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# An exploratory analysis of blockchain technology research in humanitarian supply chains and logistics using the Latent Dirichlet Allocation based topic modelling approach

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# Abstract

In humanitarian relief operations, the logistics aspect accounts to approximately 80% of the effort (Ko & Verity, 2018; Trunick, 2005; Van Wassenhove, 2006) wherein the sector experiences significant challenges related to the last mile distribution, transparency, collaboration, accountability, trust, information sharing, time, cost and resilience (Aranda et al., 2019; Cozzolino, 2012; Dubey et al., 2020; Kovács & Spens, 2007; L'Hermitte & Nair, 2020; Negi & Negi, 2020). Extant literature suggests that the academia and industry have extensively researched the use cases and applications of emerging blockchain technology in commercial supply chains and logistics, and identified promising benefits such as trust, transparency, traceability, immutability, provenance, disintermediation and compliance for enabling its adoption (Kshetri, 2018; Min, 2019; Nandi et al., 2021; Niranjanamurthy et al., 2019; Sharma et al., 2019; Wang et al., 2019). However, corresponding blockchain technology led research initiatives in the context of non-commercial humanitarian supply chains have remained extremely scant.

Subject matter experts, noted academics and specialists in the humanitarian sector have been calling for emerging technology led and interdisciplinary research initiatives in this scantly explored area (Aranda et al., 2019; Baharmand & Comes, 2019; Coppi & Fast, 2019; Dubey et al., 2020; Keenaghan et al., 2019; Zwitter & Boisse-Despiaux, 2018). Taking into consideration the research gap as well as the strong endorsement from the expert humanitarian logistics community, the study at hand explores the blockchain technology research literature in humanitarian supply chains and logistics operations by employing a generative probabilistic Latent Dirichlet Allocation (LDA) topic modelling technique.

A predetermined dataset comprising 54 full-text documents pertaining to blockchain technology research in humanitarian supply chains and logistics is analysed using the LDA topic modelling method to reveal three i.e., k = 3 topics – Technology, Organisational Operations, Systems Adoption. The LDA topic model also uncovers pertinent key words such as trust, transparency, coordination, traceability, smart contracts, cost, time, communication, coordination, and food which are consistent with the factors confirmed in the previous and ongoing research initiatives on blockchain technology applications in humanitarian supply chain and logistics.

Next, a comparative analysis between the manual thematic analysis and the machine learning based topic model illustrates that in case of a successful LDA topic extraction process, there is

ample scope to integrate the two methods and utilise them as a concurrent mixed methods strategy to inform subsequent qualitative and quantitative research initiatives. Correspondingly, based on the LDA topics and thematic analysis of the literature, researchers may contemplate on diversifying and extending the extant socio-technical information systems theories such as the TOE Framework (Baker, 2012; Tornatzky et al., 1990) with state-of-the-art macro and micro level theories such as the Mikropolis model (Wahoff et al., 2012) for advancing the knowledge in the context of blockchain technology and humanitarian supply chains and logistics studies. And lastly, the application of the LDA topic model in conjunction with the thematic analysis approach and literature reviews may demonstrate the viability of a unique type of a secondary mixed methods approach.

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# 1.0 Introduction & Background

## 1.1 Blockchain Technology

Blockchain technology works on the principle of storing replicated transactional data over a distributed computer network in the form of digital ledgers. As a part of the 4th Industrial Revolution (Gerger, 2021; Moll & Yigitbasioglu, 2019; Singh et al., 2019), blockchain technology is built on the fundamental pillars of three established computing concepts viz. decentralisation, consensus and cryptography (Friedlmaier et al., 2018; Gupta et al., 2020). The blockchain consists of an ordered list of timestamped tamper proof blocks, cryptographically linked to one another using an append-only technique (Xu et al., 2016). Also known as the distributed ledger technology, the blockchain was conceptually designed in 2008 and technically implemented in 2009 as a core protocol for digital cryptocurrencies known as the "Bitcoin" with the sole purpose of resolving the peer-to-peer double spending problem by eliminating the need for a centralised intermediary or an administrator (Nakamoto, 2008; Salviotti et al., 2018).

Progressing from "Blockchain 1.0" i.e., its core application as a digital currency, the "Blockchain 2.0" and "Blockchain 3.0" (Xu et al., 2016) have evolved which incorporate additional capabilities such as smart contracts, decentralised apps (DApps), decentralised autonomous corporations (DAC) or decentralised autonomous organizations (DAO) (Swan, 2015). Based on the degree of openness of the system and allocation of permissions, the main variants in blockchain design can be categorised as 1) public or private permissioned blockchains 2) public permissionless blockchain 3) hybrid blockchain (McBee & Wilcox, 2020; Ølnes et al., 2017). External to the blockchain network, third-party oracles or entities such as hardware oracles, software oracles, inbound oracles, outbound oracles and consensus-based oracles exchange data, information and intelligence with blockchains for the execution of smart contracts (Al-Breiki et al., 2020; Beniiche, 2020). The blockchains combined with the capabilities of smart contracts and blockchain oracles have become an enabler for advanced blockchain applications and have found divergent use cases in the areas of supply chain management, healthcare, smart cities, smart government, manufacturing, transportation, and energy distribution to name a few (Abdelmaboud et al., 2022; Chen et al., 2022).

Leading organizations such as the World Economic Forum (Ulieru, 2016), Gartner Group (Panetta, 2016), United Nations (Mulligan, n.d.), Walmart and IBM (Park & Li, 2021) have recognised the increasing potential of blockchain technology due to its inherent characteristics such as transparency, disintermediation, trust, smart contracts, cryptography, decentralisation and regulatory compliance. In a report published in 2021, Gartner indicates that the acceptance of disruptive blockchain technology and digital currency is becoming mainstream and enterprises should ensure that they do not trail behind (Gartner, 2021). As per another Gartner estimation, blockchain technology would result in 176 billion USD added business value and that its combined aggregated value could rise to a value of 3.1 trillion USD by 2030 (Shin, 2018). As of Q4 2016, 28 out of the world's largest 30 banks were involved in blockchain proof-of-concepts (Shreves, 2017) and in the period between 2014 and 2017, more than 2500 blockchain patent applications have been filed, with more than two dozen countries investing in blockchain related initiatives (Baruri, 2016). In 2018, the information and communications technology sector (ICT) received USD 694.33 million venture capital funding for blockchain related initiatives, amounting to 36.5% of all blockchain related start-ups created in the industry (Friedlmaier et al., 2018), highlighting a greater need for the utilisation of distributed ledger technology in the information systems domain.

Based on the positive experiences of blockchain in financial institutions and the digital cryptocurrency space, there is an optimistic outlook towards blockchain technology in large industries and governmental organisations (Al-Jaroodi & Mohamed, 2019). Enterprises from several industries have either explored the use cases and applications of blockchain or entered a full commercialisation stage (Brown, 2018; Iansiti & Lakhani, 2017; Kapnissis et al., 2022; Park & Li, 2021). Of all advanced blockchain applications, the commercial supply chain management (CSC) sector has received special attention from the industry and academia as its application leverages key supply chain management objectives such as collaboration, quality, cost, dependability, speed, flexibility, coordination, risk reduction and sustainability (Kayikci et al., 2022; Kshetri, 2018; Govindan et al., 2022; Park & Li, 2021).

Deriving from the Occam's razor principle, Higginson et al. (2019) suggest that practitioners at the blockchain "coalface" reveal impediments such as scalability, immaturity, standardisation, stagnation and recommend that the technology would find limited practical value in niche applications as well as organisations that are oriented towards modernisation and reputational value. Furthermore, Gstettner (2019) states that considering blockchain technology as a 'silver bullet' that resolves most problems in supply chains could be specious and alternate technologies need to be evaluated. A few potential drawbacks for embracing blockchain technology in the enterprise include 1) Integration with legacy or incumbent information systems 2) High resource consumption 3) Security considerations 4) Lack of industry standards 5) System ownership 6) Economic viability 7) Regulatory uncertainty and 8) Inadequate blockchain knowledge (Gaur et al., 2018; Jabbar et al., 2020; Niranjanamurthy et al., 2019). However, Niranjanamurthy et al. (2019) further argue that the prevalent blockchain implementation barriers would be progressively resolved as the technology matures through practice-based implementations in the industry. Moreover, with the integration of blockchain technology with 5th generation mobile networks (5G), Internet of Things (IoT) and artificial intelligence (AI), the challenges and demands of digital transformation in Industry 4.0 can be met (Chen et al., 2022).

### 1.2 Humanitarian supply chains

As global supply chains become highly complex and extended, disaster related events cause huge disruptions in the supply chains severely harming the finances as well as the reputation of companies and such events can be detrimental to both, commercial as well as non-commercial supply chains (Abe & Ye, 2013; Abeyratne & Monfared, 2016). Aggravating the situation further, humanitarian crises are becoming increasingly frequent, protracted and affecting a larger population than ever before (Kostovska, 2020). For instance, the war in Ukraine resulted in the displacement of 8 million people within the country and more than 6 million refugee movements have been recorded (UNHCR, 2022). The social and economic disruption caused by the COVID-19 pandemic has been catastrophic as tens of millions of people are at risk of falling into extreme poverty and undernourishment (WHO, 2020). The COVID 19 crisis and the Ukraine war has wreaked havoc on commercial as well as humanitarian supply chains (Nandi et al., 2021; Queiroz et al., 2020; Simchi-Levi & Haren, 2022). The social existence of humanity has been threatened by both, natural and manmade disasters such as wars, conflicts, terrorism, refugee crisis, earthquakes, floods, famines, epidemics and hurricanes. According to a prediction by Thomas and Kopczak (2005), over the next thirty years there would be a drastic rise in humanitarian disasters resulting in an enormous toll on human life. Forecasts based on previous studies suggest that the professionals in the humanitarian sector should grasp the existing trends and patterns of humanitarian disasters and plan ahead for the future (Van Wassenhove, 2006).

In 2017, approximately 141 million people from 37 countries called for humanitarian assistance for a record $23.5 billion US dollars (UNOCHA, 2017). In 2019, the humanitarian sector was worth approximately 30 billion euro and the Logistics Cluster received 613 metric tons of food items and the equivalent of 10,887 cubic meters of relief items for stockpiling (Vega et al., 2020). As of 2021, the World Food Programme has shipped more than 200,000 metric tonnes of food and increased its storage capacity by 40% i.e., to 88,000 metric tonnes (WFP, 2021). Moreover, in 2021, 235 million people required humanitarian assistance, and in 2022 this figure was projected to increase by 17% to 274 million (OCHA, 2021). Across 63 countries, the United Nations along with its partner organisations provided relief to 183 million people and required a funding of 41 billion USD (OCHA, 2021). By 2030, the humanitarian funding is expected to grow to 50 billion USD, at a time when approximately 66% of the poor people are anticipated to be living in conflict prone areas (Pantuliano, 2018). In accordance with its Sustainable Development Goals (SDG), the United Nations aims to cease poverty and hunger across the world as well as improve overall health and well-being of the people (UNDP, 2015).

Owing to the unpredictable nature of disasters, it is almost impossible to anticipate the time, location and magnitude of a catastrophe that can bring about significant harm to the economy of the affected area and therefore, robust humanitarian supply chains (HSC) could help in alleviating the situation. There are significant similarities and differences between commercial and humanitarian supply chains (Vega et al., 2020) i.e., in commercial supply chains the main objective is to generate monetary profit whereas the non-commercial humanitarian supply chain deals with the process of planning, implementing and controlling the flow and storage of relief goods, materials and related information from the point of origin to the point of destination with the purpose of meeting the needs of the end beneficiaries in an efficient, timely and cost effective manner and preventing maximum number of casualties (Thomas & Kopczak, 2005). In humanitarian supply chains, the value is measured in terms of deprivation costs i.e., the economic assessment of the human suffering caused due to the lack of relief services or goods (Holguín-Veras et al., 2013).

In humanitarian relief, approximately 80% of the effort is spent on logistics and therefore, the coordination between key supply chain participants is critical for improving the performance of relief chains (Ko & Verity, 2018; Trunick, 2005; Van Wassenhove, 2006). By establishing an effective information infrastructure, the humanitarian supply chains could be made more agile and responsive to the changing needs of multiple humanitarian stakeholders (Oloruntoba & Gray, 2006). The stakeholders in the humanitarian supply chain management typically involve parties such as the governments, international and domestic relief organisations, armed forces and private sector organisations each with a differing capacity of expertise, mandates and interests (Balcik et al., 2010). Last mile distribution, transparency, collaboration, accountability, trust, information sharing, time, cost and resilience are some of the critical factors identified for successful operations in the humanitarian supply chains (Dubey et al., 2020; Iqbal & Ahmad, 2022; L'Hermitte & Nair, 2020; Zhang et al., 2021). Therefore, the role of electronic links and information flows between firms, enterprises and business processes is critical for the effective integration of information in the humanitarian supply chains and logistics domain. As an embryonic technology, blockchain promises five key benefits - trust, transparency, traceability, immutability and compliance (Sharma et al., 2019; Singh & Sharma, 2022) and thus, could potentially find appealing use cases in the humanitarian supply chains.

Humanitarian supply chains and logistics remains an exploratory area of research from both an academic as well as a practitioner's perspective and although comprehensive in-depth studies have been undertaken in the commercial supply chain management domain, only a small number of researchers have paid attention to its humanitarian aspects. In commercial supply chains, the coordination of information and material flows across all stakeholders involved in the process has been widely addressed but unfortunately, humanitarian logistics has been struggling for attention and is decades behind its commercial counterparts (Van Wassenhove, 2006). However, on a different note, Behl and Dutta (2019) recognise that humanitarian supply chain management is an emerging area within the supply chain management practice, and state that it requires understanding of three key areas 1) Contextual factors 2) Underlying socio-political issues 3) Application of interdisciplinary theories and principles. Based on a handful of preliminary academic and practice led initiatives, subject matter experts, noted academics and specialists in the humanitarian sector have explicated the relationship between blockchain technology and humanitarian supply chains with optimistic results and have been calling for emerging technology led and interdisciplinary research initiatives in this scantly explored area (Baharmand & Comes, 2019; Baharmand et al., 2021; Coppi & Fast, 2019; Dubey et al., 2020; Hunt et al., 2022; Zwitter & Boisse-Despiaux, 2018).

### 1.3 Research approach

Latest developments in digital technology have facilitated the growth of massive quantities of unstructured data in the form of text documents, archives, audio-video blogs, web pages and social media content (Moro et al., 2019). Such explosive growth in electronic information and digitised documents has enabled the development of automated tools that possess the ability to organise and analyse such unstructured forms of data (Lee et al., 2022). Conventional business research methodologies involving qualitative and quantitative methods have been long-established however, require thoroughly trained specialists and experts for its execution (Rose

& Lennerholt, 2017). Moreover, conducting a manual review and analysis on a vast number of structured or unstructured textual documents can be humanly impossible or time consuming. Thus, to overcome such limitations of a manual text analysis, fully automated or semi-automated text mining techniques have been developed using computer-aided tools that can extract the knowledge embedded in the vast amount of digitised literature that is generated today (Thakur & Kumar, 2022).

The advances in text mining methods can be attributed to the developments in disciplines such as computational linguistics (CL), machine learning (ML) and natural language processing (NLP) (Rose & Lennerholt, 2017). Text mining serves as a powerful tool for analysing text in the form of unstructured data that is contained in academic literature, transcripts, blogs, websites, emails and social media content (Moro et al., 2019; Rose & Lennerholt, 2017). Text mining can be utilised for the purpose of conducting exploratory data analysis and textual intelligence research across an extensive range of subjects and disciplines such as economics, politics, information systems, business and so forth (Hassani et al., 2020). Some standard implementations of text mining include, 1) Content analysis 2) Topic modelling 3) Web analysis 4) Text visualization 5) Sentiment and opinion mining 6) Subjectivity analysis 7) Dialogue classification (Chen et al., 2012; Kaiser & Bodendorf, 2012; Pang & Lee, 2008). From an organisational standpoint, text mining may, 1) Enhance decision making processes 2) Provide performance insights 3) Improve product and service offerings 4) Gain improved customer engagement (Moro et al., 2019).

Traditional data collection and analysis methods can be time consuming, require ethics approval and demand considerable effort from the researcher (Hadi & Closs, 2016; Tariq & Woodman, 2013). Majority of the research studies concerning blockchain technology exploration in HSC are conducted using resource-intensive and time-intensive qualitative and quantitative research strategies involving surveys, extensive literature reviews, expert interviews, and pilot projects (Baharmand & Comes, 2019; Coppi & Fast, 2019; Dubey et al., 2020; ESA, 2019). For example, a qualitative researcher may consume up to 20 weeks or 1000 hours of researcher time while conducting a moderate sized interview survey (Rose et al., 2016; Rose & Lennerholt, 2017), while the topic modelling method requires no investment in terms of establishing contacts, conducting interviews and transcribing the interviews. The Latent Dirichlet Allocation (LDA) i.e., a type of topic modelling approach, offers a low cost and low effort method for extracting meaningful information latent in the academic text and literature, and in turn may simplify or extend the prevailing qualitative research strategies (Blei, 2012;

Rose & Lennerholt, 2017). The Latent Semantic Analysis (LSA), Non-Negative Matrix Factorization (NMF) and Principal Component Analysis (PCA) are some other non-probabilistic topic modelling methods however, LDA remains the most popular technique for mining text documents (Medhi, 2020; Stevens et al., 2012). Moreover, for text mining applications in which human interaction with the extracted topics is anticipated, the flexibility and the coherence advantages of LDA warrant a strong consideration when compared with alternate text mining techniques such as the NMF (Stevens et al., 2012).

As blockchain technology literature in humanitarian supply chains and logistics is steadily growing, the study at hand explores the emerging topics present in blockchain technology research on humanitarian supply chain logistics (HSC BCT) by implementing a low-cost LDA topic modelling method. To the best of the researcher's knowledge and at the time of conducting the research, it is probably the only study that uses a LDA based topic modelling approach for analysing the literature on blockchain technology research in humanitarian supply chains and logistics for the purpose of topic extraction.

As part of the initial LDA analysis, the below research question explores the implicit topics emerging from the HSC BCT literature.

**Research Question 1:** What are the latent topics emerging from the literature on blockchain technology research in humanitarian supply chains and logistics using the LDA topic model?

Further, the study compares the thematic analysis of the literature with a machine learning based LDA approach and identifies the opportunities for more impactful research in the areas that lie at the convergence of blockchain technology and humanitarian supply chains literature. Hence, the following two research questions are addressed.

**Research Question 2:** How does the manual thematic analysis of blockchain technology research in humanitarian supply chains and logistics literature compare with the machine learning based Latent Dirichlet Allocation topic modelling analysis performed on the HSC BCT dataset?

**Research Question 3:** What are the opportunities for more impactful and contributory enquiry from the standpoint of blockchain technology research in humanitarian supply chains and logistics?

In the following section, the literature review using a thematic analysis uncovers the general concepts related to blockchain technology and then specifically considers its utility in the context of humanitarian supply chains and logistics information systems.

## 2.0 Literature Review

Numerous academic and non-academic studies have been conducted in blockchain technology area from an information systems perspective (Casino et al., 2019; Kshetri, 2018; Sharma et al., 2019; Wang et al., 2019) but the extant literature related to blockchain applications in the humanitarian supply chains is limited and immature in nature. Majority of the studies in the humanitarian supply chain area tend to span from the year 2005 onwards (Fosso Wamba, 2020) and the first blockchain white paper appeared in 2008 (Nakamoto, 2008) and for that reason, the relevant literature from these periods was considered for the thematic analysis approach.

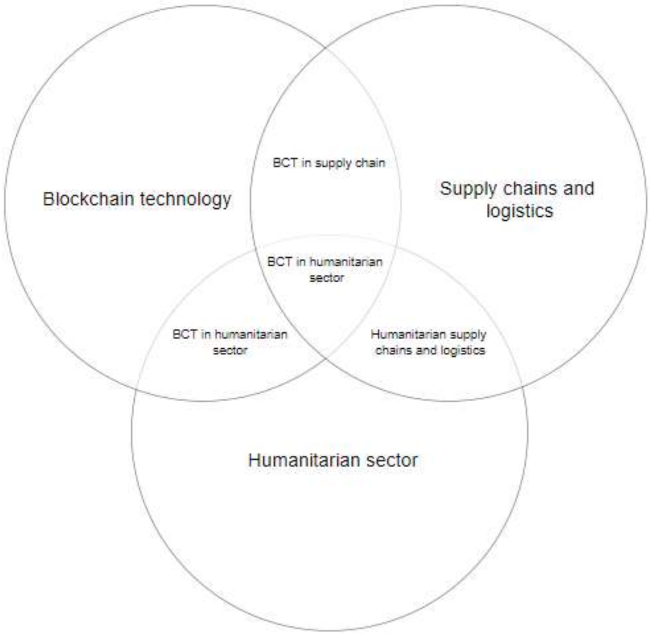


*Fig 1. Intersecting contexts of research*

As shown in Fig 1. the intersecting contexts of the research informed the literature search and therefore, based on the triangulation, the search terms “blockchain”, “blockchain supply chain”, “humanitarian supply chain”, “humanitarian logistics”, “humanitarian information systems” and “blockchain humanitarian” were used within search engines such as Google Scholar, the University Library Catalogue, Microsoft Academic, Scopus and Google Search which resulted in thousands of search results. Relevant literature from multiple publication sources such as journals, conferences and books were identified based on the criteria such as estimated number of citations, journal reputation, author’s reputation, institutional reputation and the year of publication.

The non-academic grey literature such as whitepapers and reports were identified based on the organisational reputation and relevant expertise in blockchain technology and the humanitarian sector. Each of the identified articles were reviewed based on the relevance, quality and the irrelevant articles were discarded from the search results. Additionally, a select few blockchain developer websites were referred for accessing the pertinent information that was found to be deficient in the academic literature.

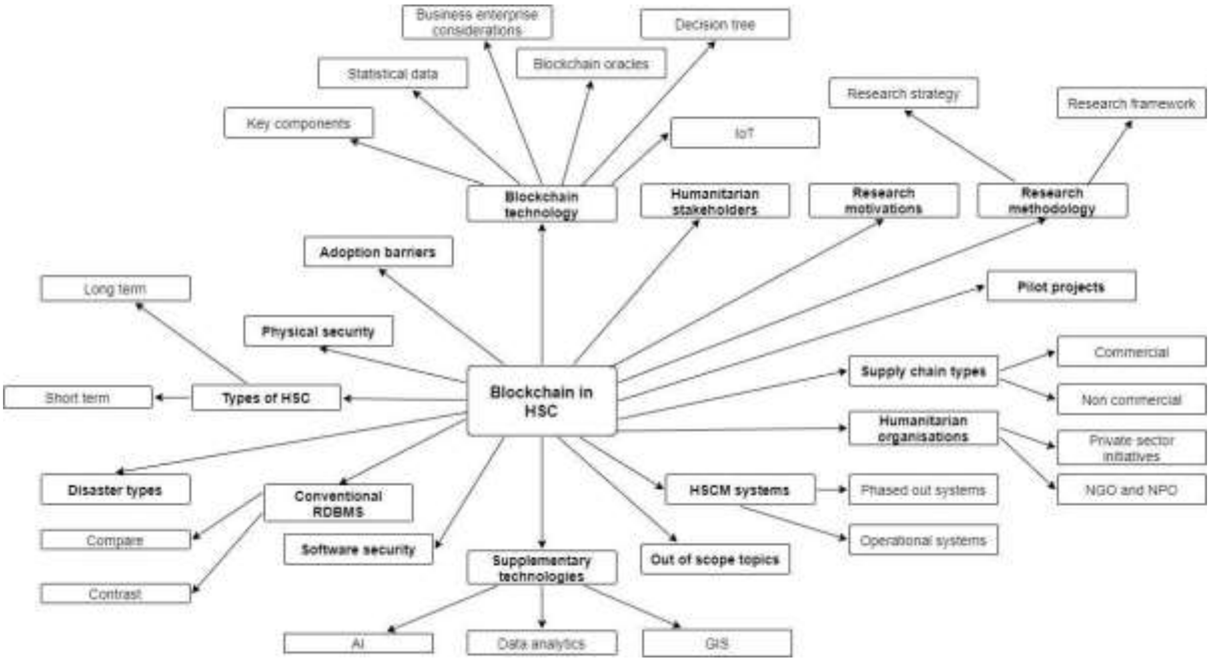


*Fig 2. Thematic map of the literature*

Next, a thematic mind map as shown in Fig 2. was created to determine the high-level themes, sub-themes, codes and new studies were added based on the review of the identified literature and additional key themes were selected after synthesising the literature. The themes identified using an inductive thematic review are discussed in the section below.

## 2.1 Blockchain Technology Overview

Blockchain is a distributed database created using cryptographic hash functions for recording the operational transactions and noted blockchain author Swan (2015) refers to it as a giant spreadsheet suitable for accounting and tracking registered assets on a global scale. Blockchain consists of nodes located on an internet network and each node has a replicated copy of the data and transactions that are created using consensus mechanisms for ensuring that the data remains immutable and preserved (Casino et al., 2019). The encoded digital ledger in a blockchain comprises data blocks that are created as each transaction is performed and stored on distributed computers in the network in a sequential manner forming an irreversible chain (Wang et al., 2019). Conventional relational databases handle the CRUD operations i.e., create, read, update and delete transactions, whereas blockchain technology utilises an append-only replication technique which ensures enhanced data integrity and availability.

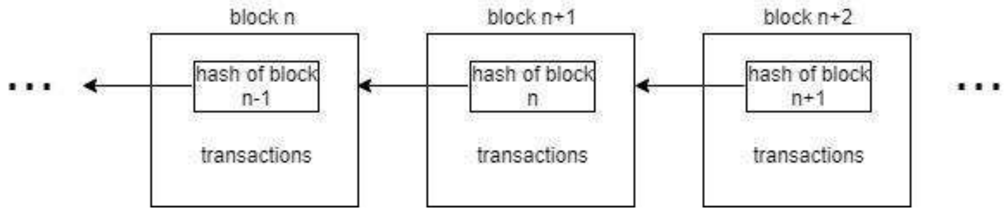


*Fig 3. A chain of blocks (adapted from Christidis & Devetsikiotis, 2016)*

As seen in Figure 3, each block consists of a set of transactions and the hash value of the previous block, except for the genesis block i.e., the root or the parent block in the chain. The transaction linking as shown is achieved using a concept known as Merkle tree or hash tree in which the hash of 'leaf nodes' is calculated and stored in the 'non-leaf node', and the hashing process is performed till the 'root node' in the tree is traversed (Gaur et al., 2018). The integrity of the data on the blockchain is maintained using the hashing mechanism. The nodes in the blockchain network can be categorised into two types 1) User nodes that can transact and maintain a copy of the ledger 2) Validator nodes that approve the blockchain modifications via consensus mechanisms for the purpose of maintaining a credible state of the ledger (Andoni et al., 2019).

The blockchain consists of three layers 1) Protocol layer - the coding and computational rules are defined at the protocol layer 2) Network layer - the network layer deals with the rules that are set on top of the protocols 3) Applications layer - the software that is developed for interaction with the end users is built on the application layer (OECD, 2018).

### 2.1.1 Blockchain consensus

The blockchain is made up of continually growing blocks in the chain and the key criteria is to publish the next block in an untrusted network of users. This functionality is achieved by securing a common agreement amongst the network participants using consensus mechanisms as the blockchain offers a democratic process for creating and verifying the transactions and ensuring that the data remains auditable and secure (Andoni et al., 2019; Casino et al., 2019). The bigger the size of the blockchain, the more tamper resistant it remains and due to its decentralised nature the blockchain mitigates the risk of a single point of access failure typically attributed to centralised databases (Wang et al., 2019).

The blockchain undergoes a process called 'mining' which ensures that the new transactions are authentic and valid. For the mining process to execute successfully, miners request consent from the network for adding new blocks to the chain and the validity of new transactions is confirmed amongst the network participants by executing the algorithms based on various consensus mechanisms (McBee & Wilcox, 2020; OECD, 2018). The mechanisms of the most popular consensus algorithms are discussed in Table 1. below,

| Consensus Algorithm | Mechanism |
|---|---|
| Proof of Work (PoW) | Used by Bitcoin, the PoW algorithm creates a new block by setting a competition amongst the blockchain nodes for solving a mathematical problem. The node that solves the problem first gets rewarded with Bitcoin (Mingxiao et al., 2017). |
| Proof of Authority (PoAu) | In PoAu a specific set of nodes are granted special privileges for the purpose of validating transactions and creating new blocks in the blockchain (Andoni et al., 2019). |
| Practical Byzantine Fault Tolerance (PBFT) | In PBFT the blockchain nodes agree on validating a set of transactions for creating a new block in an unreliable distributed network based on the Byzantine general's problem (Andoni et al., 2019). |
| Proof of Activity (PoAc) | PoAc is a hybrid between the proof of stake and proof of work consensus algorithms (Andoni et al., 2019). |

*Table 1. Blockchain consensus algorithms*

Each of the consensus mechanisms discussed in Table 1. vary in their approach for achieving network agreement and creating new blocks. The underlying principle known as the smart contract is responsible for the creation of transactions on the data blocks and is discussed in the following section.

### 2.1.2 Smart contracts

Smart contracts are written using non-Turing or Turing complete programming languages such as the Ethereum Solidity (Bistarelli et al., 2020; Jansen et al., 2020) and triggered based on the pre-defined conditions or events that are used for validating and verifying the business logic embedded in the agreement e.g., benefits, obligations or penalties before creating and committing any records to the blockchain. A smart contract can automatically and conditionally execute the terms of an agreement or contract in a cost efficient, timely manner as compared to traditional contracts. In a study conducted by Wang et al. (2019), 52% of articles consider smart contracts to be critical for supply chain automation and may have different execution mechanisms such as fully self-executing, self-enforcing, partially autonomous and network monitored. Christidis and Devetsikiotis (2016) indicate the high-level characteristics of smart contracts as,

- Smart contracts are used for accommodating the business logic in code.
- The smart contract code can be audited, and its execution traced by all the network participants.
- The smart contract can be perceived as an independent agent which can trigger autonomously when a transaction is submitted to its address.
- Based on the inputs to the smart contract the outputs are pre-determined.

Thus, a smart contract can lower the number of intermediaries by automating the manual interventions, resulting in reduced processing time and effort.

### 2.1.3 Blockchain oracles

Blockchain oracles are third party services which act as connectors between blockchain databases and off-chain data sources (Beniiche, 2020). Mougayar (2016) refers to them as smart oracles and states that the agent-like off-chain data sources may contain information, for example, related to addresses, identity, or certificates. Smart contracts and blockchains cannot directly access external data however, from a contractual fulfilment perspective, it is essential to have access to relevant off chain information to execute the agreement.

Blockchain oracles provide the necessary link between the on-chain and off-chain data sources resulting in improved capabilities of blockchains and smart contracts (Beniiche, 2020). The role of the blockchain oracle is to act as a layer that can authenticate, query, verify external data sources and transmit that data back to the blockchain database e.g., temperature measurements from sensors or pricing related information. Several types of blockchain oracles exist and its operation is based on the design and purpose of the oracle (Mou, 2020). An illustration of blockchain oracles can be seen in Fig 4.

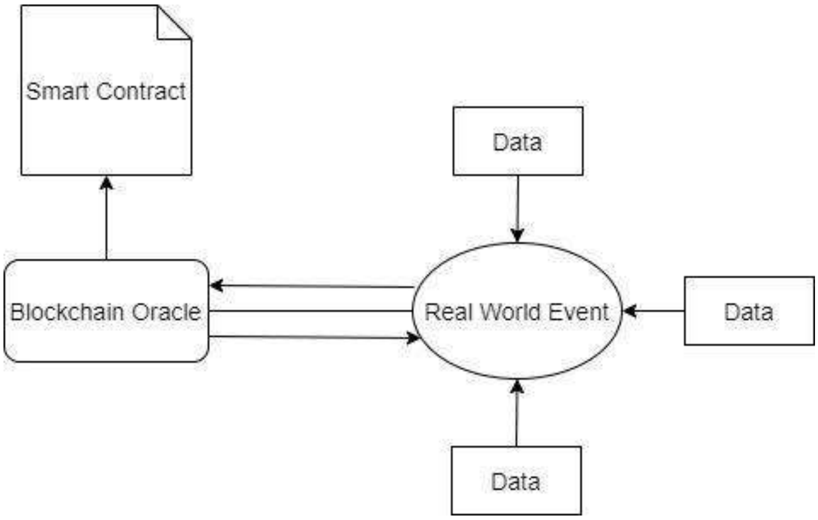


*Fig 4. Blockchain oracle (adapted from Kosinski, 2018)*

The purpose of blockchain oracles is to send or receive data from outside the decentralised blockchain network and it may consist of multiple variants based on the type and direction of the data flow (Najera, 2018). Oracles can be classified based on their type i.e., hardware and software and direction i.e., inbound and outbound and are listed in Table 2.

| | |
|---|---|
| **Hardware Oracle** | Gathers data directly from the physical world e.g., RFID, IoT devices and sensors. |
| **Software Oracle** | Deals with data or information that originates from external software sources e.g., commodity prices, flight details etc. |
| **Inbound Oracle** | Supplies external incoming data to the smart contract. |
| **Outbound Oracle** | Communicates smart contract data to external sources. |
| **Human Oracle** | Individuals with specialized knowledge or skills who aggregate and query the data which is to be fed into the blockchain. |
| **Consensus-based Oracle** | The outcome of this oracle is processed by querying multiple oracle sources and achieving a consensus amongst them. |

*Table 2. Type of blockchain oracles (Kosinski, 2018; Mou, 2020; Sharma, 2020)*

### 2.1.4 Blockchain application types

The blockchain applications built on top of the distributed ledger platforms as seen in Fig. 5 can be classified into two types - blockchain native and blockchain hybrid. Native applications run entirely on a dedicated blockchain system whereas the hybrid blockchains are purpose driven applications built on top of existing legacy or web applications.

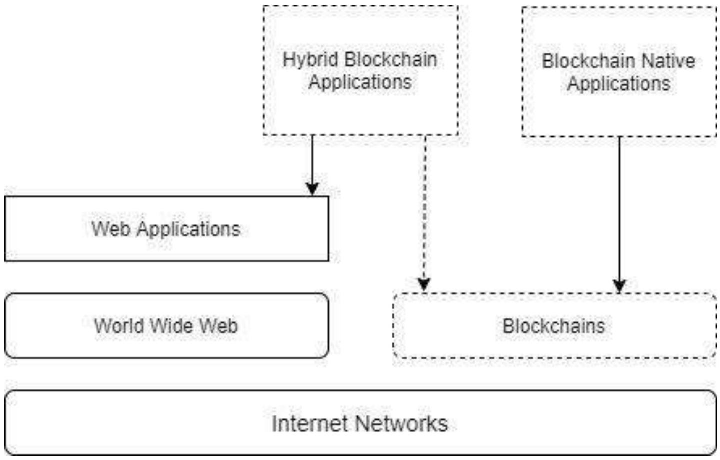


*Fig 5. Blockchain application flavours (adapted from Mougayar, 2016)*

The several architectural layers of blockchain applications comprise of components such as databases, software applications, network of computers, clients, software development environments and monitoring tools, and these artefacts can potentially displace or build upon existing enterprise systems (Mougayar, 2016). The fundamental techno-functional features of blockchain technology are discussed in the next section.

### 2.1.5 Taxonomy of the fundamental features of blockchain technology

The fundamental features of blockchain technology can be broadly classified into two types – technical and functional. The taxonomy of blockchain features is seen in Fig 6.

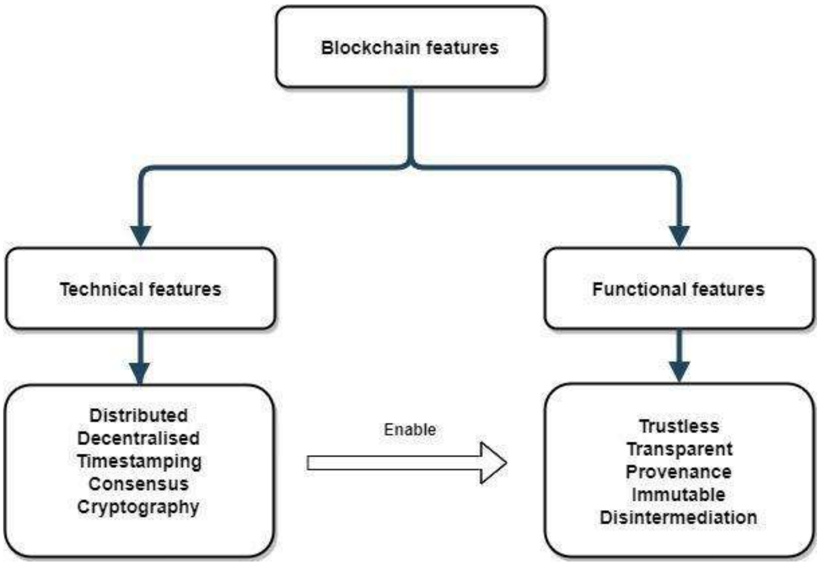


*Fig 6. Taxonomy of blockchain features*

Technical features deal with the computing principles involved in the blockchain technology development whereas the functional features define the intended operation or purpose of technology which is outlined in Table 3.

| | | |
|---|---|---|
| **Blockchain technical features** | Distributed | A blockchain is a distributed shared ledger which maintains a continuing and growing list of records across various peer-to-peer nodes. |
| | Decentralised | The blocks in the blockchain are maintained on various nodes in the network as opposed to a centralised location. |
| | Timestamping | Since the records in blockchain are created chronologically, the timestamp of each transaction is maintained resulting in better auditability of the data. |
| | Consensus | An agreement is achieved in blockchain nodes using different consensus algorithms. |
| | Cryptography | The blocks in the blockchain are linked together using the cryptographic hash of the previous block in the chain. |
| **Blockchain functional features** | Trustless | As the blockchain data is shared and cryptographically secured, it establishes trust among the network participants. |
| | Transparency | The information on the blockchain is visible to the peers or users in the distributed network and cannot be updated by a single entity. |
| | Provenance | The blockchain can record a history of the creation, chain of custody and any alterations or modifications made to the transactions. |
| | Immutability | Using consensus mechanisms blockchain can create a chronological chain of cryptographically linked transactional records which are extremely difficult to tamper with. |
| | Disintermediation | The blockchain consensus mechanism eliminates the need for a third party resulting in the exclusion of a centralized validation authority. |

*Table 3. Blockchain techno-functional features (Andoni et al., 2019; Casino et al., 2019)*

Thus, it can be derived that the underlying technical features enable the functional outcomes of blockchain technology. Despite the expedient features of blockchain technology, there are some key criteria and considerations for blockchain technology which are discussed in the next sections.

### 2.1.6 Flowchart for blockchain adoption

A number of organisations are contemplating blockchain technology adoption in their businesses (Kshetri, 2018; Park & Li, 2021), but finding the right fit for the technology is one of the challenges as it cannot be universally applied for replacing existing database technologies. For this reason, identification of the strengths and weaknesses of existing legacy systems versus cutting edge blockchain solutions is critical. Several agencies including the government, academia, software developers, technology websites and publications have created guides to determine the suitability of blockchain in the enterprise IT landscape (Yaga et al., 2019). A blockchain adoption flowchart is illustrated in Fig 7.

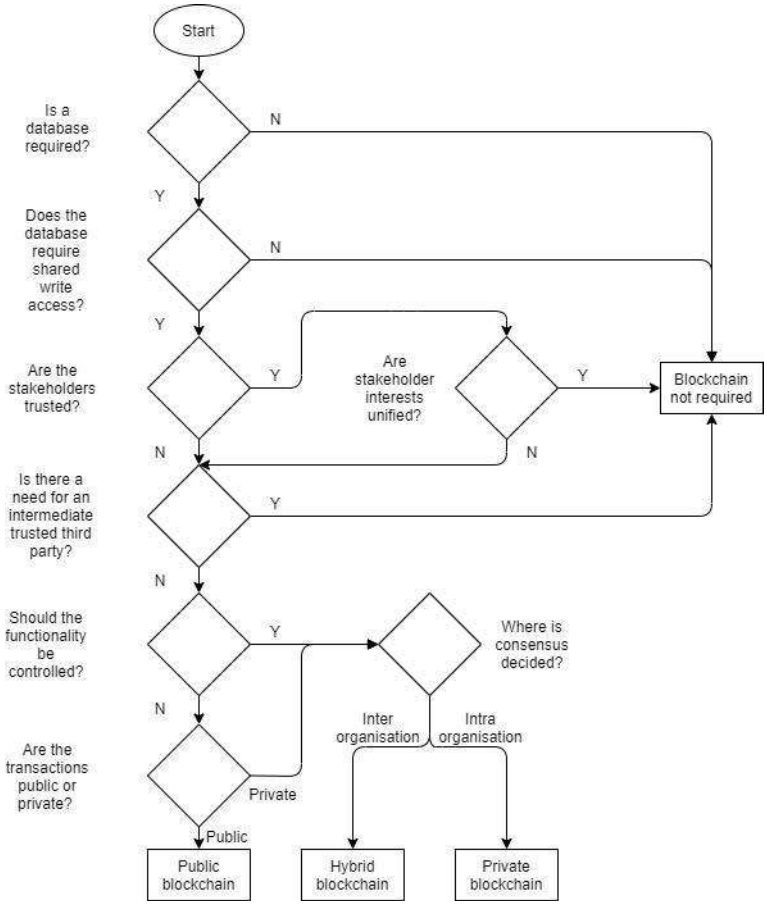


*Fig 7. Blockchain adoption flowchart (adapted from Suichies, 2015)*

According to Yaga et al. (2019), blockchain technology may find suitable use cases in systems, activities or scenarios that involve characteristics such as 1) Multiple or distributed stakeholders 2) Desire or a lack of trusted third parties 3) Transfers and exchanges of fungible or non-fungible tokens between stakeholders 4) Transactional workflows 5) Creation of digital identities 6) Decentralised registries 7) Real time monitoring of transactions between regulatory bodies 8) Cryptographically secured systems of ownership 9) Elimination of manual interventions in disputes and reconciliations 10) Maintenance of a shared audit history of tokens and transactions.

### 2.1.7 Considerations for blockchain technology adoption

The scope, limitations and misapprehensions surrounding the emerging blockchain technology are listed in Table 4. below,

| | |
|---|---|
| **Immutability** | Permissionless blockchains are not completely immutable as they are prone to the 51% attack, however, permissioned blockchains may be able to mitigate this attack. |
| **Blockchain governance** | The assertion that blockchains can achieve complete disintermediation can be discredited as there are various points in the network where ownership exists. Permissioned and permissionless blockchains are managed by a consortium of stakeholders involving network users, developers, and publishing nodes. |
| **Oracle Problem** | The source from which the blockchain oracles obtain data should be credible as it could result in security concerns related to the validity of smart contract output due to altered or inconsistent input data. |
| **Blockchain shutdown** | Due to the decentralised nature of blockchains, ensuring a complete shutdown of all the nodes in the network is a demanding task and there is a possibility that certain nodes may get exposed to malicious users. |
| **Cybersecurity** | The cybersecurity policies that organisations implement for the adoption of blockchain technology in their IT ecosystems will differ based on factors such as the risk appetite, nature of threats and vulnerabilities, and thus, there needs to be a uniformed approach for managing blockchain related cybersecurity risks. |
| **Cyberattacks** | Blockchains are not immune from malicious activities such as time spoofing, DoS attacks, zero-day attacks and vulnerability exploits in the smart contact code. |
| **Trustless system** | The claim that blockchains are trustless and do not require third party intermediation should be considered sceptically as a great amount of trust needs to be bestowed in the underlying cryptographic technologies, smart contract code, processing reliability of all nodes and all users in general in the blockchain network. |
| **Resource consumption** | A large amount of resource usage in terms of electricity and processing time is spent for achieving consensus in the blockchain network. Moreover, additional network bandwidth and data storage capacities are required for the addition of new blocks and nodes in the blockchain network. |
| **Enterprise adoption** | From an enterprise blockchain adoption perspective, considerations such as integration and preservation of the incumbent system of |

| | |
|---|---|
| | records, compatibility of data formats and technology adoption with the least amount of disruption should be considered. |
| **Business considerations** | From a business consideration perspective, the criteria that come into play are 1) openness of the system 2) economic viability 3) regulatory compliance 4) solution longevity 5) coexistence with incumbent systems 6) skills 7) global support and 8) compatibility with industry specific standards. |

*Table 4. Blockchain implementation considerations (Gaur et al., 2018; Yaga et al., 2019)*

### 2.2 Blockchain technology in commercial supply chain management

The classification of blockchain applications can be based on their purpose of development i.e., generic vs specific blockchains, for example, Ethereum provides a general-purpose platform for building an extensive range of applications and use cases while Bitcoin is exclusively designed for cryptocurrency operations (Andoni et al., 2019). Blockchain applications for supply chain management and logistics are purpose driven developments and can be built on top of open-source distributed ledger platforms such as Ethereum or Hyperledger.

The various stages in the supply chain from the point of origin to the point of destination remain opaque to the high number of external stakeholders and therefore, a distributed shared ledger provides a transparent and auditable log of transactions for the tracking of physical assets including the ultimate ‘last mile’ distribution phase of the supply chain (Dubey et al., 2020; Suzuki, 2020). Wang et al. (2019) investigated the applications of blockchain technology in supply chains across multiple industry sectors including pharmaceutical, agriculture, airlines, electronics, manufacturing, construction, advanced transportation systems and so forth with a focus on factors such as traceability, transparency, corruption, fraud reduction, inter organisational collaboration and smart contracts and their findings suggest that the application blockchain technology can have a promising effect on the supply chains. From a supply chain asset tracking context, Min (2019) states that the blockchain can record both, tangible and intangible assets on an immutable, paperless and publicly visible ledger that enables the stakeholders to track and trace the assets and in turn prevent counterfeiting or fraud.

Prominent organisations such as Microsoft, Boeing, IBM and SAP have endorsed the broader utilisation of blockchain technology in supply chains and propose that further investigations through pilot projects and case studies are required for evaluating and gathering valuable practical information for blockchain based implementation scenarios (Saberi et al., 2019). Moreover, there is a growing interest in supply chain sustainability related initiatives amongst academic and practice led communities and thus, the promising features of blockchain technology may offer a solution to the triple bottom line complexities associated with the social, economic and business dimensions of supply chains (Saberi et al., 2019). In a study conducted by Kshetri (2020) for understanding the potential implications of blockchain technology on supply chain sustainability in developing countries, the author states that sustainability related challenges such as compliance could be addressed using enhanced monitoring, auditability and provenance.

### 2.3 Humanitarian supply chains and logistics

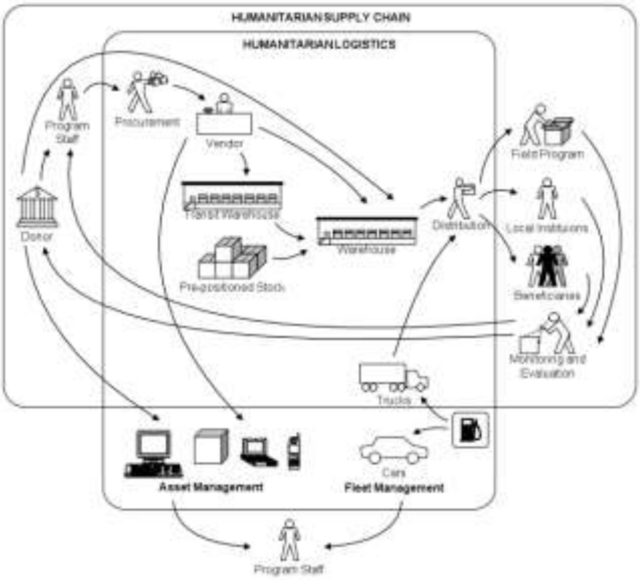


*Fig 8. Humanitarian supply chain and logistics (Howden, 2009)*

Mentzer et al. (2001) define the supply chain as "a set of three or more entities (organizations or individuals) directly involved in the upstream and downstream flows of products, services, finances, and/or information from a source to a customer" (p. 4). Humanitarian supply chains involve functionalities which conventionally fall outside of the field of humanitarian logistics and activities such as assessment of performance needs, donor relationships, supply planning, evaluation and monitoring the impact of delivered supplies are managed by the non-logistics units (Howden, 2009). The vital flows between various humanitarian stakeholders such as donors, vendors, staff and beneficiaries in the context of an integrated humanitarian supply chain and humanitarian logistics are presented in Fig 8.

Over the last century, the number of natural disasters across the world have increased tenfold and there is growing evidence that in terms of impact and frequency, such catastrophes around the world are rising with little or no warning, resulting in increased attention towards emergency relief and response operations (Sangiamkul & van Hillegersberg, 2011). In such types of humanitarian disasters, the logistics aspect which accounts to 80% of disaster relief operations has always played a critical part (Ko & Verity, 2018; Trunick, 2005). It encompasses the delivery of medicines, food and other necessities for considerable periods of time using various modes of transport such as rail, aviation, ocean shipping and motor vehicles (Kovács & Spens, 2007). Apart from the physical distribution of goods, it also involves tracking the flow of finances and information between multiple stakeholders such as aid agencies, defence forces, governments, logistics providers with loosely defined links and nonuniform perspectives on humanitarian logistics with respect to the preparation and execution of disaster relief operations (Kovács & Spens, 2007).

The goal of these operations is to protect people from casualties and suffering in catastrophes such as natural disasters, wars, political conflicts, violence or poverty and such humanitarian actions are motivated by the notion that all humans have a right to life and dignity (Gavidia, 2017). Many governmental and non-governmental humanitarian organisations with diverse interests such as the World Food Program, Red Cross, Oxfam, Médecins Sans Frontières, World Vision International, Save the Children as well as several entities of the United Nations have been created to extend the relief effort to civilians (Gavidia, 2017). In addition to NGO's, individual and business donors, defence forces and governments are key elements in the humanitarian response efforts (Balcik et al., 2010; Thomas & Kopczak, 2005).

Humanitarian supply chain processes can be split in to three distinct phases 1) pre-disaster preparedness 2) operational and 3) post-disaster recovery and these phases involve strategic measures undertaken by various stakeholders such as disaster relief agencies, government and public sector departments (Cozzolino, 2012; Tomasini & Van Wassenhove, 2009; Upadhyay et al., 2020). The political and environmental conditions play a critical role in creating favourable conditions for governments, diffusion of technology and public-private partnerships.

The aid delivered in post disaster situations is considerably different from the long-term developmental aid and the two streams of humanitarian logistics can be categorised as disaster relief and continuous aid (Kovács & Spens, 2007). The UN WFP categorises the stages of humanitarian supply chains into two phases 1) Restoration phase known as the EMOP and 2) Reconstruction phase known as the PRRO involving multiple stakeholders (Cozzolino, 2012). Relief supplies are 'pushed' during the short-term immediate response phase whereas the relief 'pull' is used during the long-term reconstruction phase, where the assurance and quality of medical and food supplies delivered to the recipients has been identified as one of the major challenges (Kovács & Spens, 2007).

### 2.3.1 Commercial supply chains versus humanitarian supply chains

The majority of the information systems research in supply chain management has been conducted based on data from and aligned towards commercial supply chains (Day et al., 2012) and a number of studies have compared and contrasted humanitarian vs commercial logistics (Oloruntoba & Gray, 2006; Pettit & Beresford, 2009; Thomas & Kopczak, 2005; Van Wassenhove, 2006). Due to the continuous nature of operations in the commercial sector, there is a large amount of performance data constantly generated which is not the case in humanitarian supply chains. Commercial supply chains (CSC) are guided by competitive forces and more predictable due to their ongoing and stable nature. Besides, Baharmand et al. (2021) assess that due to the crucial functional differences between CSC and HSC, the insights derived from CSC in relation to blockchain technology adoption cannot be extrapolated to the HSC research.

The objective of humanitarian supply chains is to alleviate human suffering, lower fatalities and therefore, it should meet key objectives such as agility, resiliency, flexibility, speed and effectiveness. To a certain extent, there is an overlap between commercial and humanitarian supply chains as the goal of both is to ensure accurate flow of materials at the right time and location, however it has been reported that commercial supply chains cannot respond effectively as they are inflexible and lack the sufficient alternatives for humanitarian situations (Park et al., 2013).

### 2.3.2 Role of information systems in humanitarian supply chains

In humanitarian supply chains, there are interconnected networks involving coordination between the multiple organisations for exchanging materials, information and achieving speed, efficiency and reliability in the operations. Due to a large number of stakeholders with disparate interests involved in the humanitarian supply chain, coordination, standardization and administration become major challenges (Gavidia, 2017). Humanitarian logistics literature constantly highlights the need for robust information systems for the effective coordination of humanitarian relief and (Day et al., 2012) note that there have been numerous calls to integrate the information systems and supply chain management literature in order to accommodate the peculiar needs of the humanitarian logistics.

Lack of proper information management and coordination have resulted in prominent failures in humanitarian response situations which highlight the deficiencies in emergency humanitarian logistics (Altay & Labonte, 2014; Holguín-Veras et al., 2013; Kovács & Spens, 2007). An independent report commissioned by the UN OCHA highlights the issues in logistics, calling for better coordination amongst NGO's and humanitarian UN agencies (Adinolfi et al., 2005). The leading impediments to disaster relief are identified as 1) limited willingness to exchange or share information 2) inaccurate filtering and diffusion of information to humanitarian stakeholders 3) poor communication between humanitarian actors 4) inaccessible information 5) inconsistent or unreliable data 6) information overload 7) low prioritization of information flows 8) disorganized storage media and 9) organisational politics (Altay & Pal, 2014; Day et al., 2009; Pettit & Beresford, 2009). Baharmand (2016) conducted a multidisciplinary field study and noticed discrepancies in the information management practices at the headquarters and local practices in Kathmandu. The author further proposes that an all-encompassing and collaborative networked response can improve the local resilience and enhance adaptive capacity of humanitarian organisations. Balcik et al. (2008) observe that the logistical problems in the last phase stem from lack of coordination between the relief stakeholders, transportation and broken infrastructure. Howden (2009) highlights that information systems improve overall effectiveness and efficiency in the humanitarian supply chains and identifies the following advantages for its adoption in the humanitarian field,

- Enhance the needs assessment requirement for stocks and supplies.
- Share procurement and supply related information with the program staff.
- Create trust between the program staff by keeping them informed about procurements.
- Accurate visibility of financial information and budgets.
- Effective monitoring and management of costs, inventory and resource utilisation.

The Global Symposium+5 have endorsed the humanitarian information management principles and Van de Walle et al. (2009) summarise them as accessibility, inclusiveness, interoperability, accountability, verifiability, relevance, impartiality, humanity, timeliness, sustainably, and add three new principles – reliability, reciprocity and confidentiality. Since 2012, the role of IT in the humanitarian sector has been discussed and the potential for adopting technologies such as web-based decision support systems, satellite and GPS technologies for vehicle tracking, big data analytics and the integration of social media tools has been considered (Ramadurai & Bhatia, 2019). In the past, improving productivity and efficiency of humanitarian supply chains have been identified as some of the challenges and studies suggest that such issues can be resolved by the inclusion of technology led designs and data analytics (Behl & Dutta, 2019).

#### 2.3.2.1 Systems adopted in humanitarian supply chains

As identified by Blecken and Hellingrath (2008), SUMA, LSS, Helios, HLS and Logistix are some of the major past and current supply chain systems deployed in humanitarian supply chain management. RITA is an open-source application used by WFP and Logistics cluster to support the wider humanitarian community.

| | |
|---|---|
| **SUMA** | • A pioneering and specialised humanitarian SCM tool used in small scale humanitarian operations.<br>• Rendered obsolete due to the increasing complexity in humanitarian operations and new technological development. |
| **LSS** | • Successor to SUMA with a web-based interface.<br>• Lacks an extensive tracing and tracking module. |
| **Helios** | • Tracks information and material flows from supplier to local warehouses.<br>• Stock organisation and last mile distribution are out of scope of the software. |
| **Logistix** | • Similar to Helios, it tracks the flow of materials and information from headquarters to field. |
| **HLS** | • Used in large humanitarian organisations such as the IFRC.<br>• Predecessor to Helios SCM software. |
| **RITA** | • Used by the WFP and Logistics Cluster for tracking the transportation and storage of relief items. |
| **UniField** | • Based on the OpenERP platform and used by MSF in slow onset disaster situations.<br>• Ability to synchronize data in offline mode in case of weak internet connectivity. |

*Table 5. Humanitarian supply chain management applications (Blecken & Hellingrath, 2008)*

The humanitarian SCM systems listed in Table 5. have been built considering different priorities which partially satisfy the humanitarian supply chain requirements and functionalities, however, do not completely fulfil all the objectives and requirements of the supply chain, for instance, the last mile distribution of relief items (Caon et al., 2020; Suzuki, 2020) is one of the lacking functionalities that has been identified in these tools. Additionally, based on the humanitarian supply chain systems implemented in Table 3. it is evident that large scale humanitarian organisations such as the WFP, MSF, Oxfam and IFRC have the capability to build asset tracking tools and can potentially adopt cutting edge blockchain technology as an incremental or synthetic solution rather than a radical transformative one.

### 2.3.3 Partnerships in the humanitarian sector

In 2005, the World Economic Forum initiated a partnership between four global transportation and logistics organisations - Maersk, Agility, UPS and DP World to create the LET (Logistics Emergency Teams) for supporting the Logistics Cluster which is led by the United Nations World Food Programme (LET, n.d.). During emergency response and large-scale natural disaster situations, the four organisations collaborate in order to support the humanitarian sector by pooling their resources, expertise, experience and capacity with the humanitarian community and provide a demand driven, efficient and effective disaster relief. The LET partnership formalises a first of its kind public-private partnership for enabling co-operation between multiple stakeholders.

Nethope is a partnership established between private technology providers and NGO's and is based in the conviction that the international development sector can greatly benefit by the integration of information technologies. The partnership identifies the business needs and operational challenges of NGO's and evaluates potential technology-based solutions to work towards a successful strategy with an aim to deliver value propositions to its partners, donors and community activists (Nethope, n.d.).

World's largest logistics company DHL provides professional logistics services to UN agencies, international humanitarian organisations, suppliers, and NGOs and in 2019, with its extensive experience in the disaster management area, consolidated its humanitarian operations and services facility under the Global Competence Center for Humanitarian Logistics in Dubai for the purpose of providing reliable humanitarian services and enhancing the global support network. This facility can be used for fast and efficient transportation of resources and services involving supply of critical medicines, healthcare and life sciences products which require temperature controlled cold chains (DHL, 2019).

### 2.3.4 Blockchain led initiatives in the humanitarian sector

Experts in the industry and academia have been exploring the use cases and applications of blockchain technology in the humanitarian sector and perceive several benefits and challenges for its implementation. The section below summarises a few compelling academic as well as practice-led initiatives involving proofs-of-concept, pilot projects and case studies conducted in the humanitarian sector.

#### 2.3.4.1 Practice led initiatives in the humanitarian sector

The Track & Trust blockchain technology-based solution developed by a consortium of organizations such as Datarella, DFID, Atlas Logistique and ESA seeks to improve trust amongst the humanitarian supply chain stakeholders by maintaining a 'single source of truth' of the data using an immutable, tamper resistant transactions for the exchange and transfer of the custody of goods (ESA, 2019). Humanitarian agencies across the world manage complex supply chains over long distances and some of the challenges they face are related to reliably tracking the custody of goods, errors due to manual interventions, loss of the chain of custody goods, lack of or limited communications networks and lack of trust between the various stakeholders. The governments and NGOs are the two user groups identified by the product developers, in addition to partnering organisations such as leading logistics companies and aid agencies. The Track & Trust solution has been successfully piloted for the efficient tracking of relief items and aims to resolve humanitarian supply chain challenges such as collaboration, last mile distribution and high costs (ESA, 2019).

Keenaghan et al. (2019) explored the potential use cases of blockchain technology in humanitarian relief for improving efficiency and effectiveness and identifying multiple 'friction points' in the supply chain. The authors from Defence Logistics Agency (DLA) reported that blockchain technology may offer improvement in terms of auditability, security, enhanced communication, reduction in transaction time, data deduplication, streamlining manual processes and conclude that the stakeholders should persist with the exploration of blockchain technology for potential adoption by partners and federal governments (Keenaghan et al., 2019).

#### 2.3.4.2 Academic initiatives in the humanitarian sector

Dubey et al. (2020) conducted a survey based empirical investigation involving 256 senior managers from various international NGOs for understanding the influence of blockchain technology on factors such as transparency, swift trust, collaboration and resilience in the humanitarian sector and their findings support the need for blockchain enabled supply chains. They state that blockchain as a transformative technology has the capability to improve trust and transparency in supply chains across various industry sectors and consequently, has the potential to enhance collaboration by building swift trust amongst various stakeholders involved in the humanitarian operations. They further assert that blockchain technology exerts significant direct and indirect influence on critical humanitarian supply chain factors such as transparency, swift trust, collaboration, and resilience.

Using the TOE Framework, Baharmand and Comes (2019) identified the barriers to smart contract adoption in the humanitarian supply chains and provided future research guidelines and propositions. They state that blockchain can increase transparency, cost and time efficiency in humanitarian supply chains, but several adoption barriers exist at the technological, organizational and environmental level. From an organisational perspective, impediments such as constrained budgets, insufficient top level management support and critical process level changes are identified whereas at the technological level, obstacles such as complex requirements, immaturity of blockchain technology, lack of infrastructure in disaster zones and immutability of data operations are identified. The environmental barriers mentioned are regulation issues, differing objectives and principles between the commercial stakeholders and humanitarian officers and the lack of sufficient pilot projects to justify the adoption of blockchain technology. They further advise that its impact should be investigated empirically, and the long-term assessment should be conducted from an interdisciplinary perspective. In another subsequent study, Baharmand (2021) designed a framework and validated the guidelines for humanitarian blockchain projects. Their framework highlighted the need to consider factors such as infrastructure, privacy and ethics, stakeholders, end-users, blockchain knowledge and intellectual property in organisational design requirements.

Applying qualitative research techniques such as literature reviews, written submissions and semi-structured interviews with various participants from the humanitarian sector and blockchain technology domain, Coppi and Fast (2019) compiled a report for understanding the applications and use cases of blockchain technology. The lessons learnt from this study are categorised into three levels – project level, system level and policy level and the specific recommendations made by them are listed below,

- Transparency should be regarded as a prerequisite for blockchain implementations.
- Blockchain initiatives should be based on evidence.
- The backend processes should be considered as an opportunity and the front-end processes as a challenge.
- Blockchain design considerations should be carefully approached.
- The significant knowledge gap in the regulatory, compliance and legal spheres should be closed by the stakeholders.
- Vulnerable communities and recipients should be prevented from digital harm.

- Blockchain should be implemented as a transformative solution rather than a reformative one.

After reviewing 64 studies related to blockchain technology applications in humanitarian operations management published between 2015 and 2021, Hunt et al. (2022) identified the current state-of-the-art and themes in the literature. The study proposes that research should be pursued in wide ranging areas related from policy development to technical advancements in the humanitarian operations management and blockchain technology space.

### 2.4 Peripheral and divergent areas of the research

Since the study attempted to explore and analyse the blockchain technology research in humanitarian supply chains and logistics, which is a part of the larger humanitarian sector, various closely related interdisciplinary topics may need to be rigorously investigated in order to comprehensively explain the phenomenon. Thus, the topics listed below, but not limited to, have been identified as peripheral or divergent from the main topic of the research,

- Modelling and network designing techniques of humanitarian supply chains.
- Operational, tactical and strategic management of humanitarian supply chains.
- Legal advocacy or recommendations involving regulatory and compliance requirements.
- Geopolitical interests.
- Establishing computing standards.
- End to end enterprise resource planning activities.

## 3.0 Methods

### 3.1 Background

The study employed a pluralist research strategy involving an interpretive approach for conducting the literature review as well as the positivist computational linguistic techniques for implementing the LDA topic model. Though tensions exist between the two philosophical positions i.e., positivism and interpretivism, researchers may reconcile these differences by using computational analysis techniques while dealing with massive quantities of textual data and gain interpretive insights by construing the text. Neuman (2014) argues that rather than creating a rigid divide based on the dichotomy between the interpretivist and positivist methods, a judicious researcher appreciates the strengths and limitations of each approach and gives equal weightage to both sides with the objective of building a better interpretation and explanation of the social world.

As part of the positivist enquiry, the machine learning algorithms applied for performing the computational linguistics analysis can be categorised into two types - supervised and unsupervised (Alloghani et al., 2020). The supervised algorithms use a set of known predictor variables and target variables while unsupervised algorithms use a set of known predictor variables to determine a set of target variables (Hassani et al., 2020; Moro et al., 2019). The LDA topic modelling technique can be used in a supervised as well as unsupervised mode however, this study only implemented the unsupervised LDA model due to a limited size of the corpus. In the preceding sections, from an interpretivist perspective, the literature review based on a qualitative thematic analysis was performed where critical data segments were initially identified and then compiled into keywords and key phrases to derive the latent themes (Clarke & Braun, 2017). Such themes are the recurrent concepts or patterns in the relevant literature and were visualised through a mind map. The themes and sub themes were interpreted for the purpose of comparing and scrutinising them against the LDA results.

As a generative probabilistic model with high ability for dimensionality reduction, LDA enables a set of unobserved groups to be explicated by a set of observations that have associated traits, for instance, words are the observations from the text documents (Chen et al., 2022; Jacobi et al., 2016). Initially, LDA identifies the topics from the corpus by clustering the documents based on the distribution of the topics and then it generates semantically linked word clusters for representing each topic (Chen et al., 2022; Li et al., 2022). Each document in the LDA dataset has a probability distribution over topics and each topic has a probability distribution over words. The fundamental generative process of LDA is shown in Fig. 9

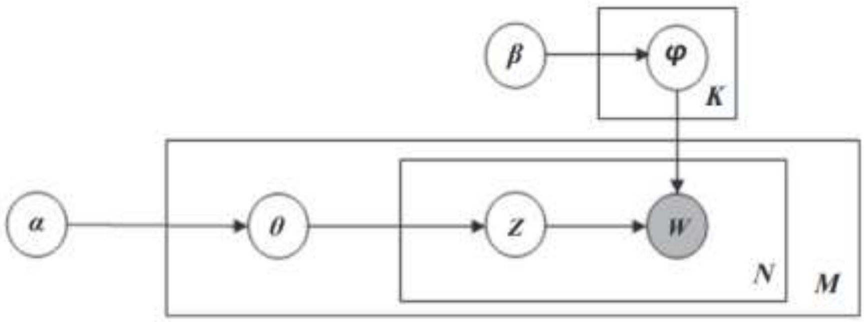


*Fig 9. LDA plate notation (adapted from Blei, 2012)*

The rectangles in the LDA notation are known as plates while the arrows represent the flow or orientation between the variables represented by circles (Computational Linguistics, 2019).

The plates represent the loops where K = number of topics (known value), M = number of documents in the corpus and N = number of words in a document. M and N are nested loops, and it executes the iterations N number of times for every M value. $\alpha$ and $\beta$ are vectors of size M and K respectively, where $\alpha$ contributes to the calculation of $\theta$. The value $\theta$ is the distribution of documents and topics that can be represented as a matrix of values M x K i.e., number of documents x number of topics. Similarly, $\beta$ contributes to the calculation of $\phi$, where $\phi$ is the distribution of topics and vocabulary, that can be represented as a matrix of values K x V i.e., number of topics x number of unique words in the vocabulary. Thus, $\theta$ = number of topics in each document while $\phi$ = number of words in a topic, and these variables represent the state of the model. In each pass, the model loops through all the words in all the documents to complete a single iteration. For instance, in the case of 2000 iterations, the algorithm will traverse through all words of all documents 2000 times each, while it updates the next state of the model. In this way, $\theta$ and $\phi$ values are updated with every iteration and the model converges to the final solution i.e., z = number of topics and w = number of words.

LDA is the most prominent and high-performance topic modelling technique that can be used for scrutinising a large collection of unstructured documents (Jacobi et al., 2016; Grün & Hornik, 2011; Medhi, 2020). Topic modelling using LDA may provide useful directions to businesses and stakeholders, select the appropriate areas and topics for research and keep researcher and practitioners abreast of the recent developments in the emergent research literature. A handful of studies in the information systems domain have used LDA for conducting textual analysis with constructive results e.g., Medhi (2020) used LDA topic modelling techniques to find the focus areas of organisational supply chain processes through the application of blockchain technology. The author provided a theoretical explanation on how supply chain firms can adopt blockchain technology to gain a competitive advantage. In a similar study using the LDA techniques, Hirata et al. (2021) identified that two key factors should be prioritised, 1) the integration of blockchain technology with IoT 2) the design considerations of blockchain technology in supply chain management. In another study conducted by Nerur and Balijepally (2017), the abstracts of four information systems journals were analysed to discover the dominant themes related to software development practices using the LDA topic modelling method.

### 3.2 Research design and sampling

The topic of blockchain technology applications in humanitarian supply chains and logistics is not thoroughly understood as the relevant literature is scant and very few pilot projects have been undertaken. Therefore, the exploratory nature of the study attempted to gain familiarity and understanding of the phenomenon by generating a LDA topic model as well as comparing the results against a thematic analysis of the literature.

Majority of the LDA text mining studies are based on the abstract of the article and prefer a sample size of 1000 or more documents (Thakur & Kumar, 2022). However, studies involving entire text articles yield more accurate results and therefore, the researcher used both, top-down and bottom-up approaches (Syed et al., 2018) for implementing the LDA topic models on a predetermined corpus of 54 full length documents (see Appendix B). The 54 documents in portable document format (PDF) were selected from databases such as Scopus, Google Search and Google Scholar and then converted into plain text (TXT) format for the purpose of creating a dataset as an input to the LDA topic model. Used search terms such as "Blockchain Humanitarian", "Blockchain Humanitarian Supply Chain and Logistics", "Blockchain Humanitarian Supply Chain", "Blockchain Humanitarian Logistics" and “Distributed Ledger Humanitarian” as keywords in Scopus, Google Search and Google Scholar to scope the literature related to blockchain technology applications in humanitarian supply chain and logistics. The HSC BCT dataset was acquired from multiple sources such as journals, conferences, book chapters and whitepapers that were identified based on the traits such as the journal’s reputation, author’s reputation, institutional reputation, organisational capability, the estimated number of citations and pertinence to the study title and research question. In conventional research terminology, the HSC BCT dataset or corpus refers to the data sample used for conducting the study.

LDA analysis can be conducted using various software packages and libraries like Gensim, Mallet and Sklearn that are available across various programming languages such as R and Python (Gottipati et al., 2020; Ray et al., 2019). In this study, Python software packages and libraries such as Gensim and Mallet for LDA computation, Pandas for data processing, Numpy for matrix calculation, Spacy and NLTK for data pre-processing and Matplotlib for data visualisation were used. Additionally, a GUI based TopicModellingTool written in Java and used for LDA topic generation (Enderle, 2017). Python version 3.8.8 was used for pre-processing and post-processing the dataset in the Jupyter Notebook version 6.3.0 development environment through the Anaconda Navigator application version 2.1.4.

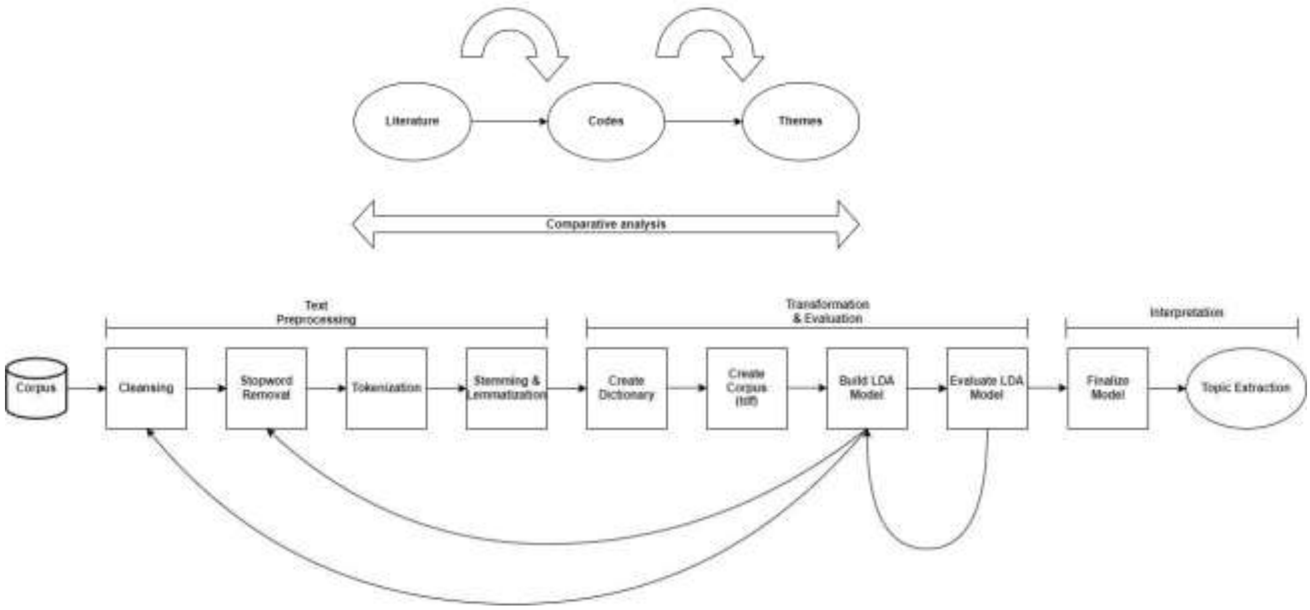


*Fig 10. LDA process flow*

The LDA steps for conducting the study are shown in Fig 10. Python libraries such as Numpy, Spacy and NLTK were used for pre-processing the HSC BCT corpus. Noise in the form of stopwords, plural forms of words, punctuation and extra spacing can negatively impact the analysis of the LDA algorithm (Rose & Lennerholt, 2017). Thus, as a first step, the noise in the HSC BCT dataset was pre-processed or cleansed. Data pre-processing involved crucial steps such as lowercasing, stopword removal, tokenization, stemming and lemmatization. Lowercasing was used to change the text case to lowercase while stopword removal eliminated characters such as extra spacing and punctuations which did not possess any meaningful semantic roles. A dictionary of stopwords was created based on the identification of high frequency keywords from the text corpus as well as incorporating the words from the Spacy package and these identified stopwords were eliminated from the corpus. In the next step, tokenization converted the texts and sentences into a list of words while lemmatization reduced a specific word variation to a single word.

Part of Speech (PoS) tagging was used to retain all forms of words i.e., of Noun, Verb, Adjectives and Adverbs from the HSC BCT dataset. The sequentially and frequently occurring word phrases in the document were handled using bi-grams and trigrams. After all the text files in the dataset were pre-processed, the final word count was approximately 2,24,772 words. Subsequently, the corpus was analysed using Python and the GUI based TopicModellingTool and run iteratively with different values of k ranging from 2 to 20 to arrive at an optimum number of topics. In fact, the GUI based TopicModellingTool uses a Mallet package for the back end, similar to the Python script (Enderle, 2017). The Python script created by the researcher for pre-processing the text files as an input to the LDA topic evaluation process can be found in the Appendix section (see Appendix A).

The rationale for using Python in combination with the TopicModellingTool was that the Python script offered a more powerful and flexible way of preprocessing and evaluating the HSC BCT dataset, while the TopicModellingTool produced meaningful and coherent results to a greater degree. The steps performed in Python informed further actions in the TopicModellingTool. In order to support the LDA model, a wordcloud and the vocabulary of words based on the word frequency, topic-specificity was generated using the jsLDA in-browser topic modelling tool (Mimno, n.d.). The results of the steps including the LDA analysis, keyword extraction and wordcloud are discussed in the next section.

# 4.0 Findings

## 4.1 Model fitting

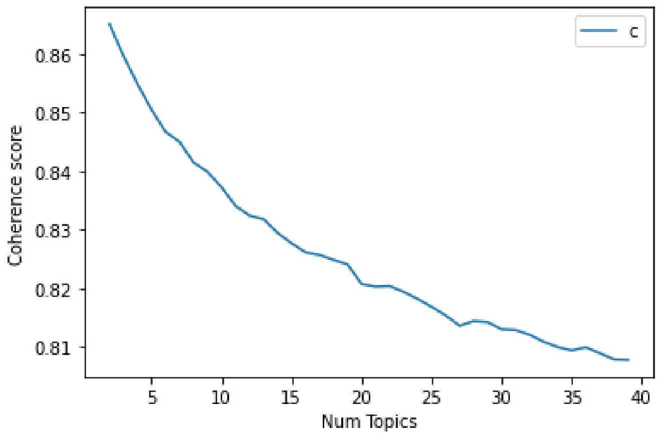


*Fig 11. Coherence scores*

The LDA model performance using the Mallet package in Python and the TopicModellingTool was satisfactory and based on the measures such as a higher coherence score, lower perplexity score, larger inter-topic distance as well as the researcher's subjective judgement, the most pertinent topics from the analysed corpus were extracted (Kapadia, 2019; Lee et al., 2022; O'Callaghan et al., 2015; Syed and Spruit, 2017). The perplexity score captures how surprised the LDA model is of unseen data while the coherence value scores a topic by measuring the level of semantic congruity between high scoring words in the topic (Kapadia, 2019). The

Gensim library results were excluded from the final analysis due to a subpar and immaterial output in terms of topic extraction and the research context.

As shown in Fig 11. for k = 3, the topic model achieved a high coherence score of up to 0.8597 and a low perplexity score of -7.42 which posits how well it has identified the latent semantic structure from the HSC BCT corpus however, albeit such scores may indicate better generalisability by the LDA model, it might distort the judgement on topic evaluation.

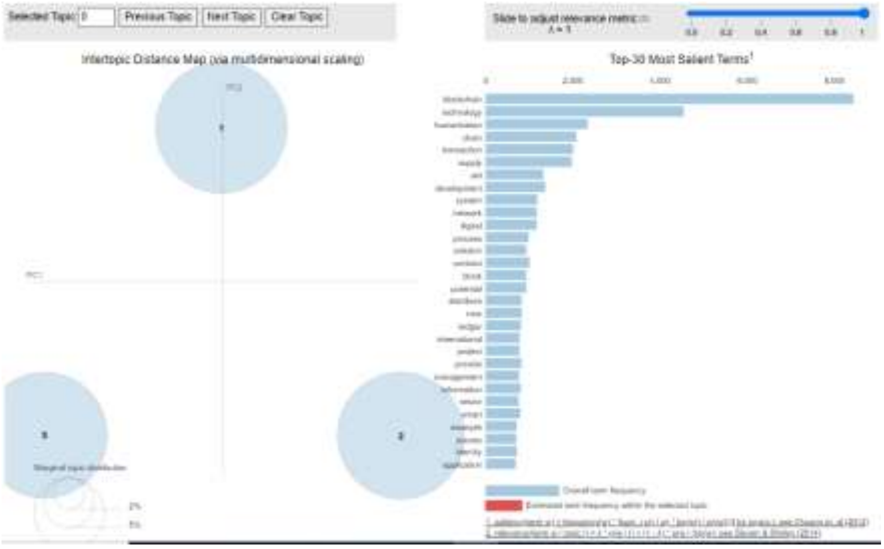

*Fig 12. Inter-topic distance*

As seen in Fig 12., after visualising the topics using the LDAvis package in Jupyter Notebook, it was observed that three topics were scattered across the four quadrants without any overlapping and a considerable inter-topic distance between them. In addition to the standard evaluative measures for arriving at the final number of topics, the researcher's subjective interpretation was applied based on the semantic cohesiveness and meaningfulness of the extracted topics. Finally, after iteratively executing the LDA topic model in the GUI based TopicModellingTool for k values ranging from 2 to 20, the eventual number of topics i.e., k for the HSC BCT dataset was finalised as 3 and the model evaluation and fitting process was concluded.

## 4.2 Word cloud and word frequency

The HSC BCT dataset was used for generating a wordcloud and can be seen in Fig 13. The irrelevant words from the wordcloud were excluded to ensure interrelatedness between the words and the research topic. The Tagcrowd website (Tagcrowd, 2022) offers a free web-based tool which was used for creating the wordcloud and it offers some level of customisation for example, the wordcloud in Fig 13. includes only the top 100 words from the HSC BCT dataset that are grouped together. The large-size and mid-size words such as 1) Information 2) Coordination 3) Technology 4) Transaction 5) Trust 6) Transparency 7) Cost in the word cloud indicate higher significance in the context of the study.


*Fig 13. Wordcloud*

Next, the output of the jsLDA in-browser topic modelling tool after processing the HSC BCT dataset produced a vocabulary of words based on the word frequency. For better visualisation purposes the word frequency was converted to a chart as seen in Fig 14.

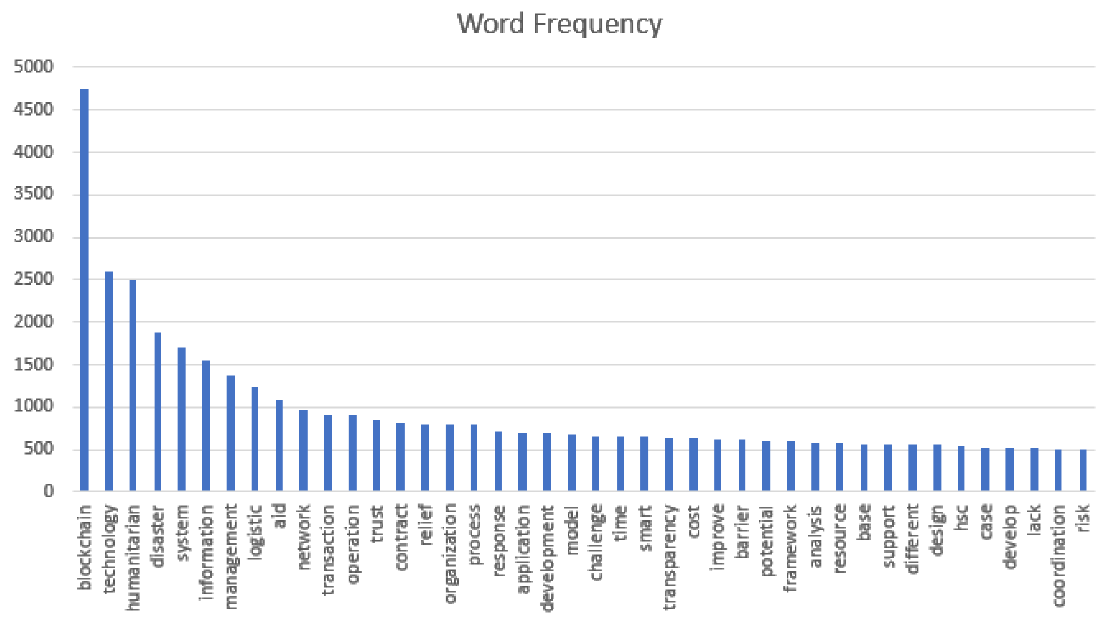


*Fig 14. Vocabulary of words based on frequency*

The top 42 words ranging from a frequency of 4743 - 503 are considered and all the words having a frequency of less than 500 are excluded from the vocabulary. The word blockchain has the highest frequency of 4753 and the word risk has the lowest frequency of 503. Table 6. shows some crucial vocabulary words along with their word frequencies.

| Word | Frequency |
|---|---|
| Trust | 849 |
| Time | 657 |
| Transparency | 639 |
| Cost | 638 |
| Coordination | 505 |

*Table 6. Significant vocabulary words*

The vocabulary results omitted certain high frequency stopwords based on the triviality to the study e.g., words such as include and need.

**4.3 LDA results**

The study reported the top 25 salient keywords discovered in each topic, and each topic is to a large extent, independent of one another. However, there are certain identical words that fall under different topic headings due to the context in which they are scrutinised. For example, the word distribute under Topic # 2 Technology suggests distributed ledger technology while under Topic # 3 Organisational Operations it suggests distribution of relief items. The output of the LDA topic model that was fitted on the HSC BCT dataset and the 25 salient words can be seen in Table 7. and the full LDA output can be seen under Appendix C.

| Topics | Salient words |
|---|---|
| Topic # 1 Systems adoption | information barrier trust adoption system transparency management improve coordination factor traceability application industry performance framework challenge service risk security implementation model organization stakeholder enhance lack |
| Topic # 2 Technology | transaction system development contract project chain smart ledger design digital participant block distribute application network cost solution record identity access dlt time innovation platform information |
| Topic # 3 Organisational operations | disaster supply chain management humanitarian information response logistic relief operation emergency resource time demand process support communication flow distribution |

| | |
|---|---|
| | coordination organization source material country inventory food |

*Table 7. LDA topic model output*

The outcome of the results as well as the responses to the three research questions are discussed in the below section.

# 5.0 Discussion

Given the small size of the corpus available for research, the identified topics are acceptable for analysing and gaining limited insights into the applications of blockchain technology research in humanitarian supply chains and logistics. The results are scant but justifiable because the literature for the HSC BCT dataset is winnowed out based on a narrow set of research contexts. Despite the narrow output of the LDA analysis, in response to the three research questions the study has, 1) Summarised the output of the LDA analysis 2) Compared the output of LDA analysis with the thematic analysis of the literature 3) Identified critical areas of research based on output of the LDA model and thematic analysis process.

## 5.1 LDA topics

In response to the first research question i.e., 'What are the latent topics emerging from the literature on blockchain technology research in humanitarian supply chains and logistics using the LDA topic model?' three i.e., k = 3 implicit topics were discovered in the HSC BCT dataset using the LDA topic modelling approach where, Topic # 1 contains a distribution of words that are consolidated under the topic Systems adoption; Topic # 2 contains a distribution of words that are consolidated under the topic Technology; Topic # 3 contains a distribution of words that are consolidated under the topic Organisational organisations. The three topics extracted from the HSC BCT corpus represent the latent themes present in the dataset.

Firstly, under Topic # 1 Technology adoption, crucial words such as 1) Trust 2) Transparency 3) Coordination 4) Traceability 5) Risk are extracted. Secondly, words such as 1) Smart contracts 2) Cost 3) Access 4) Identity 5) Design 6) Participant are extracted under Topic # 2 Technology. And thirdly, Topic # 3 Organisational operations sheds light on words such as 1) Time 2) Communication 3) Coordination 4) Distribution 5) Inventory 6) Food. The word cloud and word vocabulary highlights terms such as, 1) Trust 2) Transparency 3) Cost 4) Risk 5) Smart Contract 6) Framework 7) Design 8) Coordination. Evidently, the word cloud and word vocabulary are congruent with the extracted LDA topic model and further reiterate the importance of LDA topics in the context of the study.

For instance, in previous studies, the Track and Trust solution was pilot tested for the efficient tracking of relief supplies, and it aims to solve challenges such as collaboration, last-mile distribution and high costs (ESA, 2019). In another study, DLA reported that blockchain technology could bring auditability, security, improved communications, and faster transaction times (Keenaghan et al., 2019). Thus, it can be deduced that the academic and practice led initiatives conducted by humanitarian research experts are broadly consistent with the extracted distribution of the topics and words as they identify the key enablers and inhibitors for the acceptance for blockchain technology in humanitarian supply chains and logistics (Baharmand & Comes, 2019; Dubey et al., 2020; L'Hermitte & Nair, 2020; Negi & Negi, 2020). In other words, the salient words from the LDA topics may represent the critical success factors for investigating the BCT applications in humanitarian supply chains and logistics. Most notably, the word food under Topic # 3 stresses the significance of food distribution as a vital area in the context of humanitarian operations. In the context of humanitarian organisations such as the World Food Programme (WFP), Rakhimova (2021) states that the adoption blockchain technology can 1) Provide end to end traceability of food products 2) Enable the financial inclusion of food insecure communities 3) Ensure equitable distribution 4) Coordinate the humanitarian relief packages. Therefore, in a nutshell, the reviewed literature in the preceding sections conflated with the LDA topic model may prove to be a rich source of information and provide pointers to various stakeholders such as HSC BCT researchers, technologists, logisticians and HSC organisations.

## 5.2 Comparative analysis

In response to the second research question, a comparison was drawn between the manual thematic analysis and the machine learning based LDA topic modelling approach. The comparison in Table 9. shows that there are some striking similarities between the high-level themes and LDA topics; however, at a granular level the codes, sub-themes and LDA words are not exactly identical but rather loosely linked to one another. In the case of the study at hand, the combination of the LDA topic model and literature review methods proves to be a potent concurrent mixed methods research strategy as the output of each method is analogous and complementary to each other. From a researcher’s perspective, the mixed methods literature analysis provides a more comprehensive picture of the research topic e.g., In below Table 8. 1) Under Technology, Blockchain Technology can be mapped to its characteristics such as Design and Smart Contracts while Security can be mapped to Access 2) Under Organisational Operations, Humanitarian crises can be associated with Food. An additional theme i.e., Environment was revealed as a part of the thematic analysis process but left unextracted by the LDA topic model. Codes such as laws, regulations and geopolitics fall under the theme Environment. Thus, such a mixed methods approach using the concurrent strategy (Creswell & Creswell, 2017) may augment the literature reviews and inform further primary qualitative and quantitative investigative methods such as interviews or surveys from the standpoint of blockchain technology research in humanitarian supply chains and logistics.

| Themes / Topics | Thematic analysis codes | Salient LDA words |
|---|---|---|
| **Technology** | 1) Blockchain technology<br>2) HSCM Info Systems<br>3) RDBMS<br>4) Security<br>5) Supporting technologies | 1) Smart contracts<br>2) Cost<br>3) Access<br>4) Identity<br>5) Design<br>6) Participant |
| **Organisational Operations** | 1) HSC stakeholders<br>2) Types of HSC<br>3) HSC organisations<br>4) Humanitarian crises | 1) Time<br>2) Communication<br>3) Coordination<br>4) Distribution<br>5) Inventory<br>6) Food |
| **Systems Adoption** | 1) Research motivations<br>2) Research methodology<br>3) Pilot projects<br>4) Research framework | 1) Trust<br>2) Transparency<br>3) Coordination<br>4) Traceability<br>5) Risk<br>6) Implementation |
| **Environment** | 1) Geopolitics<br>2) Laws and regulations | X |

*Table 8. Comparison between thematic analysis and LDA generated topics*

### 5.3 Opportunities

Lastly, in response to the third research question i.e. 'What are the opportunities for more impactful and contributory enquiry from the standpoint of blockchain technology research in humanitarian supply chains and logistics?' the utilisation of pertinent technology adoption and information systems (IS) theories is proposed. There are a myriad of information systems and technology adoption theories available to a researcher in the academic literature (Dwivedi et al., 2011) and selecting the appropriate theory that fits a research topic especially, dealing with blockchain technology applications in humanitarian supply chain and logistics can be an arduous task. The output from such LDA topic models can complement a literature analysis process and assist in narrowing the selection of theoretical models. Concordant to the LDA topic model output, a previous study conducted by Fast (2019) recommends that the insights gained from the HSC BCT research can be divided into three levels - project level, system level and policy level. Similarly, Hunt et al. (2022) note that research needs to be conducted in a wide range of areas, from policy making to humanitarian aid management and the advances in blockchain technology. Multiple studies suggest that several barriers to blockchain technology adoption exist at the technological level, organizational level and environmental level in HSC (Baharmand & Comes, 2019; Dubey et al., 2020; Keenaghan et al., 2019).

Based on the LDA topic model and the reviewed literature it can be inferred that information systems theories evaluating technology adoption through the sociomaterial lenses of technology, organisation and technology acceptance could prove to be fitting in the HSC BCT research domain. More specifically, researchers may explore and extend theories such as the 1) Technology-Organisation-Environment (TOE) framework (Tornatzky et al., 1990) 2) Diffusion of Innovation (DOI) theory (Rogers, 2003) 3) Unified theory of acceptance and use of technology (UTAUT) (Venkatesh et al., 2003) or an integrated framework that consolidates such theories. Baker (2012) notes that the TOE Framework provides consistent empirical and theoretical support over a number of studies conducted in national, cultural, technological and industrial contexts. The author further attests that the TOE framework has broad applicability in the information systems areas such as EDI, open-source systems, blockchain, smart contracts, IoT, inter organisational systems and ERP systems. From the TOE framework standpoint, Clohessy et al. (2019) substantiate that organisations are unique in terms of size, culture, industry sector, structure and therefore, a combination of all these factors affect the blockchain technology adoption intentions. In proposition of the TOE framework, Wolverton and Lanier (2019) argue that in many technology adoption contexts, a micro level adoption framework such as the UTAUT may explain the individual level perception for adoption of an innovation however, institutional pressures external to the organisation may change or alter the outcome of those decisions and suggest that macro-level factors are significantly influential in such situations.

The Diffusion of Innovations (DOI) theory is often considered as one of the pioneering and widely regarded models used for understanding the spread of technological innovations over time among a group of members in a social system (Kaminski, 2011). The DOI theory proves to be a valuable lens for assessing the uptake of new innovations in a variety of contexts. Particularly, the integration of TOE framework and the DOI theories has consistent empirical support and is used extensively in the information systems adoption studies as it possesses overlapping contexts (Oliveira et al., 2014) and provides a strong validation for its use in information systems studies. Additionally, the Unified Theory of Acceptance and Use of Technology (UTAUT) examines technology acceptance as determined by expected performance, expected effort, social impact, and the impact of enabling conditions (Venkatesh et al., 2003). A methodological explanation for integrating the pertinent information systems theories can be found under Appendix D.

Though an extensive set of topics were not extracted by LDA the topic model, researchers may have an opportunity to diversify the extant organisational information systems theories by synthesising them with state-of-the-art, transdisciplinary macro and micro level theories such as the Mikropolis model, for instance, factors such as de-contextualisation, recontextualisation, formalisation gaps and technology push / demand–pull from the Mikropolis model (Wahoff et al., 2012) can be extended into the organisational level information systems framework in an attempt to elaborate on the blockchain technology application in humanitarian supply chains and logistics. Furthermore, researchers could narrow the focus of the HSC BCT research based on the critical topics and words emerging from the LDA topic model and also employ a comparative analysis of LDA topic modelling and literature review methods in order to magnify the effectiveness of the study.

## 6.0 Conclusion and Limitations

After analysing 54 full length text documents that investigated the applications of blockchain technology in humanitarian supply chains and logistics, it is evident that the LDA topics are broadly distributed over three themes or dimensions – Systems Adoption, Technology and Organisational Operations. Systems adoption covered critical words such as trust, transparency, coordination, and traceability while Technology dealt with words such as smart contracts, cost, access, identity, and design. The third topic, Organisational Operations sheds light on key words such as time, communication, coordination, and food. Both, the word cloud and word frequencies are consistent with the LDA topic model and corroborate the significant vocabularies such as coordination, transaction, trust, transparency, and cost that are critical from the perspective of blockchain technology exploration in humanitarian supply chains and logistics.

A comparison between the manual thematic analysis and computational linguistics based LDA topic model indicates that there is a significant scope to fuse the two methods and utilise them as a mixed methods approach. The mixing of the LDA topic model and literature review methods could be performed using a concurrent typology. In case of a successful topic extraction process, such topic models may have a high capacity to augment a literature review process and inform further primary investigations involving qualitative and quantitative research strategies, for example, for the purpose of designing interviews, focus groups or survey instruments.

From a theoretical research contribution perspective, researchers may consider integrating and diverging the extant sociotechnical theories that encompass the technological, organisational, and environmental dimensions i.e., TOE Framework (Tornatzky et al., 1990), UTAUT (Venkatesh et al., 2003) and DOI (Rogers, 2003) for the purpose of investigating blockchain technology applications in humanitarian supply chains and logistics enterprises. Researchers may also consider extending the TOE framework by drawing the micro and macro level constructs from state-of-the-art theories such as the Mikropolis model (Wahoff et al., 2012) and advance the knowledge on technology adoption in organisations.

Since the LDA topic model was built in an unsupervised mode, there was no validation done in terms of training the dataset. However, the model was evaluated using perplexity scores, coherence measures and the inter-topic distance which suggested that the analysis of the number of topics i.e., k = 3 is reliable. From a performance perspective, LDA can be computationally expensive on an extremely large-scale dataset and may require specialised hardware resources for its execution. Besides, the LDA topic modelling method may appeal to technically oriented researchers as compared to non-technical researchers due to the scripting steps involved in the execution and analysis of the end-to-end LDA process. The LDA analysis using the Mallet package generated cogent results in comparison to the Gensim library which did not exhibit any satisfactory outcomes and therefore, experimenting with various LDA tools, libraries and packages is pivotal. And despite the fact that statistical methods were used for executing the LDA topic model, the selection and interpretation of the topics was ultimately done based on a manual assessment.

As the HSC BCT corpus size increases with time, future studies could incorporate a large-scale dataset and diverse topic modelling techniques to reveal novel information related to the research domain. Likewise, researchers may broaden the scope of the study by adopting topic modelling techniques that investigate all-encompassing technology applications in the humanitarian sector literature rather than confining the analysis to a specific technology such as blockchain. And lastly, text mining using the LDA topic modelling and its conjunction with qualitative thematic analysis and literature reviews may offer a promising methodological avenue.

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# 8.0 Appendices

## Appendix A: Python script for pre-processing the text files

```
import glob

import os

os.chdir(r'C:\Data cleansing\Text files')

my_files = glob.glob("*.txt")

for x in my_files:

    if x.endswith(".txt"):

        # Prints only text file present in Folder

        print(x)

        filename = x

        path = r'C:\Data cleansing\Text files'

        print(filename)

        goal_dir = os.path.join(path, filename)

        print(os.path.join(path, filename))

        print(goal_dir)

        f = open(os.path.join(path, filename), mode='r', encoding='utf-8')

        pdf_data = f.read()

        text = str(pdf_data)

        #print(text)

        from autocorrect import Speller

        from nltk.tokenize import word_tokenize

        def to_lower(text):

            """

            Converting text to lower case as in, converting "Hello" to  "hello" or "HELLO" to "hello".

            """
```

```
    # Spell check the words
    spell  = Speller(lang='en')
    texts = spell(text)
    return ' '.join([w.lower() for w in word_tokenize(text)])
lower_case = to_lower(text)
#pprint(lower_case)
import nltk
import re
import string
from nltk.corpus import stopwords, brown
from nltk.tokenize import word_tokenize, sent_tokenize, RegexpTokenizer
from nltk.stem import WordNetLemmatizer
from autocorrect import spell
def clean_text(lower_case):
    # split text phrases into words
    words  = nltk.word_tokenize(lower_case)
    # Create a list of all the punctuations we wish to remove
    punctuations = ['.', ',', '/', '!', '?', ';', ':', '(',')', '[',']', '-', '_', '%']
    # Remove all the special characters
    punctuations = re.sub(r'\W', ' ', str(lower_case))
    # Initialize the stopwords variable, which is a list of words ('and', 'the', 'i', 'yourself', 'is')
that do not hold much values as key words
    stop_words  = stopwords.words('english')
    #stopwords = stopwords.words('english')
    stop_words.extend(['from', 'subject', 're', 'edu', 'use'])
```

stop_words.extend(['whatever', 'thereupon', 'side', 'an', 'his', 'bottom', 'else', 'whose', 'too', 'their', '‘s', '’ll', 'ca', 'well', 'mostly', 'mine', 'whence', 'and', 'either', 'what', 'same', 'we', 'further', 'been', 'beside', 'front', 'whom', 're', 'none', 'namely', 'someone', 'several', 'done', 'one', 'towards', 'by', 'him', 'n’t', '‘re', 'whereafter', 'n‘t', 'sometime', 'whole', 'call', 'part', 'anything', 'whereas', 'themselves', 'latterly', 'except', 'everyone', 'anyone', 'he', 'yourselves', 'therein', 'every', 'thereafter', 'doing', 'than', 'via', 'just', 'there', 'anyhow', 'former', 'seeming', 'everywhere', 'nine', 'top', 'first', 'otherwise', 'am', 'without', 'being', 'become', 'least', 'within', 'whereupon', 'move', 'through', 'afterwards', '‘ve', 'whether', 'these', 'last', 'perhaps', '’re', 'becomes', 'how', 'neither', 'during', 'always', 'the', 'over', 'something', 'whoever', 'or', 'even', '’s', 'have', 'most', '‘d', 'moreover', 'as', 'together', 'indeed', 'yours', 'to', 'full', "'ve", 'due', 'various', 'above', 'say', 'would', 'this', 'did', 'cannot', 'three', 'regarding', 'although', 'may', 'beyond', 'whereby', 'elsewhere', 'whenever', 'is', 'meanwhile', 'be', 'so', 'next', 'thus', 'below', 'who', 'can', 'enough', 'behind', 'into', 'had', 'around', 'i', '‘ll', 'made', 'toward', 'my', 'often', 'name', 'per', 'almost', 'they', 'less', 'must', 'upon', 'somehow', 'out', 'were', 'was', 'only', 'has', 'herself', 'of', 'two', 'please', 'you', 'third', 'us', 'already', 'much', 'serious', 'it', 'though', 'each', 'before', 'down', 'among', 'while', "'m", '’d', 'why', 'thence', 'himself', 'off', 'hers', 'nothing', 'her', 'in', 'thereby', 'give', 'no', 'for', 'alone', 'those', 'which', 'across', 'on', 'up', 'nevertheless', 'never', 'beforehand', 'myself', 'our', 'thru', 'sometimes', 'hereafter', 'between', 'will', 'at', 'latter', 'twelve', 'throughout', 'all', 'empty', '’m', 'itself', 'under', 'go', 'hundred', 'wherever', 'back', 'besides', 'might', 'forty', 'against', 'becoming', 'but', 'not', 'fifty', 'anywhere', 'ten', 'when', 'once', "'d", 'really', 'are', 'here', 'using', 'fifteen', 'about', 'also', 'herein', 'then', "'re", 'nobody', 'however', 'somewhere', 'your', 'do', 'from', 'such', 'get', 'after', '‘m', 'noone', 'seemed', 'other', 'now', 'nowhere', 'seem', 'four', 'eight', 'see', 'that', 'very', 'anyway', 'ever', 'many', 'everything', 'me', 'make', 'few', 'if', 'became', 'yet', 'its', 'six', 'since', 'a', 'put', 'because', 'ours', 'should', 'where', 'with', 'nor', 'seems', "'s", 'another', 'take', 'does', 'others', 'hence', 'therefore', 'five', 'them', 'again', 'keep', '’ve', 'both', 'some', 'could', 'hereupon', 'amongst', 'quite', 'rather', 'eleven', 'hereby', "n't", 'own', 'any', 'still', 'used', 'wherein', 'along', 'amount', 'ourselves', 'formerly', 'show', 'sixty', 'unless', 'whither', 'more', 'twenty', 'yourself', 'onto', 'she', "'ll", 'until'])

# Getting rid of all the words that contain numbers in them

```
        w_num = re.sub('\w*\d\w*', '', lower_case).strip()

        # remove all single characters

        lower_case = re.sub(r'\s+[a-zA-Z]\s+', ' ', lower_case)

        # Substituting multiple spaces with single space

        lower_case = re.sub(r'\s+', ' ', lower_case, flags=re.I)

        # Removing prefixed 'b'

        lower_case = re.sub(r'^b\s+', '', lower_case)


        # Removing non-english characters

        lower_case = re.sub(r'^b\s+', '', lower_case)


        # Return keywords which are not in stop words

        keywords = [word for word in words if not word in stop_words  and word in punctuations and  word in w_num]

        return keywords

    # Lemmatize the words

    wordnet_lemmatizer = WordNetLemmatizer()

    lemmatized_word = [wordnet_lemmatizer.lemmatize(word) for word in clean_text(lower_case)]

    # lets print out the output from our function above and see how the data looks like

    clean_data = ' '.join(lemmatized_word)

    #pprint(clean_data)

    #first_pass = r'C:\Data cleansing\First pass'

    #nltk_file = os.path.join(first_pass, filename)

    #with open(nltk_file, 'w', encoding='utf') as f:

        #f.write(str(clean_data))
```

```
# Gensim
import gensim
import gensim.corpora as corpora
from gensim.utils import simple_preprocess
from gensim.models import CoherenceModel
# Plotting tools
import pyLDAvis
#import graphlab as gl
#import pyLDAvis.graphlab
import pyLDAvis.gensim_models  # don't skip this
# Enable logging for gensim - optional
import logging
logging.basicConfig(format='%(asctime)s : %(levelname)s : %(message)s', level=logging.ERROR)
data  = []
data.append(clean_text(lower_case))
# This time we use spacy for lemmatizarion
import spacy
# Second lemmatization of our data
def lemmatization(data, allowed_postags=['NOUN', 'ADJ', 'VERB', 'ADV']):
#def lemmatization(data, allowed_postags=['NOUN', 'VERB', 'ADV']):
#def lemmatization(data, allowed_postags=['NOUN', 'VERB']):
#def lemmatization(data, allowed_postags=['NOUN']):
#def lemmatization(data, allowed_postags=['VERB']):
    """https://spacy.io/api/annotation"""
    texts_output = []
```

```
    for sent in data:
        doc = nlp(" ".join(sent))
        texts_output.append([token.lemma_ for token in doc if token.pos_ in allowed_postags])
    return texts_output
#nlp = spacy.load('en', disable=['parser', 'ner'])
nlp = spacy.load('en_core_web_lg')
nlp.max_length = 999999999999
# Lemmatize keeping only noun, adj, vb, adv
data_lemmatized = lemmatization(data, allowed_postags=['NOUN', 'ADJ', 'VERB', 'ADV'])
#data_lemmatized = lemmatization(data, allowed_postags=['NOUN', 'VERB', 'ADV'])
#data_lemmatized = lemmatization(data, allowed_postags=['NOUN', 'VERB'])
#data_lemmatized = lemmatization(data, allowed_postags=['NOUN'])
#data_lemmatized = lemmatization(data, allowed_postags=['VERB'])
# Remove all the special characters
new_data_lemmatized = re.sub(r'\W', ' ', str(data_lemmatized))
new_data_lemmatized = re.sub(' +',' ', new_data_lemmatized)
second_pass = r'C:\Data cleansing\Second pass'
spacy_file = os.path.join(second_pass, filename)
print(spacy_file)
with open(spacy_file, 'w', encoding='utf') as f:
f.write(str(new_data_lemmatized[:]))
```

**Appendix B: List of 54 documents used as an input dataset to LDA**

| SR # | Title |
|---|---|
| 1 | Integration Of Internet Of Things (Iot) And Blockchain To Increase Humanitarian Aid Supply Chains Performance |
| 2 | The Role Of Blockchain In Reducing The Impact Of Barriers To Humanitarian Supply Chain Management |
| 3 | Solving Humanitarian Aid Inefficiencies With Blockchain Technology |
| 4 | Blockchain And Other Distributed Ledger Technologies In Operations |
| 5 | Leveraging Partnerships With Logistics Service Providers In Humanitarian Supply Chains By Blockchain-Based Smart Contracts |
| 6 | Blockchain With Iot: Applications And Use Cases For A New Paradigm Of Supply Chain Driving Efficiency And Cost |
| 7 | Exploring The Application Of Blockchain To Humanitarian Supply Chains: Insights From Humanitarian Supply Blockchain Pilot Project |
| 8 | Using Blockchain Technology And Artificial Intelligence In Geospatial Data Sharing |
| 9 | Blockchain Technology For Enhancing Swift-Trust, Collaboration And Resilience Within A Humanitarian Supply Chain Setting |
| 10 | An Integrated Approach To Model The Blockchain Implementation Barriers In Humanitarian Supply Chain |
| 11 | Supply Chain Disruption Risk Management With Blockchain: A Dynamic Literature Review |
| 12 | Bibliometric Analysis Of The Potential Of Technologies In The Humanitarian Supply Chain |
| 13 | Blockchain Applications In Humanitarian Logistics |

| | |
|---|---|
| 14 | Assessing The Role Of Industry 4.0 For Enhancing Swift Trust And Coordination In Humanitarian Supply Chain |
| 15 | A Blockchain-Enabled Framework For Sharing Logistics Resources During Emergency Operations |
| 16 | Blockchain In Humanitarian Operations Management: A Review Of Research And Practice |
| 17 | Blockchain As A Tool For Transparency And Governance In The Delivery Of Development Aid |
| 18 | Blockchain For Sustainable Development Goals |
| 19 | Blockchain Technology Development And Implementation For Global Logistics Operations: A Reference Model Perspective |
| 20 | Blockchain Adoption In Logistics And Supply Chain: A Literature Review And Research Agenda |
| 21 | A Use Case For Blockchain Technology: Supply Chain Response To Humanitarian Assistance / Disaster Relief Defense Logistics Agency, Troop Support |
| 22 | Implementation Of Blockchain In The Humanitarian Supply Chain- Benefits And Blockades |
| 23 | Integration Of Internet-Of-Things With Blockchain Technology To Enhance Humanitarian Logistics Performance |
| 24 | Improvement Of Public Distribution System Efficiency Applying Blockchain Technology During Pandemic Outbreak (Covid-19) |
| 25 | Blockchain For Humanitarian Aid What Is The Impact Of Blockchain Technology On The Humanitarian Supply Chain? |
| 26 | The Impact Of The Traceability Of The Information Systems On Humanitarian Logistics Performance: Case Study Of Indonesian Relief Logistics Services |
| 27 | Developing A Framework For Designing Humanitarian Blockchain Projects |

| | |
|---|---|
| 28 | Expert Oriented Approach For Analyzing The Blockchain Adoption Barriers In Humanitarian Supply Chain |
| 29 | Blockchain Technology As An Innovation Strategy For Competitive Advantage By Kenya Redcross Society |
| 30 | Redesigning Supply Chains Using Blockchain-Enabled Circular Economy And Covid-19 Experiences |
| 31 | Framework To Manage Humanitarian Logistics In Disaster Relief Supply Chain Management In India |
| 32 | Humanitarian Supply Blockchain: Concluding Phase 1 Of Track & Trust - Datarella |
| 33 | Effectiveness Of Blockchain In Overcoming Barriers In Humanitarian Supply Chain |
| 34 | Multi-Perspective Exploration Of Blockchain Technology Adoption Factors For Asset Tracking In Humanitarian Supply Chains: A Mixed Methods Approach |
| 35 | Decision Making In Logistics Management In The Era Of Disruptive Technologies |
| 36 | Application Of A Blockchain Enabled Model In Disaster Aids Supply Network Resilience |
| 37 | Analysis And Design Of Systems Utilizing Blockchain Technology To Accelerate The Humanitarian Actions In The Event Of Natural Disasters |
| 38 | Blockchain For Development And Humanitarian Aidimplications And Applications |
| 39 | Disruptive Technologies And Innovations In Humanitarian Aid And Disaster Relief: An Integrative Approach |
| 40 | Blockchain Technology And The Governance Of Foreign Aid |
| 41 | Blockchain Technologies In Logistics And Supply Chain Management: A Bibliometric Review |
| 42 | The Potential Of Emergent Disruptive Technologies For Humanitarian Supply Chains: The Integration Of Blockchain, Artificial Intelligence And 3d Printing |

| | |
|---|---|
| 43 | Supply Chains In Humanitarian Operations: Cases And Analysis |
| 44 | Humanitarian Logistics Performance Improvement Model Using Blockchain Approach |
| 45 | A Revolution In Trust Distributed Ledger Technology In Relief & Development |
| 46 | Blockchain For Improvement Of Emergency Response In Humanitarian Logistics Indonesia |
| 47 | System Dynamic Approach To Improve Emergency Response In Humanitarian Logistics In Indonesia |
| 48 | Technology Usage In Humantarian Response |
| 49 | Blockchain In Humanitarian Aid: A Way Out Of Poverty And Famine? A Case Study Of The Use Of Blockchain Technology By The World Food Programme In Jordan |
| 50 | Emerging Technologies In Emergency Situations |
| 51 | Humanitarian Supply Chain: A Bibliometric Analysis And Future Research Directions |
| 52 | Inclusive Deployment Of Blockchain For Supply Chains |
| 53 | Connecting Refugees To Aid Through Blockchain-Enabled Id Management: World Food Programme's Building Blocks |
| 54 | Blockchain For Humanitarian Action And Development Aid |

**Appendix C: LDA output for the top 50 words using the TopicModellingTool**

1) Topic # 1 Systems Adoption

| |
|---|
| supply chain humanitarian information barrier logistic trust adoption system transparency operation analysis management provide network result improve coordination factor traceability application industry performance framework decision smart challenge contract service issue method increase base risk security implementation model organization expert propose stakeholder main process relief context role identify enhance present lack |

2) Topic # 2 Technology

| |
|---|
| humanitarian aid transaction system development contract donor project chain smart ledger design organization potential digital participant block distribute provide process application network cost trust sector supply solution work create financial transparency transfer record government identity case public action access people problem dlt time require innovation stakeholder develop international platform information |

Topic # 3 Organisational operations

| |
|---|
| disaster supply chain management humanitarian information response logistic system relief operation emergency model resource network time demand process support communication area challenge provide develop cost framework analysis flow distribution manage coordination propose base share identify number organization improve food state source material approach author country case lack activity inventory follow |

## Appendix D: Research proposal submitted as a part of INFO 614 coursework grading

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UC UNIVERSITY OF CANTERBURY
Te Whare Wānanga o Waitaha
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# INFO 614 Research proposal

Multi-perspective exploration of blockchain technology adoption factors for asset tracking in humanitarian supply chains and logistics: A sequential mixed methods approach

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