Blockchain in healthcare

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Abstract

Blockchain is treated as a ledger system that manages data and their transactions using time-stamped blocks through cryptography and works in a decentralised manner over the computing network. Although blockchain is originally used as a backbone for the cryptocurrency, Bitcoin, its capabilities and applications have yet to be extended far beyond cryptocurrencies. In this paper, through conducting a latest systematic literature review aiming to produce new source of evidence, we identify potential applications of the blockchain technologies in healthcare. The comprehensive review looks at the professional and academic open-sourced journals published between 2008 to 2019 to recognise the potential of blockchain based approaches in the purpose of healthcare information disseminations, as well as to segregate issues for the implementation and development of blockchain applications. We identify several major application domains that present research opportunities and challenges for the future advancements and directions for the benefits of IS researchers and professionals.

Keywords: blockchain; IS solution design; healthcare; smart contracts

1 Introduction

Blockchain is considered as a ledger system that assists in managing and storing data in time-stamped blocks that works mainly decentralised manner over any computing networks and linking using cryptography. Introduced in the fintech area, the blockchain capabilities have a potential of wider realisations. However, application venues and effective solution design are still underdeveloped. Blockchain promises fundamental changes across different industries, including fintech, government, health and supply chain (Casino, Dasaklis, & Patsakis, 2019). Its potential benefits include reduction in costs and complexity of transactions between parties, enhanced security, improved transparency and regulation.

Healthcare is characterised as a traditional industry that is considerably rigid to measure due to the facts of change and resistant to innovative practices. Issues in healthcare (e.g. privacy, quality of care, information security) have been drawing attention in recent years worldwide. Blockchain technologies have been increasingly recognised as a tool to address existing information distribution issues. It may improve immediate healthcare practices for example in improving health service delivery and quality of care support. A recent report of Market Research Future (MRFR) shows that blockchain technology in healthcare is expected to generate over 42 million in value and reach a compound annual growth rate of 71.8% by 2023. Such strong growth is driven by inherited blockchain characteristics of decentralised ledge technology with greater transparency, improved security and privacy, increased traceability, boosted efficiency and reduced costs.

Considered as a major disruptor in the industry, blockchain is defined in a context-sensitive manner. For instance, the blockchain is defined as an increasing collection of records, usually referred to as blocks, that are linked together using cryptography in such a way that does not allow modifications (Deloitte, 2018) and promotes transparency and security. This way, the technology can assist to improve health service delivery and quality of care support through elimination of costs and privacy concerns, enhancing coverage and quality, while enabling user provisions of healthcare (Gordon & Catalini, 2018).

Based on peer-to-peer networks, one of the benefits of using blockchain is, it updates with real-time, leaving no space for intermediaries and associated costs (Zhang, Schmidt, White, & Lenz, 2018). Being resistant to modifications, blockchain offers a transparent environment where health professionals as well as patients are able to access records seemingly and without added costs (Zhang, White, Schmidt, Lenz, & Rosenbloom, 2018). It also increases security of the system by reducing the chance of lost records and errors (Benchoufi, 2017).

Various innovative IS solution have been proposed to utilise blockchain oriented applications in healthcare. Such still-growing solutions are mainly designed for healthcare professionals and patients to make decisions regarding treatments, care and administration arrangements for service support. Illustrative examples can be as follows:

- Nebula Genomics (https://nebula.org): a company uses blockchain technology to enhance genomic data protection, enable buyers to efficiently acquire genomic data and address the challenges of genomic big data.
- Secure Health Chain (https://secure.health): a company offers a blockchain healthcare EMR solution, which maintains personal digital medical records with help of blockchain.
- Doc.AI (https://doc.ai): a company uses natural language processing, computer vision and blockchain to generate insights from medical data.

At the same time, numerous surveys highlight that understanding of the blockchain in general and its applications in healthcare is still at their emergent stages. Despite a growing hype around the blockchain technology, a recent Deloitte (2018) survey shows that understanding of the technology varies due to its facts of what purposes are served. Although with little knowledge (e.g. almost 40% of US senior executives had little knowledge about blockchain), 55% of US senior executives are planning to invest more than $1m USD in the blockchain technology over the next year. These data suggest that while senior management is optimistic regarding the blockchain prospects, there is an emergent call for knowledge growing to build understanding on applications and provisions of such technology, in particular for IS industry practitioners and researchers. This reinforces the needs to develop a landscape study that illustrates potential benefits of the technology and how it can address several traditional problems in terms of wasted resources, unmet expectations and slow adoption of emerging technologies.

The focus of the paper is to landscape the newly emerged area in IS domain to develop a theoretical understanding to illustrate key components of the blockchain technologies and promote IS research in this area.

For the IS research the study pioneers blockchain research by presenting a consistent and systematic review of current research and developments in health blockchain. Triangulating academic research, practical implementations and user experience develop a unique perspective in blockchain applications in health to equip researchers and professionals with a knowledge and skills required for further knowledge advancements. The paper contributes to the research in blockchain by presenting a structured overview of existing academic research in healthcare blockchain and identifying directions of future developments. Contribution of the paper in healthcare research is embodied by highlighting new critical areas of health information systems research that employs blockchain opportunities.

The paper is structured as follows. The next section provides the background information on the blockchain and its applications across various industries. Section 3 overviews the methodology and provides the summary of the research process. Section 4 presents the finding of the research and section 5 concludes the paper by discussing the results and summarising limitations and outlining the directions for future research.

2 Background

2.1 Blockchain: what is it?

As a recent survey shows Deloitte (2018), while applications of the blockchain technology are rapidly growing, understanding of the actual technology and its potentials is far from wide-spread. This creates an obstacle for further developments and implementation of blockchain which has a potential to introduce a dramatic change in the society, including improvements in the healthcare information exchange. This technological solution works mainly in a decentralised manner to immutably store digital data, so that generated data or meta-data can be securely shared across networks and users. Blockchain includes a list of records that are linked using cryptography (Zhang, White, et al., 2018). This design makes modification of the data impossible: once recorded in a block, the data cannot be altered without alteration of all subsequent blocks, requiring a consensus of the network majority.

As a decentralised ledger system, blockchain allows independent agents to collaborate within the ecosystem ensuring transparency and time-stamped recording of the information to bring improvement in processing speed, revenue generation, security, while decreasing risk and costs (Deloitte, 2018). Unlike traditional ways to store information on one central point, the blockchain uses a peer-to-peer (P2) network involves multiple copies of the same data that are stored in different locations and different devices. A peer allows a portion of computing resources (e.g. disk storage, network bandwidth, processing powers), to be used by other participants without the need for central coordination by servers. Such nodes can take different roles within the network while ensuring preservation, coordination and security of business data exchanges (Van Rijmenam & Ryan, 2018).

The security of the blockchain is implemented using cryptographic keys, a distributed network and a network servicing protocol by recording information in a block. Once information (e.g. a transaction request) is validated, meta-data is recorded in a block and cannot be disputed, removed or altered without the knowledge and permission of those who created the record as well as the network. When a block is added to the chain of other blocks it remains unchanged.

One of the applications of blockchain is smart contracts, also referred to as self-executing contracts, blockchain contracts, or digital contracts (Griggs et al., 2018; Zhang, White, et al., 2018). Smart contract is a software program that self-execute complex instructions, thus reduces the costs of contracting, monitoring and enforcing contracts and making payments. Smart contracts open up ways to develop rich applications that can act as autonomous agents. This arrangement eliminates agency and coordinating costs and can potentially lead to any distributed enterprises such as in hospital systems.

While the initial growth was happening within the financial industry, implementations are under way across a wider range of fields, including marketing (Kumar, 2018), supply chain (Zheng, Xie, Dai, Chen, & Wang, 2017). For example, in marketing, especially MarTech, blockchain implementations based on smart contracts are used to ensure unified promotion actions and timely launch of promotional campaigns. This approach has a potential to simplify the industry landscape and eliminate cost-adding middleman parties as well as reduce the risk of fraudulent traffic reports and multiple ad requests (Sklaroff, 2017). In supply chain popular applications of blockchain include, but not limited to smart contracts and global searchable databases of transactions. A real-world example of the application of such technology includes the collaboration between Wave and Barclays, which are two start-ups working in the area of blockchain (Kelly, 2016). In 2016 they completed their first smart contract for a trade finance transaction between an Irish agri-food cooperative and Seychelles trading company. Further application of the technology can be seen with Walmart which introduced a blockchain-based system for some of its suppliers in 2018 (Corkery & Popper, 2018). The use of blockchain in supplier-customer relationship allows to ensure that the product is delivered timely and in good condition without involvement of the intermediaries, thus cutting the cost, reducing the waste and promoting sustainability (Corkery & Popper, 2018).

2.2 Blockchain in health

The characteristics of the blockchain, which are its decentralised nature, openness and permissionless, may offer a unique solution for healthcare. Wider applicability of the technology paves its way into different aspects of healthcare, including wearables and progress of medical research. Healthcare sector has growing demands for blockchain developments and a recent survey by Deloitte shows that the traditional industry is actively explores new avenues for the use of the blockchain to address its critical needs. (Deloitte, 2018).

Immutability of the blockchain is the vital option for healthcare data. It can secure health records, the results of clinical trials and ensure regulatory compliances. Employment of smart contracts demonstrate how blockchain can be used to support real-time patient monitoring and medical interventions (Griggs et al., 2018). Such systems ensure security of records while providing access for patients and medical professionals in a Health Insurance Portability and Accountability Act (HIPAA) compliant manner.

Further application of blockchain relates to supply chain in pharma and developing measures against counterfeit drugs. While the development of new drugs incur substantial costs related to trials to evaluate safety and efficacy of the drug, the use of smart contracts allow to facilitate the procedure of the informed consent as well as improve identify management and data quality (Razak, 2018). Providing access to patients for managing their own identify also allow integration of the informed consent procedure while ensuring privacy of individual heath data.

3 Systematic Literature Methodology

To understand the potential of the blockchain in healthcare, assess its application and uncover implementation issues, the study has conducted a systematic literature review of academic and industry publications between 2008 and 2019. Considering the innovative nature of the blockchain and longer time frames for reviews and publications of academic papers, the main focus was given to the analysis of publications through open-sourced Google Scholar. The criteria for inclusion of the papers in the review were defined as being published between 2008 and 2019, published in premier academic journals and conference proceedings[1] that were in English. This ensured credibility of the sources. We also reviewed industry publications to ensure the rapidly changing nature of the blockchain is validly reflected in the selected academic publications. The time frame for the analysis was selected from the first reference to the blockchain appeared in 2008 and continued until the paper online publication in 2019. It is due to the fact that most of the whole research have been appeared in recent years going beyond the widespread conversations or online blogs. The preliminary results showed that very limited substantial publications were available before 2016, but further analysis included all selected papers.

We started the review by collected papers through two sources, including academic databases and Google Scholar. Overall, we perform the search in 14 journal databases related to information systems and healthcare and included published papers as well as articles in press (till March 2019). Appendix A illustrates the names of the 14 electronic databases. Through the database search, we have reviewed over 25 premier healthcare, information systems and business journals (provided in Appendix B). The selected journals are ranked as Q1 in the SCImago Ranking system[2], which was our initial basis of inclusion in the review process (see Appendix B for the list of the selected journals). To automate data collection through databases, we developed a script in R programming language that accessed the journals meta-data using Application Programming Interface (APIs) of the relevant databases. The extract from the script is available in Appendix C[3]. The list of search terms included "blockchain", "block chain", "distributed ledger", "smart contracts" to satisfy PRISMA conditions (Moher, Liberati, Tetzlaff, Altman, & Group, 2009)[4]. The PRISMA (i.e. Preferred Reporting Items for Systematic Reviews and Meta-Analyses) framework specifies an evidence-based minimum set of items for reporting in systematic reviews and meta-analyses and has been widely utilised in the academic studies, including (Kruse, Goswamy, Raval, & Marawi, 2016). The benefits of using PRISMA for the analysis allowed to employ guidelines to review clearly formulated questions and use systematic and explicit methods to locate, select, and critically evaluate relevant publications to address the research questions identified earlier.

The downloaded meta-data was further examined independently by two independent researchers to analyse its relevance to the study. The articles not in English were excluded. The

[1] The full list of reviewed sample papers (136) is available at the online repository: https://github.com/mariaprokofieva/DigIt

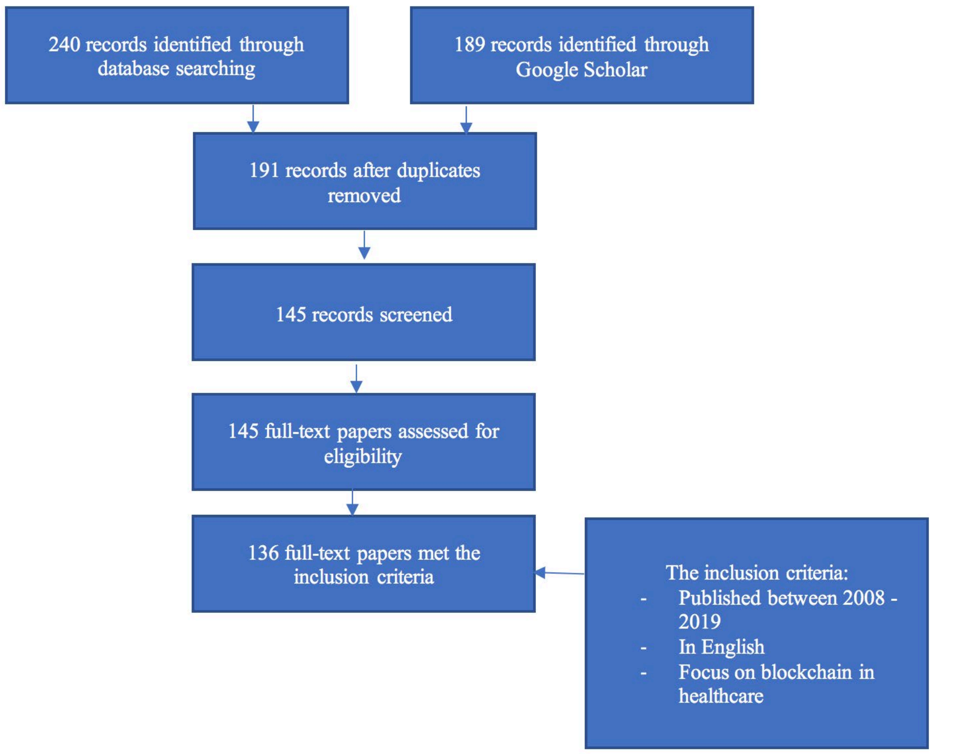
[2] SCImago (https://www.scimagojr.com/journalrank.php) is a Scopus driven ranking system for classifying the academic journals into various rankings on the basis of citations and H-index.

[3] We also provide a link to the full script available at the GitHub repository, https://github.com/mariaprokofieva/DigIt

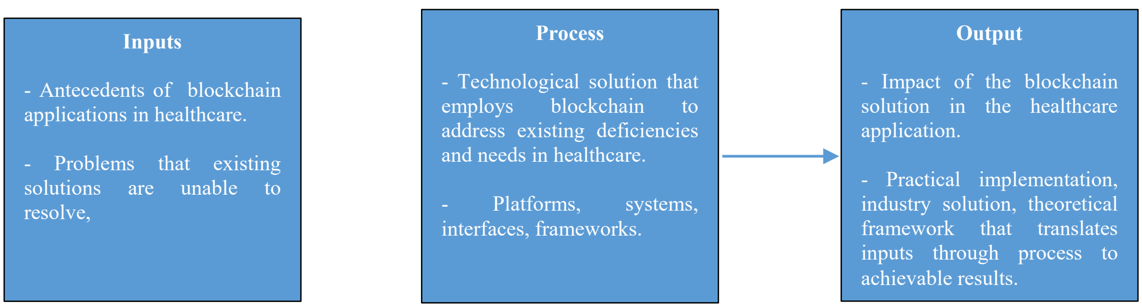
[4] PRISMA checklist includes 27 items related to the content of a systematic review. The full checklist is available at http://www.prisma-statement.org/documents/PRISMA%202009%20checklist.pdf

selection method is presented in Figure 1 Panel A. The results were analysed to produce the final list of papers that included 136 articles.

Further analysis of the identified papers was performed using content analysis technique which is a research method for exploring content from human interaction process, verbal and written document with a purpose of analysing data (Creswell & Poth, 2018). It is a powerful method that allows researchers to analyse documents as important sources of information to identify patterns of content quantitatively as well as qualitatively analyse meanings of content to identify new phenomena. Content analysis has been widely used in IS research (Al-debei & Avison, 2017; Miah, Gammack & Hasan, 2017). We employed both qualitative and quantitative approaches to content analysis. Further review of the selected papers was done using an input-process-output perspective (IPO). This approach has been widely used in prior research (Chan & Ngai, 2011) and is based on analysing inputs and outputs and understanding the underlying processes, i.e. antecedents, processes and consequences of blockchain application in healthcare.



Panel A. Sample papers selection process



Panel B. Input-process-output
Figure 1. Literature review process

The developed IPO framework is presented in Figure 1 Panel B.

Findings

The analysis of the findings showed that 136 papers identified as final samples are originating from different areas of healthcare-related fields. Generally, publications come from three major topic areas, including technology, life sciences and biomedicine and social sciences.

Figure 2 shows distribution of articles across these three areas, including the breakdown of particular research fields. The majority of the publications are cross-disciplinary research, and the separation between the research areas is relatively blurred. The identified three research areas suggest three aspects of blockchain life cycle in healthcare, from idea generation and experimentation, to commercialization and to diffusion and implementation. These stages coincide with stages of innovation process (Desouza et al., 2009) as well as key elements in diffusion of innovations (Greenhalg, Robert, Bate, Macfarlane, & Kyriakidou, 2005). While, inclusion of life science and bio-medicine area is a natural extension of the healthcare application of blockchain, IT and IS provide critical components in blockchain life cycle as they provide the technological foundation for implementation, diffusion and business use of the blockchain in healthcare. The social science area signifies the commercialisation and adoption of the blockchain in organizations and society (Desouza et al., 2009). It also reflects the adoption aspect of the blockchain as affected by social characteristics of its application and diffusion throughout the social system (Valente, 1996).

The timeline of publications (Figure 2 Panel B) suggests that the majority of publications are from the last 2 years while the volume is growing. The results demonstrate the network effect which becomes visible as the increase in the number of users improve the value of a product or service. This is also supported by the recent Gartner report (Gartner, 2018) that suggests that blockchain is entering the early majority adoption stage as the technology is spreading out throughout the society. However, the use of blockchain in healthcare is at the initial stage and mainstream adoption is likely to be reached only in 10 years. Driven by the cryptocurrencies development which current usage reached more than 20 million users worldwide (Coinbase, 2019), the use of blockchain in other areas is also growing. The accelerated development is generally slowed by costs of private ledgers deployment and positive returns from it (Gartner, 2018). This is in part due to undeveloped application market and complexity. Companies use self-created cryptocurrencies, i.e. Initial coin offerings (ICO) that has a value of company shares. ICO provides blockchain developers with an option to crowdsource development funds and accelerate the development of the blockchain. ICO tokens are generally associated with access to platforms or service provided by developers, while do not give ownerships or decision-making rights. The review of blockchain projects available at ICObench[5] shows 5,533 published projects out of which 54.67% projects related to the development of blockchain platforms, followed by cryptocurrency (39.85%) and business services projects (22.48%), while healthcare projects take only 4.97% (ICObench, 2019). The healthcare blockchain market in 2017-2018 was assessed at USD $34.47 million and is expected to grow at compound annual growth rate of 70.45% to generate revenue of USD $1,415.59 million by 2024 (Zion Market Research, 2018).

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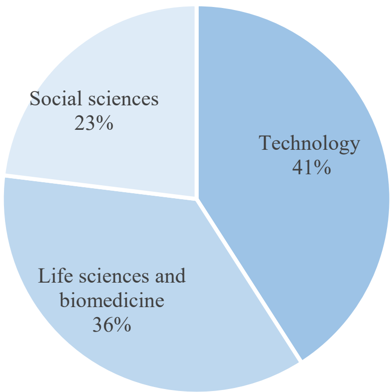
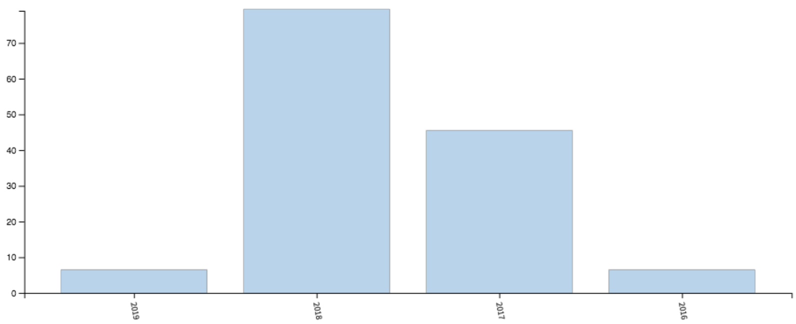
[5] ICObench.com is free initial coin offering (ICO) rating platform supported by the blockchain community which provides insights to the investors.

The majority of publications are coming from US and China (see Figure 2 Panel C). While the original blockchain interest was stimulated through developments in the US, the latest breakthrough of China deserves a special interest. China was reported to have 263 blockchain projects as on November 2018 under development which is accounted for more than 25 percent of projects worldwide (China Daily, 2019). These projects include well established Chinese companies, such as Baidu, Alibaba and Tencent, while each of these companies show interest in healthcare applications and establishing their strong presence there. China is also reported to be a leader in blockchain patents with more than half of all patents applications in 2017 (China Daily, 2019). The development of blockchain has a strong support from the Chinese government through the development of the Blockchain Development Centre and publication of a list of objectives to encourage the introduction and standardization of blockchain technology in 2018. While the Chinese government has introduced various bans on cryptocurrency trading and use, the blockchain technology is promoted at various levels. For examples, the China's 13th Five-Year Plan is shown to link domestic and international resources, support investments in blockchain projects and participation in blockchain related events at the international level.

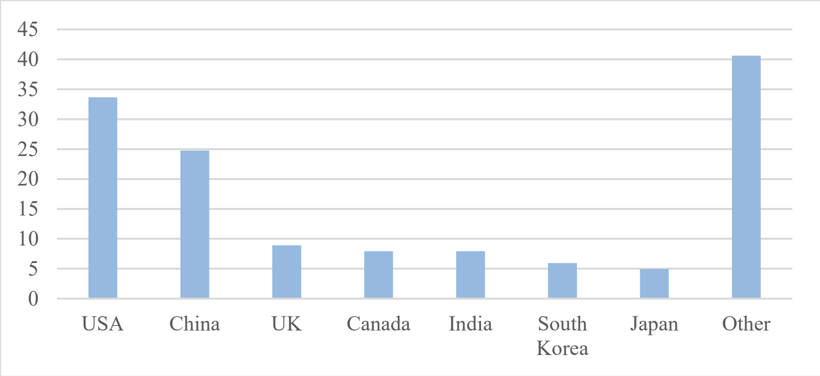


Technology area includes such subfields as computer science, engineering, telecommunication, information science, automation control systems. Life Sciences & Biomedicine area includes such subfields as healthcare sciences services, medical informatics, computational biology, legal medicine, medical ethics, biochemistry, biotechnology, general internal medicine. Social sciences area includes such subfields as business economics, communication, behavioral sciences, psychology, sociology, law. Definition of the areas and subfields

Panel A. Distribution of identified papers across research areas



Panel B. Distribution of publications across years



Panel C. Distribution of publications across countries/regions
Figure 2. Analysis of the results

The analysis of the papers identified the several major topics that present research opportunities and challenges for current and future advancements. Application of IPO framework allowed to organise the findings to focus on business problems, rather than the technological solution. The results of the analysis are presented in Table 1.

Input Business problem	Process Solution	Output	ICObench projects	Examples of academic papers
Low transparency of contracts and high intermediary costs	Use of smart contracts	Decentralised consensus improves the healthcare system transparency while removing an intermediary party that inflates the cost of healthcare. Further benefits include a significant reduction of inefficiency and waste in the healthcare ecosystem(Zhang, Schmidt, et al., 2018). The use of encryption, transparency and decentralised ledger removes miscommunication and mistrust and promote a transition to value-based care (Griggs et al., 2018) resulting in negotiations of complex bundle claims that are tied to value, but not on opportunistic fee-for-service model, while making claiming adjudication process seamless.	**Insure Network**: a decentralised network that uses smart contracts and artificial intelligence to ensure low cost, transparency and integrity of data when dealing with insurance claims. **Aimedis**: a medical ecosystem that is based on smart contracts to connect patients, doctors, and hospitals. Users are given full control over their medical information and can share it using right management system. The system also integrates a videochat and allows communication with other patients and doctors, provision of online prescriptions and online appointments, as well as inclusion of fitness trackers and wearables. HCX PAY: an insurance platform that provides payment and data solutions using smart-contracts and HCXI tokens.	Dagher, Mohler, Milojkovic, & Marella, 2018 Griggs et al., 2018 Macrinici, Cartofeanu, & Gao, 2018 Stanciu, 2017
Difficulties in supervision of drug intake and distribution	*Healthcare supply chain processes*	The use of the distribute ledger can improve supervision of drug intake and distribution (Tseng et al., 2018), promote regulatory compliance or managing healthcare supplies (Raghavendra, 2019), such as in compliance with HIPAA. The use of blockchain is shown to address a vital problem in healthcare supply chain which is lack of standardisation of business processes. It can promote the missing cooperation between business partners is necessary in areas such as product identification and barcoding, master data synchronisation, ordering, delivery and invoicing	**FarmaTrust**: a platform to facilitate supply chain within the Pharmaceutical industry. The platform aims to eliminate counterfeit drugs and increase efficiencies, while ensuring customer access. **Baikalika**: a solution to ensure protection against counterfeit products, and water safety and quality control. The solution uses blockchain to confirm the place of origin and a transparent chain of supply to the end-user.	Jayaraman, AlHammadi, & Simsekler, 2018 Mackey et al., 2019 Radanović & Likić, 2018 Tseng et al., 2018

		processes as well as logistics processes. With rising costs and standards of living, healthcare is experiencing increasing political pressure to control costs and improve efficiency, making the need for optimisation even more urgent.		
Absence of unified access to patient data	*Data storage and exchange*	A unified decentralised database can store individual patient details, including claims, medical history, transactions, overdue payments, etc. This database facilitates the transfer or scheduling of appointments with medical staff which can be activated using smart contracts. The use of smart contracts can ensure medical staff availability and timely payments (Yue, Wang, Jin, Li, & Jiang, 2016). Further opportunities are present by extended the stored data by the massive data accumulated through healthcare hardware and wearables (Liang, Zhao, Shetty, Liu, & Li, 2017). Such devices, including life support machine, activity trackers etc., monitor and record physical development, while a unified distributed access to this information can ensure effective decision making by medical staff, patience satisfaction and privacy. Blockchain offers a strong opportunity to streamline such data networks and secure security and privacy of information that they produce and retain.	**NWPSolution**: a platform that integrates smart devices and databases to provide access to healthcare. The platform uses artificial intelligence, data security and blockchain to minimise the healthcare costs. **MedicoHealth**: a platform that allows unified access to patient data as well as provide patients with access to physicians or specialists of their choice to receive a prompt, fordable and reliable consultation about their condition **Alphacon**: a platform to distribute healthcare data and provide personalized healthcare solutions using big data and analytics. **Cura Network**: a platform that facilitates managing and sharing healthcare data by providing a secure and instant access to records seamlessly across institutions.	Efanov & Roschin, 2018 Gordon & Catalini, 2018 Yue et al., 2016 Zhang, White, et al., 2018

Data integrity issues through concerns of confidentiality and protection	*Integration and encryption of digital assets*	Blockchain provides opportunities to integrate and encrypt digital assets, including medical records, or processing claims on a ledger (Yue et al., 2016). The ledger can ensure patient confidentiality and protection of relevant data as well as ensure regulatory compliance, for example HIPAA. Private blockchain can be used to store and access research output conducted in compliance with HIPAA laws in a confidential and secure manner, which can ensure access via extra authorization by concerned parties.	**MedicoHealth**: Apart from creating a doctor-patient environment, the platform ensures fully anonymous and protected communication with leading physicians. Physician details, including license validity information are stored in an immutable decentralised database. Patient data is anonymous and accessed only by selected physicians for a limited amount of time. Payments are fully tokenised and anonymous. The system operates on tokens that are used to compensate service provider.	Anjum, Sporny, & Sill, 2017 Esposito, De Santis, Tortora, Chang, & Choo, 2018 Yue et al., 2016
Lack of centralised approach to financing opportunities to promote and disseminate high quality medical research	*Facilitation and promotion of medical research*	Another strong application of the blockchain technology is facilitation of clinical studies and disease prevention (Ekblaw, Azaria, Halamka, Lippman, & Vieira, 2016). With competition of funding for medical research, centralised approach to financing opportunities promotes high quality research. A suggested approach may include using a research-based blockchain ledger where researcher create their own tokens, or participate in the ledger to fund their projects. The ledger allows donors to interact and choose areas of interest, access real-time research data and as well as allow for crowdfunding-like donation system based on micropayments. The trustless nature of the ledger and transparency minimize the chance of academic fraud and of duplication of work. The same	**Embleema**: a network that connects patients directly with medical research providers, allows patients to manage their data and provide incentives to share their data through the use of tokens. The network introduce an alternative way on how clinical research data is currently collected by pharmaceutical companies through Contrat Research Organisation. The data can be used to assess the efficacy of new investigational drugs and speed up the process of drug approvals through data exchange between patients, life sciences and regulators.	Ojomoko et al., 2017 Shae & Tsai, 2017 Till, Peters, Afshar, & Meara, 2017

		ledger further allows distribution of digital research information and its transparency.		

Table 1. Input-process-output framework of blockchain health

The analysis of the literature allowed to identify the following issue in current healthcare blockchain solutions:

- Privacy issues: increase in the user base of blockchain-related implementations leads to the increase in the information required to be verified and distributed across the network. With multiple validators that are required, such distribution creates a potential privacy issue.
- Coordination issues: inflated flow of information in the decentralised blockchain bring the issue of coordination among agents on the network and requires technical proficiency.
- Time issues: the flow of information poses a question of its organisation and speed of processing.
- Human factor issues: adoption and development of blockchain-based system requires sufficient familiarity with the system and benefits/risks it introduces.

4 Discussion and conclusion

The blockchain have become an important technological movement for IS application design. It is therefore of paramount task to landscape knowledge for developing understanding so that design practices can be improved. In healthcare, there are critical challenges for information exchange and disseminations, service providers and patients are required to have combined secured data exchange technologies to make informed clinical decisions. In this paper, we uncovered insights of blockchain based technologies and their potential applications for healthcare sectors.

As it was discussed earlier, digitalization of the records allows to create further opportunities for analysing medical trends and evaluation of the quality of care, relevant technologies are still emerging and blockchain can offer various benefits for the support service. While records are digitised, they are isolated in locally centralised data storages which present a strong impediment to further developments. Implementation of blockchain improves the connectivity while security and privacy and reduces the costs are also ensured for the parties.

In this paper we introduced an automated method for collecting published relevant literature through the use of a text mining algorithm which provided expected outcome successfully for conducting the review study. We provided the R script of the searching method to access journal's meta-data using the database API (Application Programming Interface) in the Appendix C. The literature review initiated to develop strong profile of blockchain in the following areas of healthcare application where provisions can be viewed in terms of smart contracts, data storage and exchange, physician credentialing and peer-to- peer data exchange. These would be considered as further aspects for healthcare solutions design and their innovations in meeting contextual or organisational demands for information disseminations. In addition, it is anticipated that Blockchain based medical records can improve the accuracy of diagnoses, a more information treatment choice and a more cost-effective solution by using a database with medical records as individual patience information.

Concluding the paper, it is necessary to highlight rapid development of blockchain implementations in healthcare, which is slowed down by the issues identified earlier. Our systematic literature review revealed opportunities as well as challenges that blockchain offers to the healthcare industry. Data privacy and security are the primary concern, identified in more than 50% of the paper. Further challenges relate to data structure and coordination. The findings of the paper identify directions for future research that will promote further developments and innovation in health information systems design (eg public healthcare decision support (Miah et al, 2017) or other similar problem domain such as agricultural decision support system (eg knowledge-based decision support platform (Miah, 2008)) in which blockchain can offer authenticated data dissemination methods.

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Appendix A.

Journal databases related to healthcare, information systems and business disciplines

- Academic Search Elite
- ACM Digital Library
- AIS Electronic Library (AISeL)
- BioMed Central
- BMJ journals collection
- Business Source Complete
- Directory of Open Access Journals (DOAJ)
- Emerald
- JSTOR
- MEDLINE
- PubMed
- Sage Journals
- ScienceDirect
- SCOPUS

Appendix B.

Example of premier healthcare, information systems and business journals used in literature search

- ACM Transactions on Information Systems
- Asia Pacific Journal of Management
- Australasian Journal of Information Systems
- Briefings in Bioinformatics
- Computational and structural biotechnology journal
- Decision Sciences
- Decision Support Systems
- European Journal of Information Systems
- Implementation Science
- Information and Management
- Information and Organization
- Information Systems Research
- International Journal of Medical Informatics
- Journal of Biomedical Informatics
- Journal of Intelligent and Fuzzy Systems
- Journal of Management
- Journal of Medical Internet Research
- Journal of the American Medical Informatics Association: JAMIA
- Journal of the Association of Information Systems
- Journal of the Medical Library Association: JMLA
- Medical Reference Services Quarterly
- MIS Quarterly: Management Information Systems
- Nursing education perspectives
- Telematics and Informatics
- Trials

Appendix C.

Example of the R script to access journal's meta-data using the database API

#The full script is available for public use at the Github repository https://github.com/mariaprokofieva/DigIt

#fulltext is a package to help R users to get published literature from the web in preferred formats and across different publishers

#the package allows to search for articles, gets abstracts and full text articles, extract text from articles, etc.

#fulltext currently supports search for PLOS, Crossref, Entrez, arXiv, and BMC, Biorxiv, EuropePMC, and Scopus.

#a typical workflow with the package is to search for articles with ft_search(), download articles with ft_get(), collect the text into an object with ft_collect(), get particular sections with ft_chunks(), or use other text-mining packages to analyse the text further

```
#install the latest version of fulltext library from CRAN
#using devtools library

install.packages("devtools")
devtools::install_github("ropensci/fulltext")

#load  fulltext library
library(fulltext)

# searching Crossref
(res2 <- ft_search(query= ‘blockchain’, from='crossref'))
res2$crossref

#searching BMC
(res <- ft_search(query='blockchain', from='bmc'))
res$bmc
```

```
#searching Europe PMC
(res <- ft_search(query=' blockchain', from='europmc'))
res$europmc

#searching Scopus
(res <- ft_search(query = 'blockchain', from = 'scopus', limit = 100,
scopusopts = list(key = Sys.getenv('ELSEVIER_SCOPUS_KEY'))))
res$scopus

#the list is long, applying pagination
(res <- ft_search(query = 'blockchain', from = 'scopus',
scopusopts = list(key = Sys.getenv('ELSEVIER_SCOPUS_KEY')), limit = 5))
```