et al.*, 2021; Dubey *et al.*, 2020; Gorey, 2016; Hunt *et al.*, 2022; Kenny, 2017; Kewell *et al.*, 2017; Saad *et al.*, 2022; Verhulst, 2018; Zwitter and Boisse-Despiaux, 2018).

The review revealed that the integration of BT into humanitarian operations holds significant promise for revolutionizing the management of financial flows. By leveraging blockchain's inherent features, including decentralization, encryption and immutability, organizations can establish a secure and transparent foundation for handling funds. This mitigates risks associated with fraud and mismanagement, fostering increased accountability and trust among stakeholders. Streamlined processes facilitated by blockchain enable more efficient financial transactions, ensuring prompt and transparent delivery of donations to beneficiaries. Optimizing financial flows not only boosts donor confidence but also allows humanitarian organizations to allocate resources more effectively, ultimately leading to improved outcomes for those in need. Thus, blockchain's potential to optimize humanitarian operations lies in its ability to enhance efficiency, security and transparency, paving the way for a more impactful and accountable humanitarian ecosystem.

Despite being in its early stages of integration into humanitarian contexts, BT is generating growing enthusiasm (Chen, 2018; Khadke and Parkhi, 2020; Ramadurai and Bhatia, 2019; Thomason *et al.*, 2018). Scholars recognize the challenges of adapting BT to humanitarian operations, yet the increasing volume of research indicates a trend toward adoption (Dubey *et al.*, 2020). This research offers promising solutions for addressing key supply chain challenges such as tracking, transparency, data sharing, communication, collaboration and navigating interorganizational hurdles (Aranda *et al.*, 2019; Dubey *et al.*, 2020; Ozdemir *et al.*, 2021; Rodriguez-Espindola *et al.*, 2020).

Ethical considerations add a layer of complexity to the discussion. While there is optimism about BT's potential to enhance transparency and reduce transaction costs in HSCs, concerns regarding equity, privacy and trust need addressing (Stathakis, 2019). Scholars emphasize the importance of navigating these ethical implications alongside technological advancements (Baharmand and Comes, 2019; Chen *et al.*, 2023; Coppi and Fast, 2019; Dubey *et al.*, 2020; Dubey *et al.*, 2021a, 2021b; Dubey *et al.*, 2022a, 2022b; Hunt *et al.*, 2022; Izadi *et al.*, 2023; Seyedsayamdost and Vanderwal, 2020).

Looking ahead, the increasing research focus on BT's application in the humanitarian sector signals a growing adoption trend. As humanitarian organizations, including UN agencies, progressively integrate BT across supply chain stages, the potential for improved information administration, aid coordination and financial augmentation becomes increasingly tangible (Riani, 2018).

Table 2 illustrates several real-world applications that exemplify the practical implementation of BT in HSC.

Based on the outcome of the findings, the author's representation of blockchain usage in the humanitarian sector is depicted in Figure 2.

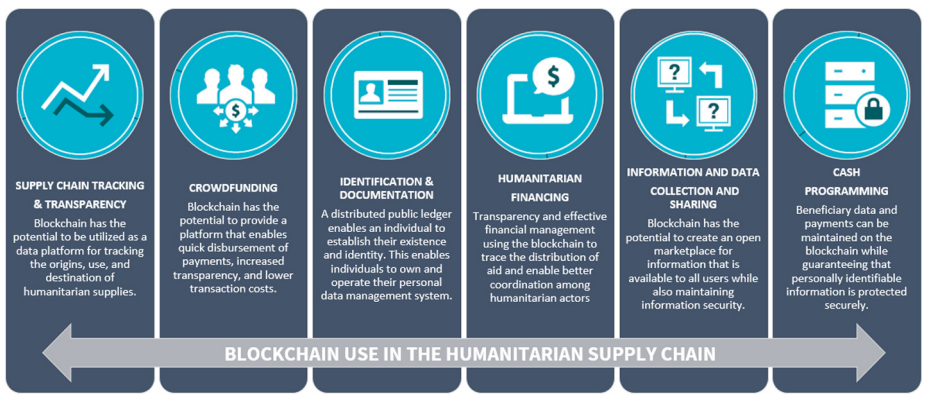
The figure outlines various applications of BT throughout the HSC cycle, with each benefit strategically positioned to address specific stages. In the upstream segment, "supply chain tracking and transparency" uses blockchain as a data platform to trace the origins, use and destination of humanitarian supplies, enhancing transparency and traceability in the early stages of the supply chain. Moving to the midstream, "information and data collection and sharing" uses blockchain-enabled data exchange to overcome unreliable information and silos, fostering efficient information sharing and management. Simultaneously in the midstream, "humanitarian financing" leverages blockchain for transparent fund distribution, ensuring effective financial management and coordination among humanitarian actors. Towards the downstream, "cash programming" securely manages beneficiary data and payments on the blockchain, ensuring smooth financial flows in the later stages of the supply chain. Similarly, "crowdfunding" in the downstream stages benefits from blockchain's quick fund disbursement, increased transparency and lower transaction costs. "Identification and documentation" use a distributed ledger for individual identity management, contributing to a more robust and secure flows across all supply chain stages.

Table 2 Cases of blockchain technology implementation in humanitarian supply chain

Organization / source	Use case/example	Added value/impact
World Food Program (WFP) (WFP, 2018)	Building blocks project: secure fund transfer via vouchers, collaboration in the supply chain	Enhanced accountability, transparency
International Federation of Red Cross and Red Crescent Societies (IFRC) and Kenya Red Cross (Coppi and Fast, 2019)	Blockchain open-loop payments pilot project: improve transparency and accountability in cash transfer programs	Enhanced transparency, independent digital identity
Oxfam (Hallwright and Carnaby, 2019)	UnBlocked cash project: enhance efficiency and transparency in aid distribution	Reduced distribution costs, expedited delivery times, accountability measures
Finn Church Aid, Finland (Zanoni, 2021)	Exploring blockchain for cash distributions: improve efficiency, transparency and reliability in cash distributions	Streamlined donation processes, enhanced tracking of donations
UNICEF, WFP (Zwitter and Boisse-Despiaux, 2018)	Various initiatives in digital identities and payment transmissions: exploring blockchain's potential in digital identities and payment transmissions	Enhanced transparency, smooth financial flow
Helperbit (Harper, 2019)	Multisignature e-wallet donations and insurance using Bitcoin	Increased security, transparency in donations
Start Network (Start Network, 2016)	Private blockchain for 42 NGOs	Enhanced collaboration, secure transactions
Sikka, Nepal (Coppi and Fast, 2019)	Digital Assets in the HSC in Nepal: Blockchain-based application putting money in the hands of Nepal's rural communities	Digital asset transfers to financially marginalized communities in post-disaster scenarios

Source: Author's compilation

Figure 2 Application of blockchain in HSC



Source: Author's compilation

4.2 Benefits of blockchain applications in humanitarian supply chain

The humanitarian sector has the potential to reap significant benefits from BT, including secure data exchange, SCM, donor financing, cash programs and crowdfunding. The following are the benefits of BT in the humanitarian sector as per the outcome of the interview with various experts in the field of BT, IT, humanitarian logistics and SCM:

- *Accountability and transparency:* The interview findings underscored the transformative impact of BT on accountability and transparency within the HSC. The decentralized and transparent ledger inherent in blockchain ensures that every transaction and movement of humanitarian resources, encompassing aid and funds, is meticulously recorded and visible to authorized stakeholders. The utilization of timestamping and immutability features further enhances the integrity of the recorded data. As explained by some experts (F1, I1, I2 and I3), this level of transparency holds all parties involved accountable for their actions. "The immutability aspect is particularly noteworthy, signifying that once data is entered into the blockchain, it cannot be altered or deleted without consensus from the network," added one expert (F2). As highlighted by the experts, this robust transparency mechanism acts as a powerful deterrent, significantly reducing the potential for fraud, corruption or mismanagement of crucial resources within the humanitarian domain.
- *Efficient supply chain control:* The interview insights shed light on the profound impact of BT in revolutionizing the control and monitoring aspects of the entire HSC. As per the experts, a key enabler of this transformation is the incorporation of smart contracts, which are self-executing agreements triggered by predefined conditions. One

expert in the field of the supply chain (S3) shared: "These smart contracts introduce a new level of automation to various facets of supply chain operations." Another expert added (S2): "The automation driven by smart contracts proves instrumental in optimizing the supply chain, leading to a reduction in transaction costs and minimizing the likelihood of delays or disruptions."

The strategic implementation of BT, as emphasized by one expert (F2) – a senior blockchain expert – significantly enhances the humanitarian actor's ability to manage aid distribution and funds. The expert mentioned, "The integration of smart contracts not only streamlines operational processes but also ensures the precision and accuracy of aid distribution." The overall participants' response highlighted that BT has the potential to reduce transaction costs and enhance the flow of publicly monitored disaster relief supplies, information and funds. This streamlined approach guarantees that funds reach the right victims at the right time, amplifying the effectiveness and efficiency of humanitarian operations, as added by the experts (H2, H3, I2 and S2). In essence, the introduction of blockchain in supply chain control marks a paradigm shift, leveraging automation to create a more agile, cost-effective and responsive HSC.

- *Streamlined humanitarian financing:* According to the findings, blockchain facilitates the efficient and accountable management of humanitarian financing. Donations and funds can be tracked in real-time from donors to beneficiaries. As per one expert (F3), smart contracts can automatically release funds when specific criteria are met, such as reaching a certain phase in a relief project or achieving predetermined goals. This aligns with the responses of other experts. One expert (F1) shared that this automation reduces administrative overhead, ensures funds are used as intended and enhances the transparency of financial flows. The expert also added that BT has the potential to alter many elements of aid delivery, as well as the connection between donors and charity. To begin with, this technology's qualities enable the elimination of corruption and fraud by providing accountability and transparency, as added by other experts (F2, H1 and I3). This identifies this new technology as a critical innovation for enhancing the administration of the complex HSC. One expert (F2) added, "A donation is more than a mere sequence of flows from donor to receiver. Since BT eliminates the need for third parties, the likelihood of perpetrating fraud decreases." One expert (H1) highlighted that BT can assist in tracking and verifying where funds are going, providing contributors with much-needed transparency. The expert further shared, "Indeed, some humanitarian and development organizations are exploring the possibility of combining public and private funding mechanisms with BT to improve transparency, accountability and efficiency."
- *Cost-effective financial exchanges/transactions:* It is found that blockchain enables direct peer-to-peer financial transactions with lower transaction costs compared to traditional financial intermediaries, such as banks. The expert (F1) said "The reduction in fees and currency conversion costs means that more of the donated funds can be directed toward humanitarian aid efforts rather than administrative expenses." According to some experts (F3, I2 and H2), BT simplifies international funds transfer by expediting the procedure and lowering charges, which is a significant benefit for international non-governmental organizations. "The rationale for embracing BT lies in its capacity to automate numerous aspects of SCM and contractual agreements through the utilization of smart contracts and innovative technologies," added by one expert (S1).

The discussion revealed that due to the technology's total digital nature and ability to be fully automated, it enables the reduction of a wide variety of costs, leading to increased efficiency within global payment services, risk management processes and insurance policies. During an interview, some experts (H2, H3, I1, F2 and S1) emphasized the growing enthusiasm among charities through BT due to significant cost savings in transactions. The experts pointed out that various aspects of SCM and contractual arrangements can benefit from automation through smart contracts. "Notably, technologies like IOTA, which is an open-source distributed ledger and cryptocurrency tailored for the internet of things (IoT) play a pivotal role in this automation," added an expert (I3). One of the experts (H1) specifically mentioned: "Humanitarian organizations, including prominent ones like the World Food Program and United Nations Children's Fund, are actively exploring the potential of BT for digital identity and cash-based relief." This insight from the interview underscores the practical interest and ongoing exploration of blockchain applications within the humanitarian sector, particularly in optimizing transactional processes and advancing digital solutions for aid distribution.

- *Reliable information sharing:* The study revealed that blockchain allows secure and efficient sharing of critical information among various stakeholders in the HSC, such as aid organizations, government agencies and logistics providers. According to I1, I2, I3, H2, H3, S2, F1 and F2, participants can access real-time data, ensuring that everyone operates with consistent and up-to-date information, which fosters better coordination, reduces information silos and enhances the overall efficiency of humanitarian efforts. As per one supply chain expert (S2), "humanitarian supply networks grow rapidly during disaster response, and delayed information flow is a significant impediment to building trust among responding institutions." Therefore, BT may potentially alleviate such information-sharing difficulties and promote the enhancement of traceability, trust and transparency throughout the supply chain. Moreover, the blockchain can help eliminate the hurdles associated with unreliable information sharing by establishing a public marketplace for information that is open to all operators while also maintaining data security, as added by an expert in blockchain (I3).
- *Smooth digital cash flow management:* The study highlights that BT can be used to support and alleviate issues associated with centralized databases, data security and information sharing among many players. According

to one of the experts (F2), "digital cash has been recognized as a critical idea for practitioners of cash-management programs." Digital currency and payments are advocated because they increase transparency on the amount of help that reaches affected populations, reduce the cost of payments, increase security and expedite financial inclusion. Another expert (I3) added that since cash transfers frequently rely on digital technology, data privacy, security, data exchange protocols and encryption are key components of the process. One expert (F1) shared: "Another difficulty is the usage of centralized databases, as cash programming enables more integrated programming. The blockchain may be able to address these concerns." A blockchain-based shared platform might enable humanitarian actors to share demographic and consumption statistics, as well as anonymized transaction data, simply and responsibly, the expert further added. The expert (F2) emphasized that BT facilitates the creation of digital wallets for beneficiaries in humanitarian crises. The expert mentioned:

> These wallets can store digital tokens or cryptocurrencies, enabling quick and secure transactions. This not only provides beneficiaries with a convenient way to receive and manage aid but also ensures that aid funds flow smoothly without the need for physical cash distribution, which can be logistically challenging and costly.

- *Facilitation of crowdfunding and microfinance in emergencies:* The research findings illuminate the transformative role of BT in simplifying the complex processes of crowdfunding and microfinance during humanitarian emergencies. The integration of blockchain introduces a novel mechanism for facilitating these financial activities, offering increased efficiency and accessibility. According to one expert (I3), "Through the process of tokenization, the contributions, no matter how small, from a global community can be seamlessly aggregated and directed to precisely where they are most needed." This represents a paradigm shift in democratizing financial support during crises, allowing a broader community to actively contribute to humanitarian causes. One of the blockchain experts (F1) emphasized that smart contracts play a pivotal role in automating the disbursement of funds based on predefined criteria. This level of automation ensures not only timely but also targeted financial support for individuals and communities affected by crises. The discussion with some experts (I2, F2, F3, H2, H3 and S3) further highlighted that BT provides versatile avenues for emergency crowdfunding and microfinance. This can be achieved either by leveraging existing digital currencies or by establishing a distributed funding platform. The flexibility in approach, as expressed by experts, underscores the adaptability and inclusive nature of blockchain in addressing financial challenges during humanitarian emergencies.

In essence, blockchain's integration proves instrumental in reshaping the landscape of emergency fundraising and microfinance, making it more efficient, transparent and accessible on a global scale.

The findings highlighted that the identified benefits collectively enhance the effectiveness, transparency and efficiency of HSCs. These advantages empower humanitarian organizations and stakeholders to deliver critical assistance more swiftly and responsibly during emergencies and humanitarian crises. The mutual relationship between these benefits establishes a foundation for a more responsive and accountable humanitarian ecosystem. Figure 3 provides a visual representation of the key benefits of BT within the context of HSCs, summarizing the transformative impact of BT in advancing humanitarian operations.

4.3 Blockchain applications in humanitarian supply chain: challenges and corresponding mitigation strategies

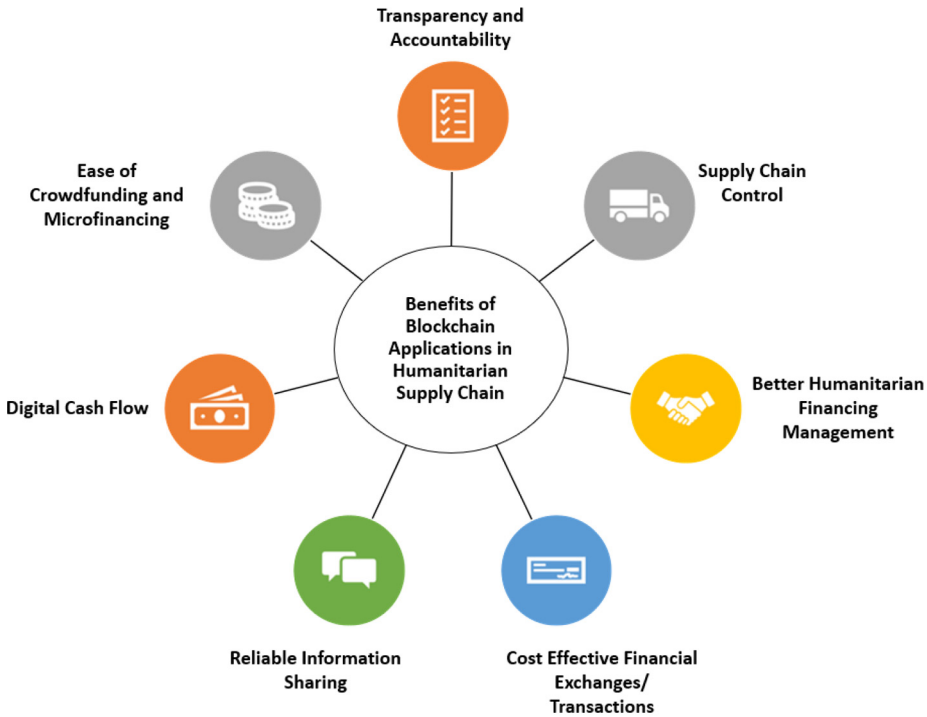
Blockchain applications in HSC offer numerous benefits, but they also face several challenges that need to be addressed for successful implementation. This section delves into the challenges and corresponding mitigation strategies, which are classified based on the responses to interviews with experts in the supply chain, humanitarian operations, fintech and IT. It was discovered that most of the participants have highlighted identical challenges.

- *Costs and resource requirements:* One prominent challenge highlighted by all experts pertains to the significant costs associated with implementing and maintaining a blockchain system within the HSC. Experts (I1, I2, I3, F1, F3, H2, S1 and S3) underscored that the initial investments required for hardware, software and specialized expertise, coupled with ongoing maintenance costs, can pose financial hurdles, particularly for smaller humanitarian organizations. Blockchain systems often require robust and secure hardware infrastructure to support the distributed nature of the technology, as per some experts (I3, F1 and F3,). In addition, "the procurement of software solutions tailored to the specific needs of humanitarian operations contributes significantly to the financial burden," as highlighted by one expert (F1). As per the experts, these expenses are unavoidable prerequisites for establishing a resilient blockchain framework capable of meeting the unique demands of the HSC.

To manage costs effectively, organizations can explore collaborative initiatives such as forming consortiums or partnerships with other entities within the humanitarian ecosystem. "By sharing the financial burden of implementing and maintaining the blockchain network, organizations can collectively overcome the economic challenges associated with blockchain adoption," added a supply chain expert (S1). According to one expert (H2), seeking financial support from various sources becomes imperative. Humanitarian organizations can actively pursue funding from governmental agencies, international donors or through dedicated blockchain-focused grants.

The responses suggest that financial support will serve to offset the initial setup costs and provide ongoing support, ensuring the continued integration and functionality of BT in the HSC. By adopting these mitigation strategies, organizations can navigate the financial complexities, fostering a more inclusive and sustainable approach to implementing blockchain solutions in the humanitarian domain.

Figure 3 Benefits of blockchain applications in HSC



Source: Author's finding

- *Scalability issue:* According to the findings, the challenge of scalability in the context of blockchain applications within the HSC revolves around the inherent characteristics of blockchain networks, particularly public ones. As participation increases or during periods of increased transaction volumes, such as emergencies, scalability becomes a critical concern, shared by experts (F2, H1 and I2). This challenge demonstrates congestion within the blockchain network, leading to slow transaction processing, they further added. One expert (S2) shared: "In the HSC, where the demand for rapid and efficient supply chain activities is increased during emergencies, delays in transaction processing can impede the timely distribution of aid and fund transfers." The experts (F1, I1 and I2) emphasized that the increased volume of transactions during crises can overwhelm the blockchain network, emphasizing the need for strategic solutions.

To tackle the challenges of scalability within the HSC, strategic adoption of Layer-2 scaling solutions, such as state channels or sidechains, emerges as a promising approach (according to I3). According to the expert, these solutions play a pivotal role in alleviating congestion on the main blockchain by efficiently offloading transactions, thereby augmenting its overall capacity to handle increased transaction volumes. In addition, as per one expert (F2), prudent consideration in the selection of the blockchain platform based on specific scalability requirements is paramount. One expert (F3) mentioned: "Private or consortium blockchains present themselves as viable alternatives, offering enhanced scalability in comparison to their public counterparts." As per the expert, this dual-pronged strategy of leveraging advanced Layer-2 scaling solutions while cautiously choosing the appropriate blockchain platform underscores a thoughtful and practical approach to mitigate scalability challenges in the HSC.

- *Lack of network reliability:* The study found that one significant challenge in the application of BT within the HSC is the lack of network reliability. The responses highlighted that blockchain networks heavily rely on consistent and reliable internet connectivity. In regions where internet access is limited or unstable, maintaining a constant connection to the blockchain becomes a formidable challenge, as highlighted by experts (F1, F2 and I3). The responses highlighted that locations with insufficient infrastructure or unreliable connectivity pose significant hurdles to the effective implementation of blockchain solutions. This challenge emphasizes the need for robust network infrastructure to ensure seamless blockchain operations within the HSC, underlining the importance of addressing connectivity issues in diverse geographical and technological contexts, according to most of the experts (F2, F3, I1, I2, H2, S1 and S2).

To address the challenge of lack of network reliability in regions with limited or unstable internet access, the findings highlighted that implementing offline mechanisms presents a viable solution. According to one expert (I3), "Strategies such as satellite communication or mesh networks can be used to ensure connectivity even in areas with unreliable internet infrastructure." In addition, advocating for infrastructure improvements, including enhanced internet connectivity, in regions prone to supply chain disruptions becomes essential

(according to S1, S3 and H2). By integrating these measures, humanitarian organizations can mitigate the impact of network unreliability, fostering more robust and resilient blockchain applications within the HSCs.

- *Lack of data privacy and security:* The study revealed that lack of data privacy and security is also one of the critical challenges in the integration of BT within the HSCs. According to the experts (F1, F2, I1, I2, I3, H1 and S3), while blockchain provides robust security features through encryption and immutability, achieving a delicate balance between transparency and safeguarding sensitive humanitarian data poses a substantial challenge. Experts expressed significant concerns regarding this complex issue, emphasizing the imperative to uphold the privacy and security of sensitive information within the humanitarian context. This challenge highlights the necessity for robust solutions that preserve the integrity of blockchain's security features while ensuring the confidentiality of critical humanitarian data, a few experts added (F3, H2 and H3).

Privacy-enhancing technologies, such as zero-knowledge proofs and confidential transactions, were identified as effective measures to protect sensitive information that allows the validation of data authenticity without disclosing the actual content (according to I1, I2, I3 and F3). The importance of robust access controls, encryption methods, compliance with data privacy regulations and the establishment of clear data handling policies were emphasized by the participants. An IT expert (I3) added: "Compliance with data privacy regulations and the establishment of clear data handling policies are essential to address data privacy and security concerns."

- *User adoption:* The challenge identified as user adoption in the implementation of BT within the HSCs highlights the difficulty of persuading all stakeholders, including beneficiaries and local communities, to embrace blockchain-based systems. Insights gathered from the responses emphasize that resistance to change, coupled with the perceived complexity of blockchain interfaces, can pose significant barriers to user adoption. This challenge highlights the tricky dynamics of introducing new technologies, where the readiness of diverse stakeholders to adopt blockchain solutions is pivotal, shared by I1, I3, F2, H2 and S1.

The mitigation strategy for addressing this challenge emphasizes a user-centric approach.

To encourage adoption, the strategy proposes prioritizing user-centered design principles, aiming to develop intuitive and user-friendly blockchain interfaces. The key recommendation is to engage with beneficiaries and local communities early in the adoption process (as per F2, I1, I3, H1, S1 and S2). The experts highlighted that this proactive involvement is deemed crucial for understanding their specific needs and concerns, facilitating their participation in decision-making processes and ensuring that blockchain applications are not only functional but also user-friendly and aligned with the unique requirements of managing financial flows in the HSC.

- *Supply chain integration:* This challenge highlights the complexity associated with integrating blockchain into existing supply chain systems and processes. The insights from experts (mainly from H1, H3, S1, S2 and S3) emphasize that this challenge is prevailed by the prevalent use of legacy systems in many humanitarian organizations and governments for SCM. As per some experts (H2, H3, S1 and S2), the transition from these legacy systems to blockchain is perceived as a time-consuming and resource-intensive process by the experts, indicating the need for careful consideration and strategic planning to facilitate a seamless integration that aligns with the unique requirements of the HSC.

The mitigation strategy for addressing the challenge of supply chain integration advocates for a phased approach, as highlighted by many experts. The strategy suggests initiating the integration process by focusing on critical areas that provide immediate benefits. Collaboration with specialized technology providers and system integrators in the field of blockchain is recommended to ensure seamless integration with existing supply chain processes (shared by F2, I2, H1, S1, S2 and S3). Moreover, the strategy proposes coexisting legacy systems with blockchain during the transition phase, allowing organizations to migrate gradually without disrupting ongoing operations. Implementing hybrid solutions that facilitate communication and data sharing between blockchain and legacy systems is also highlighted as a viable approach to streamline the overall transition process by some of the experts (F1, F2, I1 and I3).

- *Knowledge and training gaps:* The challenge identified as knowledge and training gaps emphasizes the potential barrier posed by a lack of understanding and expertise in BT to its adoption in the HSC. Insights from the experts (F2, H3, I1, I2, S1, S2 and S3) highlight that humanitarian organizations lack fundamental knowledge about blockchain, including its development processes and the diverse objectives it can serve beyond mere hype. One expert (H3) said: "Organizations know the basics of blockchain, but detailed knowledge of its usage and purposes for humanitarian organizations is still lacking." These findings underline the need for comprehensive training programs to bridge this knowledge gap and equip humanitarian organizations and supply chain participants with the necessary skills to effectively implement and use blockchain solutions in the HSC.

Addressing the knowledge and training gaps challenge involves implementing comprehensive training programs for staff and stakeholders engaged in humanitarian operations. To bridge this gap, collaboration with universities and educational institutions is proposed, aiming to develop specialized courses and certifications in BT. By offering structured educational opportunities, humanitarian organizations can empower their workforce with the essential knowledge and skills required to navigate and effectively implement blockchain solutions within the HSC, added by experts (H1, H2, S1 and S2). This strategy aims to enhance the overall understanding and expertise in BT, fostering its successful adoption in the field of humanitarian operations.

- *Lack of regulatory and legal frameworks:* The challenge of lack of regulatory and legal frameworks is highlighted as one of the major challenges in the application of blockchain in HSC operations. All experts feel this is a major challenge in BT applications. According to one expert (I3), "the regulatory environment for

blockchain is evolving, with unclear or restrictive regulations posing obstacles to its seamless adoption in HSC." Legal challenges related to data ownership, intellectual property and liability further complicate the landscape, added by F1, F3 and I2. The responses emphasize that the social, legislative and regulatory frameworks for blockchain are evolving at a slower pace than the technology itself. To address this challenge, it is crucial to advocate for the development of clear and adaptive regulatory frameworks that align with the unique characteristics of BT.

The strategy for addressing this challenge involves a multifaceted approach. The responses emphasized that advocating for favorable regulatory environments is paramount, and this can be achieved through education, engagement and collaboration with regulatory authorities. As per the experts (F1, F2, F3, I2 and I3), seeking guidance from legal experts specializing in blockchain and technology law is crucial for navigating the complex regulatory landscape. To ensure a smooth adoption process in an HSC, organizations must prioritize compliance with local regulations, obtaining necessary licenses and seeking approvals where applicable, further added by the experts (H3, I2 and S1). This proactive engagement with legal and regulatory considerations is essential to create a conducive environment for the effective integration of BT in HSC operations.

- *Ethical considerations:* The study brings attention to the ethical implications of blockchain's immutability, emphasizing that once data is recorded, it becomes permanent and cannot be easily altered or deleted. This characteristic raises concerns about the ethical handling of data, particularly if inaccurate or sensitive information is stored on the blockchain, highlighted by the experts (F1, F2 and I3). Some experts (F2, F3 and I2) highlighted that the potential for unintended consequences due to the permanent nature of recorded data prompts ethical considerations in the application of BT in the HSC.

To navigate ethical challenges, it is imperative to establish robust governance frameworks that incorporate mechanisms for rectifying, redacting or removing data in instances of inaccuracies or sensitivity on the blockchain, the study revealed. Concurrently, the development and strict adherence to ethical guidelines become pivotal, ensuring the responsible and ethical application of BT within the HSC, as per the responses (F1, F2, F3, H3, I2, I3 and S3). According to them, this approach aims to strike a balance between the immutability of blockchain records and the ethical considerations surrounding the accuracy and sensitivity of stored data in the HSC context.

- *High energy consumption:* A few of the experts (F3, I1 and S3) have also raised their concerns about the environment, thereby emphasizing the challenge from an environmental perspective, particularly high energy consumption. According to them, this misalignment with sustainability goals in the HSC is a noteworthy challenge, as it raises questions about the environmental responsibility and long-term viability of blockchain applications in the context of humanitarian operations, added by the experts.

To address concerns about the high energy consumption associated with certain blockchain networks, such as those using proof-of-work consensus mechanisms, humanitarian organizations and relevant entities can explore blockchain platforms using energy-efficient alternatives (as per I2 and F2). One expert (I3) added: "Some of the blockchain platforms that can be implemented are proof-of-stake (PoS) or delegated proof-of-stake (DPoS)." Moreover, adopting environmentally responsible practices, such as offsetting energy consumption through renewable sources or supporting carbon-neutral initiatives, can contribute to alleviating the environmental impact of blockchain networks within the framework of HSC operations, added by the experts (F2 and I3).

The challenges of BT applications for HSC and the corresponding mitigation strategies based on the findings of the present study are summarized in Table 3. By implementing these comprehensive mitigation strategies, humanitarian organizations can harness the potential of BT while effectively navigating and overcoming the challenges inherent in the context of HSC operations.

While uncovering the transformative potential of blockchain applications in the HSCs, this study has explained a range of benefits and challenges. It is crucial to acknowledge the major

Table 3 Blockchain applications in humanitarian supply chain: challenges and mitigation strategies

Challenges	Mitigation strategies
Costs and resource requirements	Consortium blockchains Seek funding and grants
Scalability	Use of layer-2 scaling solutions Proper blockchain selection Regular network upgrades
Network reliability	Implement offline mechanisms Infrastructure investment
Data privacy and security	Utilization of privacy-enhancing technologies Implement access controls Legal compliance
User adoption	User-centered design Community engagement
Supply chain integration	Phased integration Collaboration with technology providers Implement hybrid solutions
Knowledge and training	Develop comprehensive training programs Partnerships with educational institutions
Regulatory and legal frameworks	Advocacy and collaboration with regulatory bodies Legal expertise consultation Licensing and compliance
Ethical considerations	Establish governance frameworks Develop and adhere to ethical guidelines
High energy consumption	Alternative consensus mechanisms Practice environmental responsibility

Source: Author's finding

constraints that emerged across various dimensions. From the energy consumption concerns associated with specific consensus mechanisms to the complex issues surrounding data privacy and security, each benefit is accompanied by a distinct set of constraints. Simultaneously, challenges such as scalability and supply chain integration present obscure hurdles that necessitate urgent solutions. This holistic understanding of the constraints provides a comprehensive foundation for future research, policy considerations and strategic implementations in the dynamic intersection of blockchain and humanitarian logistics.

5. Discussion

The findings of this study align with and build upon the existing literature that highlighted the benefits and challenges of BT applications in managing financial flows within HSCs. The identified benefits and challenges, as discussed with experts in the field, resonate with key themes previously highlighted in the literature.

The study reaffirms the importance of BT in ensuring accountability and transparency within HSC, echoing the responses of prior literature (Baharmand *et al.*, 2021; Dubey *et al.*, 2022b; Privett, 2014). The decentralized and transparent ledger of blockchain, as described by the experts, acts as a robust mechanism for recording and visualizing all transactions, aiding in fraud prevention and resource management, consistent with prior literature (Stathakis, 2019).

The granular control facilitated by blockchain, particularly through the automation of supply chain operations using smart contracts, is a recurrent theme found in both the present study and the literature (Dubey *et al.*, 2020). The ability to precisely manage aid distribution and funds, as emphasized by the experts, corresponds with the existing understanding of the potential of blockchain in optimizing supply chain processes.

The study's findings regarding the real-time tracking of donations and funds, along with the automated release of funds through smart contracts, align with established literature (Kenny, 2017; Poorterman, 2017). The discussion on the elimination of corruption and fraud through blockchain resonates with prior studies emphasizing transparency and accountability (Zwitter and Boisse-Despiaux, 2018).

The reduction in transaction costs and the efficiency of international fund transfers highlighted in the study are consistent with the literature (Babich and Hilary, 2020; Cole *et al.*, 2019). The enthusiasm among charities for cost savings in transactions, as mentioned by experts, echoes the ongoing discourse on the financial advantages of BT in humanitarian operations.

The study's emphasis on secure and efficient information sharing, vital for rapid response in humanitarian supply networks, aligns with the literature's recognition of blockchain's potential to alleviate information-sharing difficulties and enhance traceability and trust (Cole *et al.*, 2019; Queiroz *et al.*, 2020).

The study introduces the concept of digital wallets for beneficiaries in humanitarian crises, presenting a novel finding not extensively covered in existing literature. This insight adds a new layer to the discussion by addressing practical solutions for managing aid funds securely and efficiently. The study's exploration of blockchain's role in simplifying crowdfunding and microfinance during emergencies through tokenization contributes a fresh perspective to the literature. While the potential of blockchain in financial inclusion has been discussed, the specific application in emergency contexts is a notable addition.

In summary, this study not only reinforces the established benefits of BT in HSC but also introduces novel findings related to digital cash flow management and the facilitation of crowdfunding and microfinance during emergencies. These additions contribute to a more nuanced understanding of the practical implications and emerging areas of application for blockchain in the humanitarian sector.

Discussing the challenges in blockchain applications in HSCs, the study's revelations on high implementation costs align with the broader understanding presented by Baharmand and Comes (2019) and Patil *et al.* (2021), emphasizing budgetary constraints as a substantial barrier. Scalability issues highlighted in emergencies resonate with existing literature acknowledging BT's limitations in handling surges in transaction volumes (Baharmand *et al.*, 2021; Khadke and Parkhi, 2020). Concerns over network reliability, particularly in regions with limited internet access, align with Swan's (2015) emphasis on internet dependency for blockchain. The delicate balance between transparency and data privacy echoes literature concerns raised by Kafeel *et al.* (2023) and Patil *et al.* (2021).

The study's focus on user adoption parallels the literature's recognition of resistance to change and interface complexities (Coppi, 2020). Integration complexities align with broader literature emphasizing challenges in transitioning from traditional to blockchain systems (Baharmand *et al.*, 2021; Sahebi *et al.*, 2020). Knowledge and training gaps identified in the study correspond with literature highlighting the need for education in BT (Saad *et al.*, 2022; Sahebi *et al.*, 2020). Regulatory and legal challenges align with existing literature recognizing the evolving regulatory environment for blockchain in HSCs (Baharmand and Comes, 2019). Ethical considerations raised in the study resonate with literature acknowledging the ethical implications of blockchain (Hunt *et al.*, 2022; Negi, 2023; Zwitter and Boisse-Despiaux, 2018). Environmental concerns regarding energy consumption contribute a nuanced perspective to the literature, emphasizing the specific environmental challenges in HSCs (Patil *et al.*, 2021).

In addition, the present study brings forth novel insights into the challenges. Noteworthy findings include the identification of high energy consumption, particularly in BT networks using the proof-of-work consensus mechanism, as an environmental challenge that may conflict with sustainability goals in HSCs. The study also sheds light on the ethical concerns arising from blockchain's immutability, emphasizing the potential ramifications if incorrect or sensitive data is recorded. In addition, the research highlights a distinctive challenge related to the lack of regulatory and legal frameworks specific to blockchain in HSC operations. This underscores the evolving regulatory landscape for blockchain, indicating the need for clearer frameworks to facilitate its adoption in humanitarian contexts. The study thus contributes fresh perspectives to the existing literature by addressing environmental sustainability,

ethical considerations and the regulatory landscape as distinct challenges in the application of BT within HSCs.

Collectively, these findings reinforce the multifaceted nature of obstacles in BT adoption in HSCs, emphasizing the need for strategic mitigation and adaptation to the evolving humanitarian landscape.

5.1 Contributions and implications

5.1.1 Theoretical contributions

This research significantly contributes to theoretical discourse by leveraging the diffusion of innovations theory as a lens to understand the adoption of BT within HSC operations. By aligning the findings with this theoretical framework, the present study illuminates the factors influencing BT adoption in humanitarian settings, thus deepening the understanding of the diffusion process. The study identifies how concepts such as relative advantage, compatibility, complexity, trialability and observability play pivotal roles in shaping the acceptance and implementation of BT solutions within HSC operations. Moreover, the exploration of innovative concepts like digital wallets for beneficiaries and blockchain-enabled crowdfunding provides empirical evidence of their potential acceptance and impact, further enriching theoretical discussions within the diffusion of innovations paradigm.

Furthermore, the research delves into the ethical implications and environmental sustainability considerations associated with BT adoption. By examining concerns related to persistent data records and environmental impact, the study offers nuanced insights into the ethical dimensions of humanitarian blockchain applications, thus advancing theoretical debates on the intersection of technology adoption and ethical considerations. In addition, the analysis of the evolving regulatory environment and the balance between transparency and data privacy in blockchain applications adds depth to theoretical considerations surrounding the legal and regulatory dimensions of humanitarian blockchain implementations. Through these contributions, the study provides a comprehensive theoretical framework for understanding the adoption and diffusion of BT in HSC operations, enriching scholarly discourse on technology adoption and offering practical insights for implementing blockchain solutions.

5.1.2 Practical and contextual contributions

This study provides actionable guidance for organizations adopting blockchain in HSC operations by integrating theoretical concepts with real-world implementation challenges. By integrating the diffusion of innovations theory with empirical findings, it illuminates challenges and mitigation strategies, enhancing the practical knowledge base. Insights from expert interviews offer practical considerations for organizations integrating blockchain in humanitarian contexts, thereby facilitating informed decision-making and implementation strategies grounded in theoretical understanding.

5.1.3 Implications

The implications of research extend to researchers, practitioners and society at large. For researchers, it offers a roadmap for future research endeavors, highlighting avenues for further exploration within the theoretical framework of Diffusion of Innovations theory. It aims to bridge the gap between theory and empirical findings, catalyzing further scholarly inquiry into technology adoption in humanitarian contexts. Practitioners gain insights into integrating blockchain for secure data exchange and streamlined financing, enhancing aid distribution efficiency. In a broader societal context, the research contributes to more transparent financial transactions and increased public confidence in humanitarian efforts, driving positive change toward more effective and accountable humanitarian operations.

6. Conclusion

The humanitarian aid sector confronts challenges related to transparency, funding and trust, intensified by scandals that have shaken confidence in charities worldwide. In response, promoting transparency, accountability and reporting have emerged as imperatives for rebuilding trust and engaging donors effectively. Within this landscape, BT emerges as a promising tool to transform the humanitarian sector, fostering trust and collaboration among stakeholders to enhance traceability and transparency in fund flows within the emergency relief supply chain.

In the pursuit of understanding BT's potential, this study addressed three central research questions: how can BT be used to improve financial flows in an HSC, what are the benefits of integrating BT into the HSC and what challenges accompany its implementation along with corresponding mitigation strategies? Using an exploratory research approach through in-depth, semi-structured interviews, the study uncovered insights that shed light on BT's role within the HSC.

The findings underscore the capacity of BT to enhance financial flows by fostering transparency, accountability and efficiency throughout the HSC. Notably, applications ranging from tracking to crowdfunding, documentation, humanitarian financing, data collection, information sharing and cash programming demonstrate BT's potential to revolutionize humanitarian operations. Leveraging features such as transparency, smart contracts and decentralized ledger technology, BT mitigates the risk of fraud and mismanagement of humanitarian funds and resources.

Moreover, BT facilitates real-time data sharing, streamlined processes and peer-to-peer financial transactions, thereby enhancing coordination, reducing transaction costs and providing inclusive financial services in underserved and disaster-affected areas. Despite the promising prospects, our study also revealed challenges associated with BT implementation in the HSC and identified corresponding mitigation strategies.

The study's insights highlight BT's transformative potential in reshaping humanitarian aid and financing, paving the way for resilient, data-driven and sustainable responses to emergencies and crises. While showcasing BT's positive impact on financial flows within the HSC, including secure data sharing, SCM, donor financing, cash programs and crowdfunding, the research emphasizes the critical importance of ethical standards and monitoring procedures.

To fully harness the potential of BT, the humanitarian sector must transcend initial enthusiasm and establish ethical practices conducive to the advancement of development aid

and humanitarian action. By aligning with the Diffusion of Innovations theory, which underscores the importance of factors such as relative advantage, compatibility, complexity, trialability and observability, the study further explains BT's adoption and diffusion processes within the humanitarian domain.

6.1 Limitations and scope of future research

This study focused on the application of BT in managing HSC operations, utilizing a semi-structured interview method to explore benefits, challenges and mitigation strategies. Notably, the study lacked statistical analysis of the benefits and challenges associated with integrating BT into the HSC. To address these limitations and provide further insights, future research could adopt diverse methodologies and sampling frames. This approach would allow for empirical investigation and ranking of challenges based on statistical rigor. Future studies should aim to identify the most suitable applications and use cases for blockchain, conducting comprehensive analyses of benefits, consequences, threats and resource requirements.

Furthermore, economic analyses, cybersecurity assessments and investigations into cross-border collaboration using BT are essential for a thorough understanding of its future role in enhancing financial flows within HSC. These comprehensive insights can contribute significantly to the advancement of development aid and humanitarian action.

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Appendix. Interview protocol and interview guide

Interview protocol: A semi-structured interview was conducted online, recorded and transcribed.

Questions:

Introduction:

- Can you briefly describe your role and responsibilities within your organization?
- How long have you been involved in your current position?

General understanding of blockchain in humanitarian supply chain:

- What is your understanding of blockchain technology and its potential applications in the humanitarian supply chain?

Benefits of blockchain in humanitarian supply chain:

- In your opinion, what are the potential benefits of implementing blockchain in managing financial flows within the humanitarian supply chain?
- Can you provide specific examples or scenarios where blockchain could enhance financial processes in humanitarian operations?

Challenges associated with blockchain implementation:

- From your perspective, what challenges or barriers exist in the application of Blockchain in the humanitarian supply chain?
- Are there specific issues related to scalability, cost or resource requirements that you foresee?

Mitigation strategies:

- How do you think the challenges identified can be effectively mitigated or addressed in the implementation of blockchain?
- Are there best practices or strategies that you would recommend to overcome potential obstacles?

Closing:

- Any questions or clarifications by the respondent
- Thanking the respondent

Executive summary for practitioner audience

This research examines the real-world applications of blockchain technology (BT) in streamlining financial processes within humanitarian supply chains (HSCs), offering practical insights for professionals in the field. The study aligns with established literature, emphasizing the pivotal role of BT in ensuring transparency, accountability and efficient supply chain management. Noteworthy findings include cost reductions, improved fund transfers and secure information sharing, contributing to the ongoing dialogue on BT's financial advantages in humanitarian operations. The study introduces innovative aspects like digital wallets for beneficiaries and blockchain-enabled crowdfunding during emergencies, providing actionable solutions for effective aid fund management. Identified challenges encompass implementation costs, scalability issues during crises and concerns over network reliability, coupled with ethical and regulatory considerations. These findings offer practical implications for professionals, highlighting the need for strategic approaches in adopting BT within the evolving humanitarian landscape.

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