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Exploring the application of blockchain to humanitarian supply chains: insights from Humanitarian Supply Blockchain pilot project

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Abstract

Purpose – Some studies and reports have recently suggested using blockchain technology to improve transparency and trust in humanitarian supply chains (HSCs). However, evidence-based studies to display the utility and applicability of blockchains in HSCs are missing in the literature. This paper aims to investigate the key drivers and barriers of blockchain application to HSCs and explore whether evidence could support that the application of blockchain improves transparency and trust in HSCs.

Design/methodology/approach – This paper puts forward a two-stage approach to explore the blockchain application in HSCs: an initial exploration of humanitarian practitioners and academicians interested in blockchain through focus group discussions; semi-structured interviews with practitioners involved at the UK Department for International Development's Humanitarian Supply Blockchain pilot project.

Findings – First, we found that main drivers include accountability, visibility, traceability, trust, collaboration, time efficiency, reducing administrative work and cross-sector partnership. Main barriers, however, are composed of engagement issues, lack of technical skills and training, lack of resources, privacy concerns, regulatory problems, pilot scalability issues and governance challenges. Second, evidence from our case study revealed the blockchain application could have added value to improve visibility and traceability, thus contributing to improve transparency. Concerning trust, evidence supports that blockchain could enhance both commitment and swift trust in the pilot study.

Practical implications – Our study contributes to a more understanding of added values and challenges of blockchain application to HSCs and creates a perspective for humanitarian decision-makers.

Originality/value – This study provides the first evidence from the actual application of blockchain technology in HSCs. The study discovered that it is still less evident in many humanitarian organizations, including medium- and small-sized nongovernmental organizations, that they engage in a direct deployment of in-house or customized blockchain-based HSC. Instead, these actors are more likely to indirectly use blockchain in HSCs through a private commercial partner.

Keywords Humanitarian supply chain, Blockchain, Transparency, Trust, Case study

Paper type Research paper

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1. Introduction

In 2019, humanitarian reports indicated that over 100 million people worldwide were in need of aid, a number that has increased to nearly 120 million in 2020 (GHA, 2020). The constant improvement of humanitarian supply chains (HSCs) plays a critical role in addressing such needs. The HSC refers to the network of humanitarian organizations (HOs), their suppliers and logistics partners that are involved, through upstream and downstream linkages, in the different processes and activities that produce value in the form of supplies, cash and/or services in the hands of the affected communities (Kovács and Spens, 2009).

To live up to the challenges posed by this level of scale up, HSCs must first overcome its current limitations. Recent studies show that HSCs still suffer from a lack of transparency and issues with trust which has led to duplicated efforts and operations deficiencies (Besiou and Van Wassenhove, 2020). SC transparency refers to reporting to and communicating with stakeholders to provide traceability regarding the history of the products and visibility about current activities throughout the SC (Morgan *et al.*, 2018). Traceability is the ability of an SC to indicate the current or historical state of activities associated with a product. Visibility refers to the extent that SC partners have access to quality information about various aspects of demands and supplies (Maghsoudi and Pazirandeh, 2016). Trust in SC is defined as the willingness to rely on an exchange partner in whom one has confidence (Tejbal *et al.*, 2013). While HOs are under increasing pressure for enhancing traceability of relief items, donors and governments have repeatedly asked to see tangible results and called for improved information exchange between humanitarian stakeholders. Moreover, the lack of trust in HSCs hampers effective disaster relief operations and can result in disallowance of funding from donors, and complex audit procedures (Piotrowicz, 2018). The lack of trust and transparency has also been cited frequently in the literature as main an obstacle for effective collaboration among humanitarian actors in disasters response (Moshtari, 2016).

Research in the operations and SC management literature suggests that distributed ledger technology (DLT) and specifically blockchain hold the promise to improve transparency and smoothen up trade within trust-less environments (Cole *et al.*, 2019; Queiroz and Wamba, 2019; Babich and Hilary, 2020). DLT has established itself as an umbrella term to designate multiparty systems that operate in an environment with no central operator or authority, despite parties who may be unreliable or malicious. Blockchain technology is often considered a specific subset of the broader DLT universe that uses a particular data structure consisting of a chain of hash-linked blocks of data (Rauchs *et al.*, 2018). Blockchain refers to a shared distributed ledger where transactions are digitally recorded and linked in a chain containing the entire history or provenance of an asset. A transaction is recorded on the blockchain only after it has been validated using a consensus protocol, and each record is encrypted to provide an extra layer of security.

In the context of HSCs, some studies have suggested different drivers for blockchain adoption such as improving visibility and accountability (Ozdemir *et al.*, 2021); enhancing swift trust, collaboration and resilience (Dubey *et al.*, 2020); leveraging partnership with logistics service providers (Baharmand and Comes, 2019) and facilitating resource sharing (L'Hermitte and Nair, 2020). Moreover, some studies have proposed combining the blockchain with Internet of things (Khan *et al.*, 2021) or with artificial intelligence and 3D printing (Rodríguez-Espíndola *et al.*, 2020) to further enhance HSC performance. However, first, empirical research on the application of the blockchain in HSC that combine multiple methods to derive practical insights is scant in the literature (Dubey *et al.*, 2020). Second, as we explain in detail in Section 2, available research on the drivers and barriers of blockchain adoption to HSC has often been informed by studies in the commercial settings without considering differences between humanitarian and commercial SCs (Kovács and Spens, 2009). We acknowledge that one reason could be the limited available information about the (very few) blockchain projects in HSCs. Nevertheless, Ozdemir *et al.* (2021) and Wamba (2020) contend that without real-world evidence, it is challenging to validate blockchain's contributions to address HSC challenges. Similarly, by solely relying on conceptual frameworks, it would be difficult for practice to realize implementation challenges and identify mitigation or solution strategies. There is a need for evidence-based studies on the blockchain application to HSCs that explore added values and challenges from real-world projects.

In this paper, we aim to address the gap through an evidence-based study. We pose the following research questions: (RQ1) what are the key drivers and barriers of blockchain application in the HSC? and (RQ2) could evidence support that the application of blockchain improves transparency and trust in HSCs? Methodologically, we leverage insights from the scant HSC literature that has conceptually investigated drivers and barriers of blockchain adoption in (e.g. Sahebi *et al.*, 2020; Khadke and Parkhi, 2020; Patil *et al.,* 2021) to inform our multi-method study: focus group discussions combined with an in-depth case study of the Humanitarian Supply Blockchain pilot. To the best of our knowledge, the Humanitarian Supply Blockchain pilot is the only humanitarian blockchain pilot project that (1) has targeted the scope of delivering relief items to affected communities (opposed to other pilots that focus on cash-based assistance), and (2) its existence is known through public information platforms (e.g. medium.com) and the researchers' own network. Our study contributes to the ongoing discussion in the humanitarian operations and SC management literature about the added value and challenges of blockchain application to HSC (Wamba, 2020) by providing evidence from a real-world project in the humanitarian context.

To address the research questions, this study builds on the contingent resource-based view (RBV) of the firm (Brush and Artz, 1999). HSC research has applied RBV frequently to explain dynamic SC capabilities such as trust and transparency (e.g. Altay *et al.*, 2018). In our research, the contingent RBV helps us to understand how blockchain application can improve the supply chain trust and transparency given that they are contingent and contextual to certain challenges and barriers based on evidence from real projects.

The rest of our paper is organized as follows: In the next section, an overview of the related background is provided. The methodology is presented in Section 3. Section 4 illustrates findings from focus group discussion and case study of the Humanitarian Supply Blockchain pilot project. In Section 5, the cross-method findings, the implications and limitations of the study are discussed. Finally, the paper concludes with the future research in Section 6.

2. The research background

2.1 Shortcomings of current information systems in HSCs

There are often two types of technology-supported information systems (IS) in HSCs. The first category aims at providing specific decision and management support functions, such as routing and navigation, inventory management and facility location or distribution planning. The second category, however, targets providing documentation, monitoring and tracking functionalities to improve different SC capabilities such as transparency, accountability, information sharing and cost efficiency (Van de Walle and Comes, 2015).

Systems in the second category (the scope of our paper) provide dedicated information on the location and use of specific goods, often in near real time, enabling analysis of patterns and detection of outliers or risks. However, as advanced as they might be, these systems typically lack integration in the overall planning, logistics decision-making and coordination processes as well as specific quality management and control functions. Van de Walle and Comes (2015) contend that the IS in HSC often fail to provide effective, end-to-end visibility and traceability. Delivering humanitarian relief through HSCs is often conducted by a large variety of HOs, agencies and actors, each using their own systems, data sets and processes. Such a working environment leaves the HSC fragmented and opaque (Besiou and Van Wassenhove, 2020). The shortcoming of current IS with respect to traceability and visibility has made HSCs prone to operational risks such as waste of relief items, duplicated efforts and corruption (Rodríguez-Espíndola *et al.*, 2020).

Moreover, existing IS at HSCs have not effectively addressed trust-related issues between actors specifically in the context of humanitarian disasters response. According to several reports, the mistrust problem hampered effective collaboration among HOs to reach beneficiaries in severely affected but remote locations in the aftermath of 2015 Nepal earthquake. Lack of collaboration resulted in duplicated relief delivery in urban areas, while some beneficiaries in remote areas had to wait a long time to receive humanitarian aid. On the other hand, the increasing privacy concerns related to both responders and beneficiaries often prevent enhancing information sharing among HSC actors (e.g. patient data in the Ebola response or the location of schools, camps, hospitals in the Syria crisis). Kovács and Spens (2009) emphasize that HSCs are quickly formed in disasters response, and slow information flow results in major hindrance for trust among the responding agencies. Indeed, DLTs and more specifically blockchain technology might allegedly mitigate such information-sharing challenges and provide further support to enhance visibility, traceability and trust along supply chains (Kshetri, 2018; Kouhizadeh and Sarkis, 2018; Cole *et al.*, 2019; Wang *et al.*, 2019; Queiroz *et al.*, 2020).

2.2 The blockchain and smart contracts

Blockchains have four main characteristics that make them interesting for the context of SC management. First, as the blockchain is designed to be distributed and synchronized across networks, it encourages involved parties to share data and is therefore ideal for multiorganizational trade networks such as SCs. Second, the blockchain is built using peer-to-peer networks, whereby there must be agreement between all relevant parties that a transaction is valid, which serves to keep inaccurate or potentially fraudulent transactions out of the database. Third, immutability of the data means that agreed transactions are recorded and not altered. This provides security on provenance of assets, which means that for any asset, it is possible to tell where it is, where it has been and what has happened throughout its lifetime (Cole *et al.*, 2019; Babich and Hilary, 2020).

Fourth, some blockchains support smart contracts. Despite its name, a smart contract is not a legally binding agreement enforceable by law but a computer protocol or a trusted application that is installed on the nodes of the blockchain (Chang *et al.*, 2019). The smart contract is intended to digitally facilitate, verify or enforce the negotiated terms of a contract – allowing for credible transactions without the need for third-party interventions as they are automated. These specific protocols can decide whether a specific operation, such as a given payment, should be permitted or not. Compared to traditional contracts, smart contracts have the advantages of diminishing risk, cutting down administration and service costs and improving the efficiency of business processes (Babich and Hilary, 2020). More importantly, smart contracts have the capacity to create trust between parties in what we term no-trust or trust-less contracting environments (Baharmand and Comes, 2019).

Blockchains are categorized into public versus private blockchains (based on who is allowed to join) as well as permissioned versus permission-less (based on who is allowed to write on the blockchain). Unlike public blockchains that are completely open for anyone to join, private blockchains require an invitation, and participants must be validated. According to Lim *et al.* (2021), private and permissioned blockchains are more favorable for SCs than permission-less public blockchains as private blockchains can provide security, timeliness and transparency to all its users. Moreover, permissioned blockchains are a more viable option for centrally governed SCs because such blockchains are restricted to known parties who would have limited access to certain data segments only. According to Kouhizadeh and Sarkis (2018), current SC actors are unlikely to accept public permission-less blockchains because revealing proprietary details such as demand, capacities, orders, prices and margins at all points of the value chain to unknown participants would be unwise.

2.3 Blockchain and smart contracts applications in SC management

Recent surveys show that there is a growing interest on the application of blockchain in the context of operations and SC management (e.g. Lim *et al.*, 2021). Queiroz *et al.* (2020) review blockchain-related journal papers and conclude that SC scholars have found blockchain contributions as enhancing product safety and security; improving quality management; reducing illegal counterfeiting; improving sustainable SC management; advancing inventory management and replenishment; reducing the need for intermediaries; impacting new product design and development and improving SC efficiency.

Quiroz and Wamba (2019) suggest that blockchain can speed up information flow (document workflow management), financial transactions through data confidentiality, and improve coordination through device connectivity among SC actors. Wang *et al.* (2019) contend that blockchain also offers increased supply chain integration, which leads to a better overall supply chain performance. Kshetri (2018) argues that the blockchain-based SC leads to increased customer confidence by providing them the benefits of real-time tracking of the products, reduction in product movement costs, highly secured transactions and protect product counterfeiting. Kouhizadeh and Sarkis (2018) contend that the transparency, visibility and security attributes of blockchains build trust in commercial SCs and can eliminate or at least expose any hidden unethical behaviors by certain SC actors. In summary, the promise of blockchain for SC management is to provide significant improvement with respect to visibility, accountability, traceability and trustworthy relationship.

Several papers in the literature have referred to smart contracts as either the most transformative blockchain application for SCs or the highly targeted area for further exploration (e.g. Prause and Boevsky, 2019). Hasan *et al.* (2019) highlight that smart contracts are becoming a desired functionality due to their flexibility and power to include business logic under certain conditions, thus removing costs and time from the supply chain via self-execution. In summary, smart contracts have been suggested in several contexts for increasing transparency and trust (Chang *et al.*, 2019); monitoring products and automating the tracking and clearance processes (Cole *et al.*, 2019); improving quality management and demand–supply management (Kshetri, 2018); reducing intermediaries, transaction costs and time (Prashar *et al.*, 2020); and managing shipment conditions while automating payments (Prause and Boevsky, 2019). However, the application of blockchain and smart contracts in the context of HSC has been rarely discussed (Baharmand and Comes, 2019).

2.4 Blockchain applications in the humanitarian setting

HOs typically work in low-technology environments, where they have to deal with complex crisis while relying on limited resources. These are mostly generated from financial support from institutional donors and sometimes private donations and bound to programming needs instead of their information technology architecture. As a result, most HOs have limited resources and capacity for investment in technology infrastructure. Once humanitarian digital systems are built, they tend to be maintained for long periods of time with little further development or evolution. Overall, enterprise humanitarian systems tend to change slowly, are rarely state of the art, suffer from a litany of technical issues and are organization-specific with limited interoperability (Blakstad *et al.*, 2020). While it is unrealistic to distinguish an inherently humanitarian blockchain given the interdependencies and overlapping with commercial and public sectors (Coppi and Fast, 2019), emerging research is framing specific design frameworks to ensure that such systems are at least compatible with humanitarian applications (Baharmand *et al.*, 2021).

Since 2017, several organizations have been testing these assumptions in a variety of fields, including cash-based assistance, auditability, identity services, community currencies, donor engagement, innovative financing and funding. The first use case is possibly the richest in concrete examples, including Mercy Corps' partnership with The Blockchain Charity Foundation by Binance, Oxfam's UnBlocked Cash transfer program in Vanuatu (Blakstad *et al.*, 2020) or Sikka by World Vision International in Nepal (Coppi and Fast, 2019). Given that most instances steer clear from sending transactions through the blockchain, often the line between cash-based assistance and audit-oriented use cases is extremely blurry, as in the case of World Food Programme's Building Blocks pilot project. On the other side of the spectrum sits the field of SC management, which has seen almost no purely humanitarian application advancing beyond proof of concept or early pilot stage.

2.5 Drivers and barriers for blockchain applications in HSCs

Research on blockchain in HSC is relatively new, and to the best of our knowledge, it has mainly focused on the drivers and barriers of adopting blockchain in HSCs. For drivers, HSC scholars have elaborated on the potential of blockchain to address the shortcomings of second category of IS in HSCs (cf. Section 2.1). The available research often refers to the motives such as improving collaboration (Dubey *et al.*, 2021), increasing transparency, accountability and security (Seyedsayamdost and Vanderwal, 2020), building higher levels of trust (Demir *et al.*, 2020; Dubey *et al.*, 2020), removing intermediaries and enhancing coordination (Khan *et al.*, 2021), improving cost efficiency and traceability (Khadke and Parkhi, 2020) and leveraging partnerships with third-party logistics service providers (Baharmand and Comes, 2019). However, much of research on this topic has remained conceptual. Sahebi *et al.* (2020) postulate that what blockchain can do to improve the HSC is yet to be backed by reliable evidence from real-world projects in the field.

Opposed to drivers, barriers to blockchain adoption in HSCs have been empirically investigated in some studies (Baharmand and Comes, 2019; Coppi and Fast, 2019; Khadke and Parkhi, 2020; Sahebi *et al.*, 2020; Coppi, 2020; Patil *et al.*, 2021). Baharmand and Comes (2019) refer to financial slacks, top management support, organizational compatibility, technology readiness, technology complexity, infrastructure, technology compatibility, legislation, the few early adopters and cross-sector partnership as main barriers. Coppi and Fast (2019) mention the lack of good understanding among HOs regarding what blockchain is, how it can be designed and for what purposes it can be used beyond the hype. Sahebi *et al.* (2020) recognize the lack of knowledge and employee training, high sustainability costs, the lack of successful validations, integration challenges with existing legacy systems and scalability issues. Coppi (2020) highlights barriers such as the low access to human and technological resources, low level of engagement, lack of governance models, lack of standardization and implementation issues in the downstream part. Patil *et al.* (2021) identify data privacy, ownership and security issues; funding issues and cost complexity and technological complexities as the most significant barriers. The study also refers to the lack of awareness and understanding among stakeholders, and interoperability, collaboration and cross-pollination among HOs as the least influential barriers to blockchain adoption in HSCs. A summary of drivers and barriers to blockchain adoption in SCs derived from previous studies is provided in Appendix 1.

2.6 Research gap

Our review has two main findings. First, our review confirms Wamba's (2020) study that empirical research with a focus on blockchain and HSCs is scant. In fact, the few available research conceptually discusses blockchain in HSCs concentrating on technology adoption theories. This outcome is in line with the findings of recent, broader surveys (e.g. Wang *et al.*, 2019; Gurtu and Johny, 2019; Queiroz *et al.* 2020) that case studies concerning the added value of blockchains in the context of SCs are scarce. There is a need for evidence-based studies to investigate added values and challenges of blockchain application in HSCs. To this end, Dubey *et al.* (2020) call for mixed-methods research including single or multiple case studies, as the use of a single method may not provide complete insights.

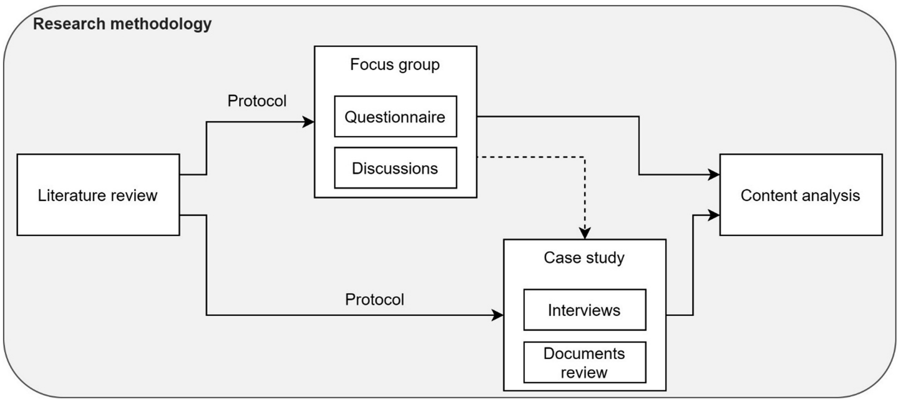
Second, our review reveals that in the absence of evidence from real-world projects in humanitarian contexts to support the arguments, drivers and barriers for blockchain adoption in the HSC are often echoed from extensive research on commercial SCs. In practice, IS for HSC are typically designed and applied upon technology that has been initially developed for the commercial sector. As such, relying solely on insights from commercial SC regarding the drivers and barriers of blockchain adoption in HSCs can be misleading. This is mainly due to the critical differences between commercial and HSCs (Baharmand *et al.*, 2021). Without evidence, there is a risk of HOs rushing to use the technology, harnessing it in the wrong way or for the wrong reasons, and being disappointed with the results. Our paper aims to address these two gaps through an evidence-based study combining multiple methods.

3. Methodology

For the purpose of our study, we combined multiple methods. The rationale for combining methods is to make sure they complement each other and build upon each other. Inspired by van Hoek's (2019) research, we structured our research into two stages: an initial exploration using a focus group and further exploration using a case study. Figure 1 illustrates the overall research methodology of paper.

3.1 Initial exploration: the focus group

A focus group was organized with 21 participants (six scholars [S1-6] and 15 practitioners [P1-15]) interested in the application of distributed ledger technologies in the humanitarian sector. The practitioners were from different organizations, including international nongovernmental organizations (INGOs) (four), small NGOs (two), UN agencies (seven) and business partners (two). The focus group members were identified based on their participation at a digital paper presentation session at the Health and Humanitarian Logistics 2020 conference on September 30, 2020. The paper was about using distributed ledger technologies for supplying food in humanitarian contexts (Lechner *et al.*, 2020). The participants were invited to a Zoom meeting after the paper presentation session.



Source(s): Inspired by van Hoek (2019)

Figure 1. Schematic illustration of research methodology (inspired by van Hoek, 2019)

The objective of the meeting was to explore considerations for the application of blockchain in HSCs through a digital workshop. As of preparation for the workshop (cf. Section 2.2), we asked participants to rate the relevance of literature-derived barriers and drivers (cf. Table 1) to provide a basis for the discussion. The questionnaire used a seven-point Likert scale, ranging from 1 “strongly unimportant” to 7 “strongly important”. We used some of the aggregated findings (cf. Section 4.1) to drive constructive discussion during the focus group work session. Moreover, we included open text to identify any missing barrier or driver. If a missing barrier or driver was mentioned, we asked the corresponding participant to elaborate on the point in a separate form.

Given the number of participants and questions that we wanted to explore in the focus group discussions (see focus group protocol in Appendix 4), we used the subgroup function supported by the digital meeting means that we used. We divided the focus group participants into four subgroups (one group had six members) and allowed internal discussions in subgroups before providing space for groups to present their viewpoints in

Added value	Example supporting quote from interviewees	Frequency
Greater accountability	The system showed potential to improve accountability through access to accurate information about who has responsibility for shipments, and how can this information be trusted. The system offered traceable accountability. All actors could see the current step of the shipment. Handover documentation was cryptographically valid. Transfer of ownership was transparent, so, for instance, we could see who was responsible for the shipment of which pint in time	18
Greater visibility	The technology provided accurate status reports on the provenance, use-by-dates, location and transfer of products. It was simple to see who has goods at any time. We tested a scenario where each agency could update a shipment’s status, while everyone in the chain was able to check or verify what is happening to it without using middlemen	14
Greater traceability	The blockchain network gave controlled access to information, allowed different permissions for those accessing supply chain data as needed. It also removed the need for separate reconciliation procedures among different participants that could demand verification. This greater traceability in a broader perspective could reduce opportunities for fraud and theft	13
Trust	[Commitment trust:] Our aim was to empower the users to have as much control of the most critical parts of the supply chain as possible. This was partly to ensure trust in the system and partly to communicate clearly to the user exactly what information comes onto the blockchain [. . .]. We could observe that real-time information about custodianship and accountability improved trust for key actors in the supply chain [Swift trust:] The system increased user trust with a transparent tamper-resilient system for recording consignment and handovers as well as geolocation data	11
Reduced administrative costs and improved time efficiency	The smart contracts protocol over the blockchain helped to complete at the necessary stages within the supply chain. I can envision that in a scaled application the blockchain could reduce administrative costs, save time and minimize the risk of disputes	8

Table 1. Added values of applying blockchain to HSCs derived from the case study

all-groups discussions. To ensure effective discussions inside subgroups, we tried to have a balanced composition of expertise and experience in each group as far as possible.

The discussions during focus group sessions were considered sufficient as we achieved theoretical saturation: The participants' opinions converged, and we concluded that further discussions would not bring incremental benefit to the theory (Rowlands *et al.*, 2016).

3.2 Further exploration: the case study

To capture a more complete, holistic and contextual understanding of how blockchain can be applied to the HSC, we used the qualitative case study methodology and followed Vega's (2018) framework. Case study research has been frequently recommended in the HSC literature. It is considered a powerful method to explore real-world examples (Vega, 2018) and bridge the gap between HSC research and practice (Kovács and Moshtari, 2019). Yin (2018) refers to the case study as an empirical inquiry investigating a contemporary phenomenon in depth and within its real-life context.

Vega's (2018) framework contains four stages. First, the "why" stage concerns defining the case study's purpose explicitly. As mentioned before, our purpose is to capture a better understanding of applying blockchain in the HSC.

Second, the "what" stage relates to the contextualization of the research method explaining the unit of analysis, including the organization, project and country. For our research, we used the Humanitarian Supply Blockchain pilot project (thereafter referred to as "pilot") as the case. The project consists of building a blockchain-based system to track a sample shipment of plastic sheeting shelter kits from an offshore warehouse in Pakistan through multiple logistics service providers to Dubai where they are assumed to be needed. The pilot was jointly launched by Palladium (a social enterprise), Datarella (a private software company), NRS Relief (a supplier in the HSC) and DFID (a donor). We acknowledge the limitations of the pilot as issues for warehousing and eventually dispatch to areas in need (i.e. last-mile distribution) were not involved. We elaborate on such limitations in Section 5.3.

Third, the "how practically" stage presents the rationale for selecting the case as well as techniques for data collection and analysis. Our rationale was twofold: (1) To the best of our knowledge, the selected project has been among the very few pilots for using blockchain in the HSC that has passed the concept phase; (2) despite its limited scope, the pilot provided baseline evidence about how blockchain can be utilized in multi-stakeholder HSCs.

The data for this case study were collected via 10 semi-structured interviews involving senior-level managers and technical experts (details of interviews are given in Appendix 4). The interviews were conducted anonymously to encourage honesty and candid perspectives. We used Skype, and all interviews were digitally recorded, transcribed and sent back to participants for potential comments. Each of the discussions lasted between 30 and 50 min and was loosely guided by an interview protocol with four questions (cf. Appendix 4). Departures from each conversation's agenda were permitted in the interest of exploring new and potentially fruitful points. To ensure triangulation among various points of view (Yin, 2018) and reduce subjectivity, we asked interviewees the same question to determine whether and to what degree their responses were in agreement. The discussions' format was adapted and changed slightly from one discussion to the next to pursue exciting and particularly relevant new facets of the case study as they emerged. Finally, following Yin (2018), particularly relevant quotations were extracted from the interviews and presented in Appendix 4. The small sample size for the interviews conducted relates to the small scale of the pilot project; we could find only a limited number of relevant experts. However, within 10 interviews with key actors, we achieved theoretical saturation and concluded that further interviews would not bring incremental benefit to the theory (Rowlands *et al.*, 2016).

Fourth, the "how conceptually" stage relates to the extent to which the case is built and discussed concerning theory. We discuss our case study findings in Section 5. In Appendix 5, we provide details on how we used leveraging screens in our research for conducting a rigorous case study research. We followed Elo *et al.*'s (2014) checklist for trustworthiness.

4. Findings from the focus group

As explained in Section 3.2, we first asked the focus group to rate the relevance of drivers and barriers using a seven-point Likert scale. Figures 2a and b show average scores for drivers and barriers calculated based on the responses. We used the figures to stimulate discussions during the focus group work session.

Figure 2a depicts that visibility received the highest score among main drivers. This result is compatible with findings from other research that stress the potential of blockchain for improving visibility in SCs in general (e.g. Prashar *et al.,* 2020). In the context of HSCs, the result can be partly related to the fact that HOs have been under mounting scrutiny in recent years to increase visibility over their SCs (Besiou and Van Wassenhove, 2020). Meanwhile, pressure from donors and/or other actors ranked lowest. In fact, HOs are often not subject to the peer pressure from their competitors as of what commercial companies often face in the business sector (van Hoek, 2019).

Figure 2a also shows motives to improve accountability, traceability and trust among the top-five-ranked drivers. Interestingly, these drivers relate to the critical challenges of IS in HSCs as described in Section 2.1. Moreover, questionnaire results do support enhancing cross-sector partnership and collaboration as relatively important driver for applying blockchain technology to HSCs. The importance of blockchain to facilitate trade and collaboration in SCs in trust-less environments has been notably discussed in the commercial literature (e.g. Wang *et al.*, 2019). The fact that this driver received a relatively lower score compared to the top-five drivers could refer to the lack of experience in the field regarding the added value of blockchain in the HSCs, as noted by Coppi and Fast (2019).

Figure 2b shows the average scores for barriers (and challenges) of applying blockchain to HSCs. We acknowledge that respondents found all barriers to be quite important as the minimum average score (3.2) depicted (also referring to the fact that the difference between minimum and maximum scores is not huge). The three highly scored challenges referred to the limited resources at HOs to apply the technology, costs-related issues and privacy concerns. Moreover, the results confirm the relative importance of change management issues and engagement problems as other impeding factors as noted by Coppi (2020). Another important observation from Figure 2b is that respondents recognized integration issues (including management support) among the least important barriers. This is opposed to Baharmand and Comes's (2019) findings and probably reflects the shift in HOs top management levels toward exploring new technologies and approaches to address HSC challenges (Zwitter and Bosse-Despiaux, 2018). Another potential reason could be that management is eager to offer support to pilots when they are grant driven, however, same support might stall when it is the time for real integration, as proven by the fact that very few blockchain pilot projects in the humanitarian sector has moved beyond that stage (Coppi and Fast, 2019).

Interestingly, the barrier "complexity of implementation in downstream" received the lowest score from the list of barriers in the questionnaire. As we discussed this outcome in the focus group, some participants suggested that the divergence could relate to the shortage of public evidence regarding lessons learned and challenges faced in humanitarian blockchain projects. We will show later in Section 5 that, at least in our case study, complexity of implementation in downstream was among the most important challenges that actors faced.

Surprisingly, the technology itself attracted a fair share of criticism in our focus group discussions despite participants noted the potential utility of blockchain to address HSC issues. The technology complexity has been noted in the literature as a main barrier (Sahebi *et al.*, 2020). This can probably explain why barriers for applying blockchain to HSCs received

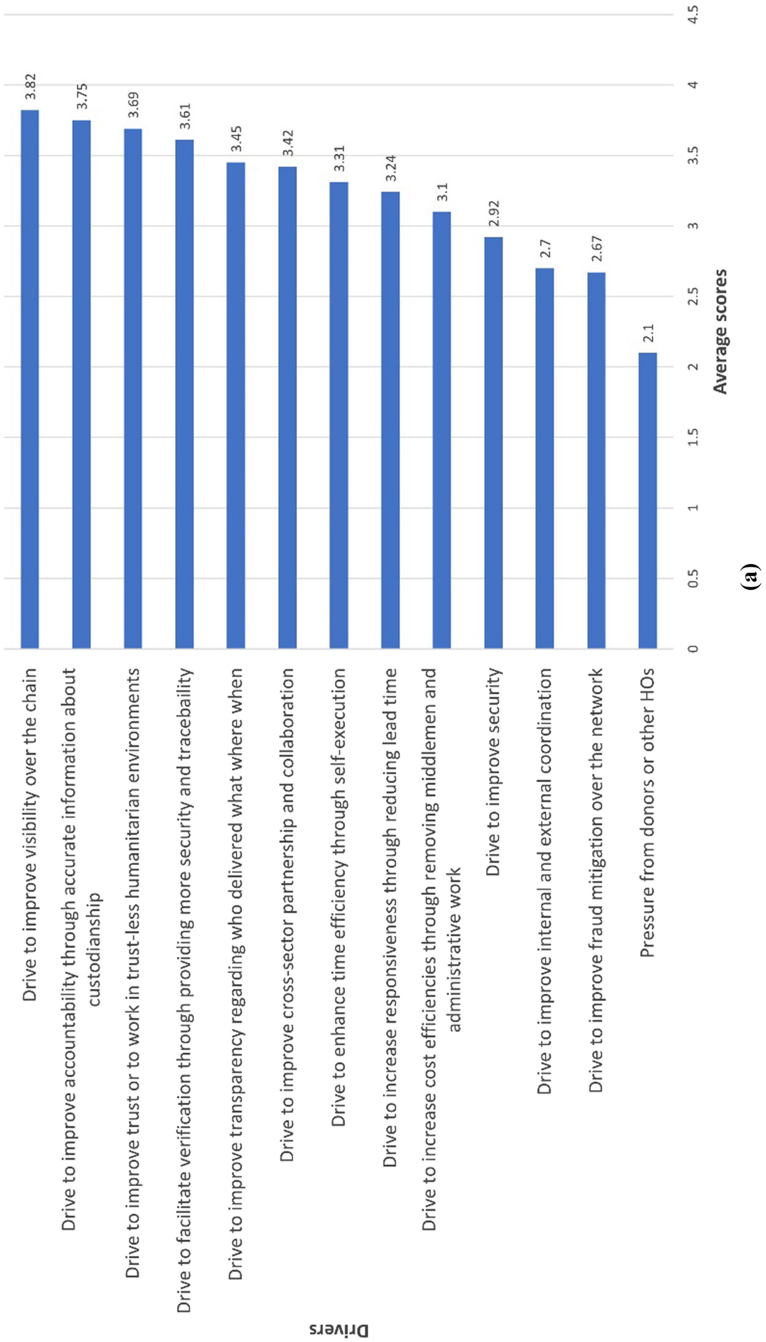


Figure 2.
Average scores of drivers (a) and barriers (b) for applying blockchain to HSCs

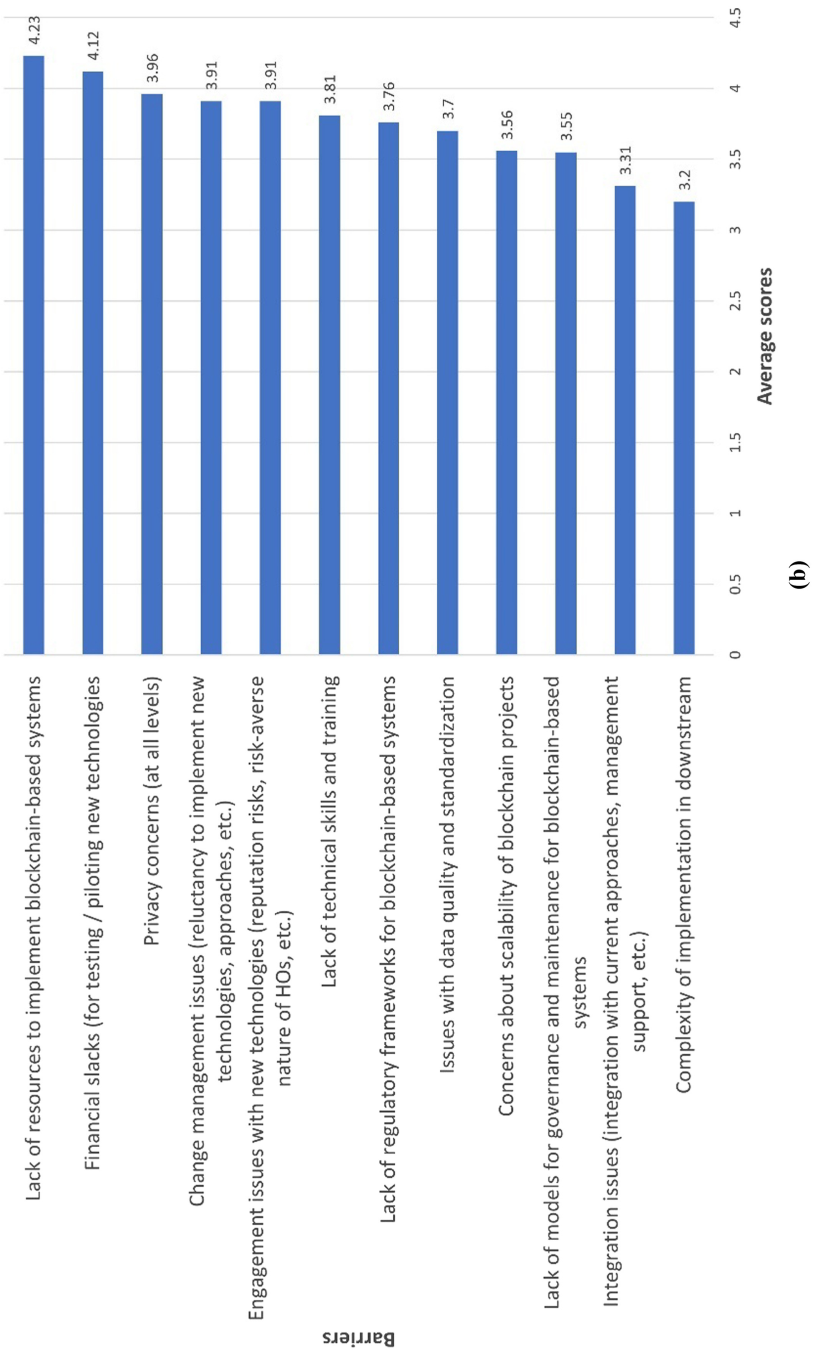

Lack of resources to implement blockchain-based systems
Financial slacks (for testing / piloting new technologies
Privacy concerns (at all levels)
Change management issues (reluctancy to implement new technologies, approaches, etc.)
Engagement issues with new technologies (reputation risks, risk-averse nature of HOs, etc.)
Lack of technical skills and training
Lack of regulatory frameworks for blockchain-based systems
Issues with data quality and standardization
Concerns about scalability of blockchain projects
Lack of models for governance and maintenance for blockchain-based systems
Integration issues (integration with current approaches, management support, etc.)
Complexity of implementation in downstream
Barriers
4.23
4.12
3.96
3.91
3.91
3.81
3.76
3.7
3.56
3.55
3.31
3.2
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
Average scores
(b)

Figure 2.

relatively higher scores than drivers in the questionnaire results (compare Figures 2a and b). As some participants highlighted, HOs, like most large bureaucracies, tend to be risk-averse and slow to innovate. Therefore, HOs are afraid to struggle in overcoming concerns about governance and operational resilience when shifting from legacy systems to a blockchain-based network. Some participants argue that there are currently no real incentives for HOs – especially large HOs – to abandon legacy systems.

Furthermore, an interesting barrier emerged from the open text of the questionnaire and the third discussion round in the focus group (cf. Appendix 4). We name the barrier "unfamiliarity with the blockchain". This is in line with Coppi and Fast's (2019) study that refers to a "lack of good understanding among HOs regarding what blockchain is, how it can be designed, and for what purposes it can be used beyond the hype". In our study, different respondents referred to the lack of understanding through distinct constructs such as (1) lack of understanding about blockchain requirements, (2) ambiguities about the blockchain design and (3) unfamiliarity about potential benefits. Our respondents did not converge to any concrete score for this barrier; however, they agreed that the impact can be high.

5. Findings from the case study

In this section, we elaborate on the evidence concerning the added values and challenges of blockchain application in HSCs derived from the case study. The information about the scope and context of the case study is provided in Appendix 3. Interview protocol and interviewees details (I1–I11) are given in Appendix 4.

Table 1 presents the evidence samples from our interviews concerning the added value of blockchain application to HSCs. The added values are ordered based on the frequency that our interviewees referred to them in conversations. The frequency of reference has been used in our study as a measure to roughly assess the importance of factors.

As Table 1 depicts, enhanced accountability was the frequent added value that interviewees mentioned for the HSC blockchain pilot. This is in line with the goals that project stakeholders set in the beginning of the pilot, according to the pilot's report (DFID, 2019). Trust was the fourth frequently mentioned construct in our interviews. However, we should note that the frequency of trust presented in Table 1 refers to a mix of evidence regarding the commitment trust (8) and swift trust (4). While commitment trust is based on contractual agreements, rules, processes and procedures between the parties, swift trust often occurs in temporary teams based on contextual cues. Apart from improved visibility, traceability and trust, increased time and cost efficiency were also mentioned rather frequently in interviews. The latter was due to the capability of implemented blockchain-based smart contracts to eliminate paper-work and administrative delays. Our case study findings regarding the contribution of blockchain application to HSCs supports focus group discussions about drivers. Accountability, visibility and trust were among the keywords of the top five highly ranked drivers (cf. Figure 2a).

We found evidence for other added values of blockchain applications to the HSC in our interviewees as well, although their repetition frequencies were lower than five times, such as *improved collaboration* (four times) or *reduced opportunities for fraud and theft* (two times). Interviewees from DFID collectively referred to observations for decreased shrinkage and better collaboration opportunities. An interviewee (I6) referred to the main success factor of the project as the fact that three separate organizations could work on the same tracking system simultaneously. Moreover, two interviewees stressed the enhancements concerning the material flow. One interviewee referred to the smooth movement of items and mentioned that "*the shipment flowed like expected, the last handover was frictionless, and all goods arrived safely (I5)*". Surprisingly, we found no evidence from interviews that could support focus group discussions regarding the contribution of blockchain to improve security and to reduce lead times in HSCs (cf. Figure 2a).

Although most interviewees referred to the pilot as a success (e.g. "*the pilot demonstrated a successful trial of the technology (I1)*"), all of them agreed that the exploration was not challenge free. Interestingly, we found that the number and the frequency of mentioned challenges were more than similar figures for added values. The three top frequently repeated challenges in interviews were low engagement level (14 times), lack of technical skills and training (14 times) and various issues with downstream implementation (13 times). For detecting other important challenges of blockchain application to HSC in the pilot, we used a threshold of minimum five-time repetition frequency in interviews. The identified important challenges include integration issues, lack of resources, privacy concerns, regulatory problems, governance issues and data accuracy problems. Details about the evidence that support challenges are provided in Appendix 4.

Interestingly, case study findings about challenges and focus group findings about barriers support each other to some extent. Highly ranked barriers in the focus group discussions such as lack of resources, privacy concerns and engagement issues were identified as important challenges in the pilot project, too. However, there are two important divergences between findings from the two methods. First, issues with downstream implementation (one of the top four challenges that practitioners experienced in the pilot) is the lowest ranked barrier discussed in the focus group discussions (complexity of downstream implementation). Moreover, the barriers financial slacks and change management issues (the second- and fourth-ranked barriers in focus group discussions, respectively) were not among the identified challenges in the pilot project at all. Although the specific reasons are unclear, this could eventually be a consequence of the small scale of the pilot project. We discuss some of the discrepancies between findings in Section 6 and explain the rest of them in Appendix 6.

We found evidence about some less frequently mentioned challenges in interviews that have also been rarely noted in the literature about blockchain in SCs. They were issues related to interoperability, intellectual property and trade-offs between features of the envisioned system. We explain these barriers in Appendix 4.

6. Discussion and implications to theory and practice

In this section, we first answer our RQs while discussing the cross-method findings. Then, we elaborate on the theoretical contributions of the research. Thereafter, we explain the implications for practice and limitations of our study.

6.1 Discussion on cross-method findings

RQ1. What are the key drivers and barriers of blockchain application in the HSC?

We discuss cross-method findings starting with the first RQ regarding the main drivers and barriers of blockchain application to HSCs. Main drivers include accountability, visibility, traceability, trust, collaboration, time efficiency, reducing administrative work and cross-sector partnership. Main barriers, however, are composed of engagement issues, lack of technical skills and training, lack of resources, privacy concerns, regulatory problems, pilot scalability issues and governance challenges. We selected main drivers and barriers from those factors that were tagged as important in both focus group findings and case study findings. When we observed any discrepancy between the importance level between focus group and case study findings, we prioritized case study findings. Our rationale refers to the evidence from the real-world project that could support the case study findings. Detailed descriptions of discrepancies are provided in Appendix 6.

For drivers, cross-method analysis shows that the top main drivers could be accountability, visibility, traceability, trust and collaboration although they should not be considered as equally important. The list of main drivers is in line with a few available research in HSC literature that have discussed drivers for blockchain adoption in HSC. For instance, Rodríguez-Espíndola *et al.* (2020) suggest blockchain to resolve the lack of accountability in the HSC, and Dubey *et al.* (2020) refer to drives to improve trust and collaboration in the HSC. The different significance of drivers was evident when we compared focus group and case study findings. For instance, the drive to "improve visibility" received the highest average score among all drivers for blockchain application to HSC in our focus group discussions, while it was the second frequently construct in our interviews. Based on insights that we received from participants and interviewees, we think that the importance of drivers could be context-dependent (e.g. size of HO, target locations of HO, target cluster of HO, etc.).

Moreover, there are some literature-derived motives that either (1) were ranked of moderate or low importance in findings from both methods or (2) we could not validate in our study. Regarding (1) we specifically highlight the driver to enhance cross-sector partnership (moderate score). Previous studies have referred to this motive as an important driver (e.g. Baharmand and Comes, 2019). This holds true for drivers "reduce administrative work" and "time efficiency". Since these drivers have been cited in the literature and we found some evidence in our findings to support their moderate importance level, we added them to the list of main drivers.

Concerning barriers, an interesting observation is that "engagement issues" was found by our interviewees as one of the main challenges of the pilot project. Meanwhile, we found that collaboration was among the important drivers of blockchain application to HSCs. SC collaboration is the capability to define a problem, to make joint decisions, to properly assign key roles and responsibilities to each partner, where two or more organizations coordinate closely to plan and execute supply chain operations toward common goals and mutual interests (Moshtari, 2016). Engagement is identified connecting to the massive need for collaboration among multiple actors. Even though initiative supports lead to the improved collaborative performance, a lack of unanimous agreement exists between partners, as each partner is used to work independently. Interviewees from the consultant company mentioned that HOs are often reluctant to provide their feedback or support to test a new technology.

Form the list of main barriers, the importance of regulatory problems and lack of technical skills and training has been noted in the literature. Sahebi *et al.* (2020) identify "regulatory uncertainty" and "the lack of knowledge/employee training" as the most important barriers. However, there is no consensus in the literature about the importance of "privacy concerns". Patil *et al.* (2021) recognize "data privacy, ownership and security issues" as a significant barrier, while Sahebi *et al.* (2020) categorize "privacy risks" among the least important barriers. The importance of barriers is a critical aspect for practice as HOs need to prioritize and develop mitigation plans to address issues accordingly. As such, the divergence between the importance levels could be misleading.

Among the main barriers, to the best of our knowledge, the barrier "lack of resources" has been vaguely discussed in the literature. The term "resources" also covers the knowledge on what resources are required for the blockchain, budget, cost of the pilot and implementation, skills, know-how, training, and quality data. Since the blockchain application is in its early stage, the survey results show that there is lack of knowledge on what resources are required for the blockchain application among the multiple actors including the government, HOs, beneficiaries and local communities. Patil *et al.* (2021) partly refer to this barrier through the barrier "technological complexities" and rank this barrier as a relatively high influence factor. In our case study, some interviewees connected the resource issues with the size of organizations and their affordability to use the technology. To address the barrier, Patil *et al.* (2021) call for synergetic cooperation between blockchain developers, donors, HOs and other HSC stakeholders. Similarly, the academic participants of our focus group noted the opportunities to use available resources from the business sector through effective collaboration. However, we noted that practitioners were somewhat reluctant in supporting cross-sector partnerships, and they commonly referred to different working language and norms. Interviewees commented that the barrier is not new to the sector, but issues with cross-sector collaborations are yet to be solved gradually.

Although the pilot scalability issue and governance problems received moderate scores in the focus group discussion (possibly due to a lack of understanding about the technology and its implications, Coppi and Fast, 2019), the case study showed that they could be important impeding factors to consider. In this regard, our case study findings support existing literature. For instance, Demir *et al.* (2020) note the governance of the blockchain system as a remarkable implementation issue and contend that "even Bitcoin blockchain has a team that develops the software and maintains the system". In our case, interviewees remained vague in answering questions regarding the likelihood of a scale-up of the project and governance problems. Interviewees provided insight on the fact that the level of interest expressed by HOs is still low, as large HOs want to experiment with their projects first. Experts noted that blockchain is very much in its ideational and infancy stage.

RQ2. Could evidence support that the application of blockchain improves transparency and trust in HSCs?

Given the definition of transparency that we follow in our study (cf. Section 1), we examine the added value in terms of transparency through the contribution of blockchain to visibility and traceability. We note that visibility received a high average score in our focus group discussions. Improved visibility was also among the top frequently mentioned added values of blockchain application to HSC in the pilot in our interviews. In the business literature (e.g. Caridi *et al.*, 2010; Wang and Wei, 2007), several conceptual measures have been introduced to assess the SC visibility such as evaluating information exchanges within the SC. Caridi *et al.* (2010) focus on the quantity and quality of information communicated to stakeholders according to timeliness and accuracy. Wang and Wei (2007) investigate information visibility according to process (e.g. production status) and completeness of information provided to or received from stakeholders. Our interviewees referred to the information completeness as a given feature in the pilot since all partners knew each other before engaging into the pilot: There was an agreement of what is supposed to be shared with stakeholders on the blockchain-based system. In the meantime, interviewees commonly agreed that the timeliness, accuracy and process-related features of information were considerably improved in the pilot. The main added value about visibility was that pilot partners could access information related to operations of the entire HSC in the pilot, besides the activities in which they participated. However, interviewees acknowledged that the benefits of using blockchain to improve visibility in a scaled project (with several participants) can hardly be realized through a private architecture. Several scholars have criticized the use of private-permissioned blockchain in humanitarian projects (e.g. Baharmand *et al.*, 2021) as these solutions make it unclear who is the real beneficiary of the enhanced visibility. As one focus group participant mentioned, "*we must be clear that the benefits occur to the HOs, not [to] the beneficiaries or end users, who may not even know that blockchain is being used.*" Interviewees found public protocols a more reliable and attractive option for HSCs, although it should be noted that having publicly available immutable record of all actors in a blockchain network might produce undesired consequences for HOs responding to politically sensitive crises.

Compared to traceability, we note that SC visibility is relatively a new stream in the literature (Sodhi and Tang, 2019). The research on the impact of blockchain on SC visibility is therefore scant. In the business literature, some studies have suggested to measure the SC traceability by focusing on the ability of the system to capture, store and transmit adequate information that enables the product to be checked for safety, quality control and location at any point in the SC (Morgan *et al.*, 2018). Several quotes from interviewees show that this ability was significantly improved in the pilot. Interviewees from consultant partner admitted that in the humanitarian sector, due to organizational changes over time, large HOs might have between 50 and 80 legacy enterprise resource planning systems, which often do not easily communicate with one another and may even differ in how they define data fields. This makes traceability a huge challenge to solve in practice. However, in the pilot project, if a partner had discovered a faulty relief item, the blockchain could enable the HO and other partners to trace the item, identify all suppliers involved with it, identify production and shipment batches associated with it and efficiently recall it. Our interviewees admitted that in the pilot project, data concerning the shipped relief items were recorded on the blockchain manually, which could challenge quality control in real operations. However, some interviewees highlighted that a blockchain-based HSC (combined with Internet of things) could record any fluctuation (for instance with respect to temperature) and allow partners to monitor quality automatically. This is specifically relevant for HOs since perishable relief items are often included in humanitarian disasters response.

Concerning trust, to the best of our knowledge, there is no consensus in the literature regarding how to measure the concept in HSC. We use the highly cited Stephenson's (2005) conceptualization of trust in disaster relief operations as a foundation to understand and measure trust in HSC. Based on the typologies provided earlier by the commercial research, Stephenson (2005) recognizes four types of trust namely companion, competence, commitment and swift. Accordingly, Dubey *et al.* (2019) contend that commitment trust and swift trust are more applicable to hastily formed HSCs in disasters response. Commitment trust is based on contractual agreements, rules, processes and procedures between the parties which can be both verbal and written. Swift trust is a form of trust occurring in temporary teams based on contextual cues (rather than inter-personal ties), particularly when there is time pressure or achieving project goals is of great importance. Regarding the impact of blockchain on trust, literature suggests that blockchain has a significant effect on swift trust (e.g. Dubey *et al.*, 2020). Our study confirms such an effect, although our interviewees referred to commitment trust more than swift trust. This could be due to the smart contracts feature of the blockchain application in the pilot which facilitated trade and follow up in the project. Concerning swift trust, interviewees highlighted the easy access to the "time-stamped" and "encrypted" information stored on the "decentralized", "permanent", "searchable", "immutable" records repository which in-principle should improve building rapid trust between HSC actors in real-world humanitarian operations. Moreover, Dubey *et al.* (2020) found a direct link between transparency and swift trust. In our study, the evidence from the pilot showed the added value of blockchain to increase HSC transparency (through enhancing visibility and traceability). Thus, we conclude that the blockchain had added value to improve swift trust as well.

6.2 Contributions to theory

Based on our results, we can argue that our study offers some useful contributions to theory. First, there is an agreement in the literature that blockchain adoption in HSCs can offer several performance improvements; however, to date, little is known about what the real added values and challenges of blockchain application to HSC can be. Due to high uncertainty and dynamics of HSCs, visibility and data tracing have proved to be challenging (Altay *et al.*, 2018). Some researchers propose that blockchain holds promise to enhance SC visibility and data tracing, and therefore, it has potential to improve HSC transparency in HSC. However, Dubey *et al.* (2020) call for evidence-based studies with multiple methods to further examine the added value of blockchain to HSC. Findings from our evidence-based study clearly suggest that blockchain can improve transparency and trust in HSC.

Second, our study contributes theoretically to the contingent RBV. The successful application of the blockchain to HSCs is contingent depending on certain contextual barriers and challenges such as access to and availability of resources, the quality of technological infrastructure, local knowledge and literacy and regulatory issues. Barriers are considered as contingent factors that HOs need to take into account for the blockchain application. Previous research shows how relief operations along HSC were constrained with certain barriers. These constraints included, but were not limited to, the unpredictable dynamic environment, fluid and uncertain information, demand–supply risks, poor planning for prepositioning of supplies and more importantly the lack of advanced technological infrastructure (Mishra *et al.*, 2020).

Moreover, our research contributes to a more nuanced understanding of implementation considerations and creates a perspective for HSC scholars. Our findings reflect that literature and theoretical works often put much weight on the drivers rather than barriers when discussing blockchain applications in HSCs. However, our case study findings (the number and the impact of) indicate that challenges with respect to engagement, skills, resources, privacy and governance can be critically important. Since drivers and barriers can evolve and change from one project to the other, we intend to reinforce the relevance of detailed investigations of pilot projects in future studies to provide pathways for the scaled implementation phase.

6.3 Implications for practice

Our research has several implications for practice. First, we provide lessons from the proof of technology stage of a real case showing that blockchain can contribute to the accountability, visibility, traceability and trust in HSCs. Our research grounds findings in an empirical study. As such, this study provides first insights for practice beyond the many conceptual research, literature reviews, blog posts and studies that consider (publicly available) high-level use case descriptions only. We provide new insights by discussing drivers and barriers with practitioners interested in blockchain technology through a structured focused group discussion. Moreover, our case study is among the first ones in the HSC literature that goes deeper into the implementation process of blockchain in HSCs.

Our study proves with evidence from the field that there are still several barriers that need to be addressed for the effective application of blockchain to HSCs. Although we cannot neglect the added value of blockchain for improving accountability, visibility, traceability and trust, we think that probably traditional centralized file-sharing systems are currently more efficient and better IT solutions than a relatively complex private permissioned blockchain-based system for HSC. Some interviewees referred to the pilot as "an overengineered solution for targeted objectives". That said, we suggest that the decision regarding whether to use blockchain or not should follow a detailed assessment workflow in the chain and among (all) the SC actors. After such an assessment, as suggested by focus group participants, piloting blockchain is among the best alternatives to explore the added values and assess trade-offs. While we received no reference data, two interviewees from commercial partners of the project confirmed that piloting blockchain in HSCs with limited number of actors (maximum five) can be relatively easy and inexpensive.

7. Conclusions

Humanitarian assistance is marked by large numbers of actors and agencies with different mandates, objectives, systems, data sets and processes. As these actors rush to help alleviate the sufferings of disaster-affected people in the shortest time, the result is usually a lack of end-to-end visibility and traceability plus fragmented and opaque HSCs prone to delays and waste and corruption. In HSCs, trust and transparency are often low, which hinders effective and efficient operations through interorganizational collaboration and coordination and requires expensive and cumbersome extra layers of scrutiny and accountability. This paper explores the application of blockchain technology in HSC to address transparency and trust issues through a multimethod approach: a focus group with multiple practitioners interested in the technology and a case study of DFID's Pilot project. We outlined a validated list of drivers and barriers (cf. Section 6.1) and provided evidence concerning blockchain had shown added value to improve HSC transparency and trust in practice. To the best of our knowledge, our study is the first to empirically explore blockchain application to HSCs. It contributes to the operations and supply chain management by adding empirical findings beyond the scope of available research.

Our research opens some future research avenues as well. First, our study is based on insights and opinions of a limited set of experts. We acknowledge that experts came from large HOs in a tech-wealthy region, while in other organizations or countries, the different access to resources, partners, skills and knowledge could result in a different perception of bottlenecks, deficiencies and points-of-improvement. As such, one future research direction could be to involve more experts. Second, we could study only one pilot project and were not able to cross-check the findings with other deployments. To the best of our knowledge, we studied what is considered the only known blockchain-based HSC case. As DFID advances their project into scale or other HOs implement similar projects, there would be an opportunity to learn more through expanding the number of cases or exploring the implementation in other geographic areas or scenarios. Third, we found some discrepancies between the findings from the two methods and the literature that should be further explored. Fourth, drivers and barriers in HSC downstream should be studied separately. HOs face several challenges in the downstream part of HSC, which interestingly was not in the scope of the studied pilot but seemingly planned for a future project (DFID, 2019).

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Appendixes

The Appendix file is available online for this article.

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