An analysis of blockchain technology for improved performance in humanitarian logistics

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Abstract

This paper analyzes the impact of blockchain technology on commercial supply chain management and reveals improvement potentials for humanitarian logistics processes. Motivated by overcoming certain inefficiencies of today's disaster response, the paper presents application areas in humanitarian logistics that could substantially benefit from blockchain implementation. In terms of methodology, this article is based on case study research including secondary data from 18 supply chain use-cases. Results of cross-case analysis indicate, that blockchain technology not only brings added value to commercial supply chains but could also lead to profound changes in the humanitarian sector.

Keywords: Humanitarian logistics; blockchain technology; case study research.

Introduction

As blockchain technology is not only the foundation of every cryptocurrency (e.g. Bitcoin), it has recently been attracting significant attention in various other financial and non-financial industries (Di Pierro, 2017; Guo and Liang, 2016). Used in digital identification, block-chain based voting or product tracking, this technology seems to be a breakthrough in information exchange and data security in particular for supply chain management (SCM) (Pilkington, 2016). Aside from making lucrative investments in digital versions of fiat money (e.g. Bitcoin), it seems that the real disruptive characteristic of this new technology is widely underestimated. Experts not only see a massive impact on the financial sector but also revolutionary effects on technology, industry and commerce (Lee and Pilkington, 2017). From a non-technical perspective, blockchain is a system that allows interaction and coordination between partners without a central controlling body. Here, transactions between partners are validated and processed based on consensus of all contributing entities in a distributed peer-to-peer network (Figure 1)

(Crosby et al., 2016). This mechanism allows transactions even between partners that do not trust each other at all (Sadiku et al., 2018).

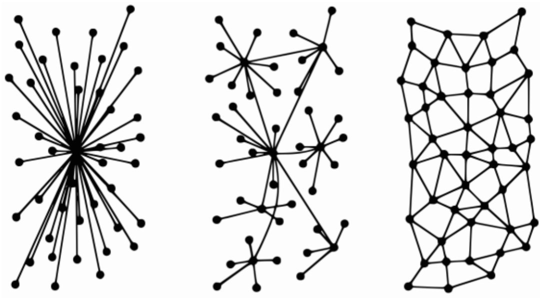

Figure 1. Network types

This trust-free environment, which blockchains provide, enables all parties in the system to keep a record of transactions (=blockchain) and to verify that transactions have not been tampered with (Di Pierro, 2017). In a wider technical sense this means if a user initializes a transaction, the transaction data is encrypted and verified by other users via cryptographic algorithms. Once there is a consensus of users that the transaction is valid, a data block is immutable added to the previous one in the chain and made available on the network (i.e. database) (Underwood, 2016). Using this consensus mechanism ensures that each member's view of the shared database is inline with the view of all others. Following this approach it is easy to detect and reject manipulated, incorrect or forged transactions from the users. The combination of consensus mechanisms and a certain type of data structure mitigates the double-spending problem (reproducing and transferring the same document multiple times) without third-party involvement (Hileman and Rauchs, 2017). Aside from security and trust issues, blockchains increase system transparency by enabling users to traverse through the entire chain of blocks and see every single transactions every made (Beck et al., 2016). Transparency in this kind of system architecture guarantees that all users can collectively verify and validate transactions, thus uncovering and excluding malicious network members (De Filippi, 2016).

Blockchains not only seem to have disruptive effects on the commercial sector, as they could also lead to profound changes in humanitarian logistics (HL). The critical need for introducing innovative information and communication technologies (ICT) to HL activities, i.e. relief items procurement, transport and warehousing, is indispensable due to existing impediments that hamper the efficiency of disaster relief. Here, performance impediments are primarily reflected in humanitarian organizations' (HOs) competition for funding, low levels of cooperation and information sharing, coordination failures and corruption, as it was observed in various response missions to mega-disasters of recent years (Trestrail et al., 2009; Schultz and Søreide, 2008). A massive lack of trust between HOs, caused by the fight for scarce resources, makes them to take decisions quite independently from each other, sometimes resulting in decision-making failures (Eftekhar et al., 2017). Taking erroneous decisions based on incorrect or insufficient information often leads to redundant actions on the ground, duplication of procurement efforts and multiple relief items supplies to single disaster regions, though demand was already covered by first responding HOs (Paul, 2006; Thevenaz and Resodihardjo, 2010). As HOs are permanently confronted with financial limitations, spending donations on supplying already covered demand locations restricts them in their scope of action for future disaster relief missions. With the increased call for introducing higher levels of trust and reciprocity between HOs, the need is given to find and introduce alternative technologies such as blockchains. The advantages of blockchain technology, i.e., increased transparency, traceability, security etc. allow to overcome some of the existing deficiencies and therefore need to be studied in detail. Motivated by paving the way towards improved humanitarian assistance we first dig into the benefits of blockchain technology in SCM and afterwards analyze its potentials for improved HL performance. Therefore, we have formulated the following research questions:

RQ1: In which areas of SCM are blockchains already in use and what are the generated benefits?
RQ2: How could blockchain technology benefit HL processes?

This paper is structured as follows: First, we draw the readers' attention to already existing academic literature in the field of blockchains in SCM and HL. Afterwards we point to the applied methodology in this paper, i.e. case study research, including research structure and case descriptions. Finally, the results of the paper are presented, followed by a discussion on the topic and an outlook to future research.

Related literature

A Web of Science search for papers that include the term "Blockchain" in the title results in only 198 papers that were published from January 2015 to April 2018 in academic journals. This underlines the fact that this field of research is still in its infancy and definitely defers intensified academic attention (Web of Science, 2018). Narrowing down this number of publications to the ones which purely concentrate on blockchain aspects in SCM and/or HL leads to a very limited number of relevant contributions. Kshetri (2018) analyzed the impact of blockchain application on various performance dimensions (cost, speed, dependability etc.) on the basis of numerous use-cases of different industries. The author found out, that blockchains could potentially reduce costs (e.g. reduce paper records, more efficient resource management) and risks (e.g. only accepted parties in the system interact with each other). Besides, this technology could enhance dependability (e.g. blockchain-based digital certifications), sustainability and flexibility along supply chains due to increased consumer response. The impact of blockchains on other industry markets is studied by Mengelkamp et al. (2018). By using simulation modelling they test blockchain technology as a new market approach in energy systems and also found out that blockchains have positive effects on costs (decreased total electricity costs for local agents), transparency, reliability and equality of agents. Among all the good things, they also mention negative effects of blockchains, pointing to scalability issues, technological hurdles and social apprehension towards new technologies. A more generic list of potential blockchain application areas is given by White (2017) and Swan (2017) who presage a blockchain revolution in digital asset registries, long-tail personalized economic services, payment channels and peer banking services. Moreover, they discuss blockchain application in performance measurement systems, consumer review and due diligence verification, medical bills payment or digital certification. According to Guo and Liang (2016), Paech (2017) and Ducas and Wilner (2017) the banking industry and financial SCM will experience significant changes with the introduction of blockchain technology. They argue that blockchains could redesign payment clearing and credit information systems, post-trade settlement, securities issuance and servicing and promote auto-executable financial transactions (i.e. smart contracts).

In the context of HL, blockchains were already discussed by Lee et al. (2017) and Mordini (2016) who see the potentials of blockchain usage for robust identity management applied for instance in refugee identification (ID) in disaster scenarios. Here, the combination of biometrics and blockchain technology serves as a solution for documenting or recovering lost IDs without the need of third-party involvement. Another blockchain application area is presented by Poblet et al. (2017) who propose blockchains to operate microtasking platforms. Such microtasking platforms are used to break down a large task into several smaller tasks that are completed by many people over the internet. Recent microtasking platforms have been run over blockchains where volunteer's contributions (i.e. donations) are recorded permanently without the risk of being misused or altered. Collecting donations more efficiently is in the research focus of Mohd Nor et al. (2017) who develop a blockchain that stores all transaction details of donors, vendors and beneficiaries. With this, a more transparent, trusted and secure network of relief is established which reduces the speed and cost for handling aid.

Methodology

Among the variety of scientific instruments available, case study research is an appropriate method for answering the research questions of this paper. It is a promising methodology for defining propositions and describing phenomenon within its real-life context - here blockchain technology for HL (Yin, 2003). In this study we follow descriptive case study research, due to the descriptive character of our research aim. The main source of information in this study constitute secondary data from 18 use-cases dealing with blockchain technology in SCM. A qualitative content analysis is applied to extract valuable information from the cases and to investigate blockchain benefits for humanitarian purposes. In order to structure the case study research of this paper, we follow the steps proposed by Stuart et al. (2002). According to the authors, case study research should be separated into five stages, i.e. definition of research questions, instrument development, data gathering, data analysis and dissemination. The first phase of their model belongs to the development of research questions, followed by the second step "Instrument development" that deals with the selection of representative cases including a precise description of each of them. Step 3 contains the collection of required data by means of open, (semi)-structured interviews, questionnaires, documents or direct observations. The fourth step (Data analysis) comprises the quantitative and qualitative content analysis by coding of information with special software. Finally, the results of the case study research are documented and disseminated to public (Stuart et al., 2002).

The developed research questions of our study reflect the descriptive character of this paper with the objective to explore blockchain application in SCM and reveal its positive effects on HL. Another vital step in every case study research is the selection of representative cases and appropriate interview partners. Representative cases reflect important elements, information and structures of the entire population in a sample deriving from the population. In this regard, a random selection of cases is not recommended due its inefficiency and risk of producing biased samples. Following the above mentioned prerequisites and the call for purpose-based case selection led us to apply the so called diverse case method. Aside from different case selection approaches, e.g. typical, extreme, deviant or influential, the diverse case method aims to maximize variance along relevant dimensions (Seawright and Gerring, 2008; Eisenhardt, 1989). As already denoted, this study relies on secondary data. The case selection process was initialized by performing a search in google scholar and google for use-cases of interest. With the developed search strings "Supply chain management AND use case OR business case; Supply chain AND use case OR business case" these platforms were scanned for press releases, white papers and corporate reports as the source of information for use cae analysis. The multiple case study sample comprises 18 cases from different industry sectors. Table 1 provides an overview about the use cases including the number of employees and annual sales in 2017.

Table 1. Case descriptions

Industry sector	Case	Number of employees	Annual sales (in US$ billion)
Aviation	C1	14,046	11.7
	C2	23,000	0.2
	C3	97,000	47. 2
	C4	35,488	9.8
Food	C5	2,000,000	500.3
	C6	60,000	133.7
Finance	C7	71,200	18.3
	C8	10,300	10.8
	C9	196,128	52.9
	C10	52,000	21.5
	C11	17,600	5.1
IT	C12	124,000	89.95
	C13	380,300	79.1
Mining	C14	26,146	38.2
	C15	43,000	14.3
Others	C16	88,000	31.1
	C17	364,445	263.8
	C18	138	0.012

The identified documents were then subjected to a process of coding using a coding software (NVivo 11). This coding procedure is used for a systematic and consistent investigation of qualitative data based on a previously defined set of dimensions (Runeson and Höst, 2009). Therefore, we developed a coding framework that comprises two coding families, i.e. application area and benefit (Table 2). Coding an interview protocol according to the families of Table 2 indicates that qualitative information from the documents is extracted and assigned to these dimensions. For illustrating the coding process, the appendix provides examples of qualitative information assigned to the dimensions of the coding scheme. Technically speaking coding means that a term or sentence which is relevant to the dimensions of Table 2, i.e. coding scheme, is marked by mouse action and assigned to a designated dimension. Afterwards the coding software assigns a code to this word. Once the extraction of qualitative information from the documents was done, we performed a cross-case analysis in order to identify potential patterns and structures in our findings. It should be noted that our aim is to generalize to theoretical concepts and not to populations, thus emphasis is put on analytical and not on statistical generalization (Juttner and Maklan, 2011).

Table 2. Coding scheme

Coding family	Description of codes
Application area	Coded as application area if blockchain technology is used in practice within a specific setting. For instance, if blockchain technology is applied for a specific purpose in aviation industry, food supply chain management or financial systems.
Benefit	Coded as benefit if the area of blockchain application gains certain advantages from its implementation. Here, benefits can be represented by reduction of costs, time etc.

Findings and discussion

Blockchain applications and their benefits in SCM

A cross-case analysis enabled the identification of structures and patterns in the results of the qualitative content analysis. According to theses results, blockchains are predominately applied in product authentication, product tracking and real-time and cross-border payments (Table 3). Now we discuss these areas of application in detail and point to the generated benefits. In the field of product authentication and track and tracing the clear advantage is the increased tractability of commodities (e.g. food, diamonds etc.) throughout the entire supply chain. Blockchain technology makes it easier to detect sources of contamination as it represents an indisputable and unchangeable chain of ownership transfers from the beginning to the end of the supply chain. Already applied in tuna supply chains, blockchains can increase customer satisfaction trough higher levels of transparency and the ability to real-time track food from the farm to the table. In addition, blockchains enable multi-party data acquisition and distributed file storage, whereby information can be exchanged in real-time, securely and seamless. Moreover, the use of digital signatures for smart contracts avoids the "double spending" of certificates and enables a robust proof of compliance to standards for all supply chain partners. A positive side-effect of digital contracts and signatures is reduced paper-work, which has a positive impact on ecological and economic dimensions.

Blockchain technology also promises to have a tremendous impact on financial supply chains. The elimination of centralized authorities, e.g. banking and financial institutions, with blockchain application facilitates direct transactions between partners without third-party involvement. Conventional money transfer with bank participation is typically more time-consuming and costlier compared to direct transactions processed by blockchain technology. The absence of back-office processes (e.g. contract negotiation including lawyers) in blockchain systems could save financial institutions at least $20 billion annually in settlement, regulatory and cross-border payment costs (Fanning and Centers, 2016). Faster payments by means of blockchains are realized by connecting the purchaser's bank directly to that of the supplier, at high levels of transparency and connectivity. Especially cross-border payments, that require long processing times, can be speed up through reduced settlement times in processing global payments. Currency exchange is no longer needed due to a financial transaction of digital money that is from the same type of currency (e.g. bitcoin, litecoin, and ripple) (Lindman et al., 2017). Other financial sectors, such as the mortgage business, could also benefit from automatically generated and transferred mortgage receipts via blockchains. Here, increased data consistency reduces costs and operational/reputational risks. Findings also indicate that identity verification for banking customers is simplified and made securer by blockchain application. While customer identities in an ordinary market are validated by centralized authorities (e.g. governments) at some degree of information leakage and risk of misused private information, the verification in a blockchain consortium is performed without disclosing of sensitive information (Catalini and Gans, 2017). With these beneficial features, blockchain technology promises to improve the flow of currency and commerce.

Data confidentiality and security, as another key area of blockchain application, benefits from richer and more flexible confidentially models that protect the individual's privacy while meeting regulatory reporting requirements at the company's level. The concept of public and private keys to information stored in blockchains enables the access to sensitive data to only authorized parties. Data confidentiality and security is further supported by the distributed network logic, on which blockchains are based. This network structure of distributed information makes it unattractive for hackers to attack them because manipulation of data and information is immediately detected by others in the system (Biswas and Muthukkumarasamy, 2016). This feature is of primer relevance for the banking sector and is also used in collecting critical data in the automotive industry. Here, the focus is put on collecting and sharing driving data anonymously within blockchain structure. This data can be either used for calculating individualized insurance rates based on the car owner's vehicle usage or for car sharing purposes, where the owner has the option to monetize their asset by selling rides, cargo space or the use of the car itself. The aviation industry, as another field of application, also becomes aware of the high potentials behind blockchain technology. Blockchains not only seem to be beneficial in tracking airplane parts throughout the supply chain but also in maintaining inventory and monitoring required service and parts replacements (Madhwal and Panfilov, 2017). Further benefits of blockchain introduction to aviation supply chains comprise increased resilience, integrity and disintermediation, as described in C4. This enables transparent information access to people in charge of aircraft maintenance, i.e. engineers, logistics, loan officers and any other technicians.

Table 3. Blockchain applications and their benefits

Application area	**Benefits [Case number]**
Product authentication and supply chain tracking	Increases tractability of products (e.g. food, diamonds, shipping containers), realizes easier detection of sources of contamination [C5], avoids "double-spend" of certificates, supports a more robust proof of compliance to standards at origin, incentivizes ethical labor practice and environmental preservation [C6], enables multi-party data acquisition and decentralized file storage [C14], reduces paperwork (using digital signatures of certificate of authority), creates an indisputable unchangeable chain of ownership transfers [C15] enables real-time, secure and seamless information exchange [16]
Identity verification	Simplifies customer identity verification (e.g. for new bank accounts, driver's licenses or utilities) [C18]
Mortgage reporting to financial conduct authority (FCA)	Reduces costs and operational/reputational risks due to data consistency, offers potential to extend this technology to other areas of mortgage operations [C7]
Bolster data confidentiality	Allows richer, more flexible, business-specific confidentially models, provides a network consortium to express and manage consortium policies, supports non-deterministic transactions, reduces energy consumption [C12], protects data privacy while meeting regulatory reporting requirements [C10]
Real-time payments	Reduces transaction costs by cutting out the middleman, allows faster payments by connecting the purchaser's bank directly to that of the supplier [C8] [C2] [C9] [C11] [C1]
Supply chain risk management	Enhances data integrity, speeds problem discovery and mitigation, reduces the volume of regression testing which lowers schedule risk [C3]
Aircraft maintenance	Facilitates more structured and transparent recording and managing parts on in-service planes, increases resilience, traceability, integrity and disintermediation in aviation supply chains [C4]
Cross-border payments	Reduces settlement time and cost of processing global payments, increases transparency for all parties, allows financial institutions to choose the settlement network of their choice, offers the potential to improve the flow of currency and commerce [C13] [C2] [C9]
Autonomous driving (Smart contracts)	Offers the possibility to securely store and share driving data, manages ride- and car-share transactions more efficiently, reduces risk of fraud and transaction costs (elimination of third party involvement) [C17]

Blockchain applications and their benefits in HL

Inspired by the above identified and discussed positive effects of blockchain technology on certain areas of SCM, we know shed more light on potential benefits in the field of HL. Having access to critical information is not only important in SCM but also essential for implementing efficient HL processes. Especially in large scale disasters, the access to information about the number of victims or demand characteristics is not always granted to all responding HOs. It is often limited to the ones having the required technical infrastructure for proper information exchange. Here, smaller HOs that generally work with obsolete ICT are excluded from disaster response, although their contributions and expertise would be highly relevant (Völz, 2005). Enabling richer access to information can be realized through blockchains that provide a shared record of information to all disaster responding HOs. Not only commercial but also humanitarian partners can benefit from this technology that makes critical information visible and available for all HOs without the need of high investments into in-house ICT infrastructure. Therefore, we propose that blockchain technology increases information transparency in HL (*Proposition 1*).

Another major problem that could be addressed by blockchain implementation is the inefficiency of present funding structure in HL. Numerous intermediaries (e.g. aid agencies, governmental institutions) that are involved in managing funds and donations for health projects and disaster aid spend a significant amount of donations just on administrative processes without having a direct impact on beneficiaries' welfare. For instance, expenses for administration and management accounted for 6.1 percent of the overall budget of 550 US HOs in 2007 (Nunnenkamp and Öhler, 2010). Donor expectation are sometimes not fulfilled, making them reluctant to donate, which limits HOs in their scope of action. A possible solution is the elimination of third-party involvement and instead directly connect donors with aid recipients via blockchain technology. Costly and time-consuming administration is removed from the funding process and donors can see the direct impact of funds, which is extremely difficult to visualize in the current funding system. Based on our findings we propose that blockchain technology increases the efficiency of present funding structure (*Proposition 2*).

The final problem area discussed in this paper constitutes redundancy in HL, as already mentioned in the paper introduction. Isolated decision-making within single HOs, incomplete information sharing and competition on the ground leads to redundancy (redundant efforts, relief supplies etc.) along supply chains into disaster regions (Paul, 2006, Duran et al., 2013). Aside from introducing incentive schemes to make HOs to cooperate, a new basis for information sharing is needed. This could be provided by blockchain technology, which enables humanitarian parties to share critical information about relief item types and quantities in real time with each other. Distributing this information to all HOs could reduce redundancy along humanitarian supply chains, as supply types and quantities are completely visible for all HOs. Supply tracking with blockchains could be another advantage not only for commercial supply chains but also for humanitarian purposes. Making emergency shipments traceable for humanitarian operators, donors and beneficiaries could increase the accuracy of delivery times, prevent fraud and increase donor satisfaction. We therefore propose that blockchain technology avoids redundancy along humanitarian supply chains (*Proposition 3*).

Conclusion and outlook

With this study, the scientific community is provided with valuable insights to the potentials of blockchain technology for improved performance in SCM and HL. We reveal certain areas of SCM that already benefit from blockchain implementation and discuss them in detail. Afterwards we introduced the concept of blockchain technology to HL. In doing so, we propose areas of application and potential benefits for enhanced HL performance. Based on the results we are able to make practitioners aware of the various application areas of blockchains for humanitarian operations. Overall, this paper should sensitize both, researchers and practitioners, to be curious and open for this innovative technology. This study is constrained by several factors. Accordingly, we only shed light on potential benefits generated by blockchain application. We are aware of the fact, that also disadvantages come along with this technical innovation that need to be studied in more detail. Aside from this, the case selection is limited in the sense that the criteria for inclusion are quite broadly defined in order to include a higher number of cases. Future research may comprise the testing of developed propositions by quantitative methods, e.g. game theoretical approaches, simulation modeling etc.

Notes

The full list of analyzed documents is not included in the paper but is made available by the authors upon request.

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Appendix

Table 3. Examples of codings

Coding family	**Examples**
Application area	Everledger built a platform on top of IBM Bluemix to digitally verify diamonds and bring more transparency to an industry that was once riddled with both counterfeits and conflict stones or ‘blood diamonds’.
	In short, the patent describes Mastercard's intention to deploy distributed ledger technology to develop a 'method and system for instantaneous payment using recorded guarantees.
	One of the largest retailers in the world, Walmart, is running a trial with IBM to trace and track every step of the produce supply chain by using the blockchain.
	Use blockchains in the development of a new mobility ecosystem that could accelerate development of autonomous driving technology.
	Blockchains for airline loyalty digital wallet capability that will help unlock the value of KrisFlyer miles to enable everyday spending at retail partners.
Benefits	The network will be designed to make it easier for consumers to verify they are who they say they are, in a privacy-enhanced, security-rich and efficient way.
	Blockchain may create transparency and trust among users, reduce risk of fraud and reduction or elimination of transaction costs, such as fees or surcharges applied by third party institutions.
	The four features of blockchain are resilience, traceability, integrity and disintermediation are well suited to the aviation supply chain.
	Blockchain would create trust about exactly where food is coming from, how safe it is, and cut down on waste in the instance of contaminated goods.