Blockchain Technology in Healthcare within the Global South: Mapping the Area and Developing a Research Scenario

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Research Article

Keywords: Blockchain, Healthcare, ICT4D, Latent Semantic Analysis, Systematic Review, Global South

Posted Date: January 27th, 2023

DOI: https://doi.org/10.21203/rs.3.rs-2202865/v1

Abstract

Africa's steady technological expansion, coupled with the advent of pandemics that cause severe public health challenges, underscores the critical need to build resilient healthcare systems. This article outlines the potential of blockchain within African healthcare and transformations it has triggered. This research fosters scientific and practical thinking for developing systems that respond to contextual exigencies. Furthermore, we conduct a scientific assessment to: 1) consolidate existing research on Blockchain within healthcare in Africa; 2) comprehend technology and theory commonalities within research; 3) outline use cases of this disruptive technology, 4) identify areas of consideration in the broad African healthcare sector, while identifying scientific lacunae to develop new theoretical guidelines. Our multi-method approach fulfills appeals by emerging literature regarding novel methodological framework development for interpreting phenomena, and comprehending global trends. Consequently, our research impacts academia and industry, primarily in the development of a legal and regulatory framework for the integration of blockchain technology into African healthcare.

1. Introduction

Blockchain is an emerging technology that offers significant prospects for the healthcare industry. While its adoption appears to be fairly moderate across the global south, and some initiatives have been fruitless, the technology is perceived as disruptive with the added potential to deliver a futuristic perspective to the healthcare system in the global south. One driver of a very low uptake in Africa, for example, is that healthcare systems are diverging in complexity across regions, and the regulatory regime of the healthcare industry inhibits the standardization of practices. Recent investigations on the technology have pointed out its relevance in various areas of healthcare, such as health information transfer, patient data management, data security, as well as the tracking of biomedical devices and pharmaceutical infringement (Abu-Elezz et al. 2020; Cyran 2018; Dimitrov 2019; Haq and Esuka 2018).

A number of leading scholars consider blockchain technology as the fourth industrial revolution, with a meaningful bearing on the world. For the healthcare industry, it is a revolutionary technology that provides practical responses to challenges that conventional technologies have failed to tackle in the past. In the global market, it is estimated that blockchain within the healthcare industry will exceed $4 billion by 2026 (Company 2022). In Africa, the blockchain market in the healthcare industry is expected to surge with 46.96% CAGR based on the 10-year forecast 2019 - 2028 (Triton 2019).

The state-of-the-art review of existing knowledge has identified a void for a synthesis research study that highlights the use of cutting-edge technologies such as Blockchain in the African health sector. Indeed, we observed a major lacuna within the literature when attempting to uncover the potential for using selected enabling technologies to address health catastrophes in Africa. To bridge this void, we provide readers with a wealth of expertise and insights on Health based on Blockchain. We outline the functional scope of such technology for controlling and responding to healthcare disasters such as Covid19 and Ebola, which have weakened Africa's health system. Besides, we also discuss the *"great technological challenges"* faced by the continent in its on-going journey towards a sustainable health system, along with various avenues of research that could be harnessed in technology-based health.

We conduct this research under the dual lens of a systematic appraisal and Latent Semantic Analysis(LSA). The application of generic tenets of systematic scientific methodology draws up a framework for decision-makers, expanding the scope of evidence-based decision making (Tranfield et al. 2003). Thus, investigations that have a systematic facet must be developed in a thoughtful, reproducible and unbiased process (Knopf 2006; Webster and Watson 2002). As an illustration, emerging literature in technology and information systems has evidenced that such research fosters idea generation (Frizzo-Barker et al. 2020; Okoli 2015; Shree et al. 2021; Zhang et al. 2015). It also leads to an expansion of existing theoretical settings through the development of fresh prospects and the exposure of loopholes and limitations (Frizzo-Barker et al. 2020). This research therefore attempts to deepen the body of knowledge regarding the transformations occurring within the African health system as an outcome of using Blockchain in a variety of settings, including external constraints that have a substantial bearing on global health.

We structure this research as follows: first, we sketch out the relevance of Blockchain in the global health system and the fight against epidemics. Thereafter, we thoroughly discuss the research methodology, together with a comprehensive breakdown of the multi-methodology design that underpins the research. In the following section, we elaborate on different outcomes stemming from previous methodological extraction. The findings of this research are subsequently elucidated regarding their theoretical / methodological and practical contributions and implications.

RQ1: What are the existing use cases and the respective key drivers of blockchain technology for healthcare within the African context?

RQ2: What are the prospective research and practical interests for future studies?

Figure 1 illustrates a Google Trends time series that highlights the trend analysis of online searches for “blockchain” in the English language worldwide; from the plot, the data is scaled such that 100 is representative of the highest number of searches. This is indicative of the high interest in the paradigm. It can be noted that in 2017 the word reached its peak popularity due to the increase in venture capital funding within blockchain development companies culminating to a massive amount of 2.5 billion USD (Martino et al. 2019).

The top 5 countries with the most Google searches regarding ‘blockchain’ since 2004 till date, ignoring low search volume, are Nigeria, Ghana, St. Helen, Cameroon, and Singapore respectively (as seen in Figure 2) – three (3) out of five (5) being African countries (West Africa to be precise). In addition to this, data collected from our Google Trends search of blockchain worldwide revealed that the top 5 cities where blockchain has had the most searches on Google are Port Harcourt (Nigeria), Benin City (Nigeria), Accra (Ghana), Lagos (Nigeria), and Abuja (Nigeria) – indicative of the fact that Nigerians, followed by Ghanaians have the highest interest in comprehending the blockchain paradigm.

2. Background

2.1 Blockchain-Based technologies for Healthcare

The results of research and scientific experiments in which Blockchain technology has been involved have offered opportunities, especially in the control and prevention of several diseases, thus implying a better management of health crises, such as Covid19. The global health crisis shook several countries regardless of their economic and financial power. It revealed the fragility of the system of epidemic surveillance of organizations in the control and management of health emergencies. Moreover, this crisis has also highlighted the deficiencies observed in the prediction of dangers based on the sharing of knowledge and the various presumptions to contain and curb a health emergency on a global scale (Fusco et al. 2020). The current generation of Blockchain (Blockchain 3.0) emphasizes several functionalities and approaches to new functionalities other than economics and finance. In the emerging literature on advanced technology topics, researchers have discovered that Blockchain could be a revolution for developing countries, especially in sovereign sectors such as health. One of the revolutions strongly mentioned in the body of knowledge is the monitoring of the use of patients' data, electronic health records (EHR), with a traced and accurate history of the different transactions (Kuo et al. 2017). If there is a break in the different transactions, thanks to the Blockchain technology, the process will not be altered since there is no deterioration of the Blockchain node (Mackey et al. 2019).

2.2 Blockchain-Based technologies to Achieve the SDG3: Ensure Healthy Lives and Promote Well-Being for All at All Ages

Blockchain technology is inherently a trusted innovation, with the potential to deliver meaningful impact on society. Because it is trust-based and transparent in concept, its feats offer a tangible impact on the 17 Sustainable Development Goals (SDGs) as seen in Figure 3 (de Villiers et al. 2021; Medaglia and Damsgaard). The SDG3, which focuses on well-being and health, has been of great relevance to blockchain scholars (Aysan et al. 2021). Research has suggested a self-sustaining option that enables patients to exercise meaningful self-ownership of their data, while preserving privacy and security (Yue et al. 2016). During epidemics such as Ebola, blockchain can play an effective role in managing data (Chattu et al. 2019). The technology can be used to map and differentiate areas of high contamination. Through this information, decision-makers can therefore be empowered to adopt suitable actions, such as secluding healthy communities and providing them with adequate measures (Platt et al. 2021).

2.3 Blockchain-Based technologies for Healthcare & Cryptocurrencies

One may ask, "What does blockchain and cryptocurrency have to do with healthcare?" – This is a valid question. This is because a huge number of everyday individuals do not fathom the concept of blockchain, digital tokens and cryptocurrencies (Jung 2021; Rahardja et al.).

According to the New York Times, approximately 100 cryptocurrencies are created each day (Segal 2021). From CoinMarketCap, our research discovered only 12 out of the 16 coins built for the healthcare industry are currently launched and trading. Figure 4 illustrates the 12 cryptocurrencies for the healthcare industry in a parallel coordinate plot. 11 out of the 12 cryptocurrencies are tokens and one (1) is a crypto coin – MediBloc (MED) which is a decentralized blockchain network developed for health data sovereignty and interoperability[1]. The oldest listed healthcare crypto token, based on our data collection from CoinMarketCap, is the Tokes (TKS) token – launched on the 27th of March 2017– which is utilized in the purchase of medical-grade cannabis[2]. Likewise, the most recently launched healthcare crypto is the DOSE token - launched on the 3rd of November 2021 - which is an ERC-20 (ethereum blockchain) Fungible Token (FT) and the heart of the OliveX (a digital lifestyle company) gamified fitness ecosystem[3].

One can infer that cryptocurrencies for healthcare (whether tokens or crypto coins) are not highly proliferated in society, but with the advancement of innovation, health-based cryptocurrencies have an exciting future ahead of them.

2.4 Blockchain-based technologies in Global Health Emergency Management: The Covid19 Experience

In light of different waves of the covid19 health crisis with their specificities, Blockchain technology has emerged as a sustainable answer to the challenges that can arise in a global crisis. It responds to the increasingly dynamic and growing needs and limitations of existing systems by extending the functionality to more and more secure and credible ones.

2.5 Disease control

Many infectious diseases such as Cholera, Ebola or even Yellow Fever in Africa can benefit from the multiple functionalities that Blockchain offers. The technology can be employed on a national, regional, and even international scale to control the speed of the spread of the epidemic through the activation of the Blockchain network on citizens' terminals. The waves of the covid19 delta variant revealed the use of Blockchain technology in recording the symptoms of patients affected by the virus. An application of blockchain technology with respect to disease control is evident in the intervention of the CDC (Center for Disease Control) of the United States of America where blockchain was adopted to record immutably patient's symptoms of infection (Sharma et al., 2020)); in a time where data integrity was of crucial necessity.

2.6 Strengthening the supply chain of protection kits, medicines and vaccines

The fragility of the financial and economic sector in developing countries during the Covid19 crisis revealed the need to shore up the supply system for protection kits, vaccines, and even medicines. Blockchain has been a major success during this period because it ensures the continuity of the material supply chain, guaranteeing foolproof security of the medical process through Blockchain encoding (Sharma et al. 2020). The practical example is that of the global company IBM, which launched a worldwide movement called "Rapid Supplier Connect", whose aim was to strengthen the medical supply chain during the different phases of the covid19 (Khurshid 2020).

2.7 Increase the degree of pellucidity in the management of patients

The Blockchain technology has this transparent character that makes it important when it is used in the processes of securing transactions and for evidential purposes. In the field of health, it is used to securely consolidate private patient data, and to save the history of citizens who have been treated with the virus. This feature is useful and important in view of the advent of fake news on social media that are likely to generate panic and stress among patients and citizens. The Blockchain technology thus allows to guarantee the relevance of information with regard to its potential to update data in real time. It transforms the way data is institutionally driven, to a patient-driven decentralization (Dimitrov 2019; Sharma et al. 2020).

[1] MediBlock, https://medibloc.com/en/

[2] Tokes Platform, https://tokesplatform.org/index.htm

[3] DOSE Token, https://www.dosetoken.com/

3. Methodology

Our research is anchored analytically within the field of Scientometrics, which draws on disciplines such as bibliometrics and informetrics. Scientometrics handles computational efforts related to the growth of scientific knowledge (Hood and Wilson 2001). For bibliometrics, it encompasses the causative bonds between the citations, correlation between cited articles, along with the sources (Hood and Wilson 2001). As for infometrics, it embodies the evolutionary nature of information and social creativity. In this research, we employ scientometric strategies such as: (1) Social Network Analysis, (2) Latent Semantic Analysis, (3) Bibliometric Analysis. The abovementioned methodological lines represent the multi-method scientometric cornerstones of our research. Figure 4 elucidates thoroughly the methodological blueprint utilized for this study.

Moreover, we are drawing on the systematic literature review methodology (SLR) known as PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses). The SLR methodology approach was utilized as a result of its accurate and reliable evidence-based summarizing prowess of content within any given domain (Liberati et al. 2009). For our study, we adopted the PRISMA guidelines to select the key concepts that revolve around research on blockchain technology and healthcare with respect to Africa (Hutton et al. 2014).

Scientific publications were collated from Clarivate's Web of Knowledge, Elsevier's Scopus and PubMed databases. The following keywords were utilized in the search queries - ***("blockchain")*** AND ***(Africa OR "Sub-Sahara" OR "Algeria" OR "Angola" OR "Benin" OR "Botswana" OR "Burkina Faso" OR "Burundi" OR "Cameroon" OR "Cape Verde" OR "Central African Republic" OR "Chad" OR "Comoros" OR "Congo" OR "DRC" OR "Democratic Republic of Congo" OR "Côte d'Ivoire" OR "Ivory Coast" OR "Djibouti" OR "Egypt" OR "Equatorial Guinea" OR "Eritrea" OR "Ethiopia" OR "Gabon" OR "Gambia" OR "Ghana" OR "Guinea" OR "Guinea-Bissau" OR "Kenya" OR "Lesotho" OR "Liberia" OR "Libya" OR "Madagascar" OR "Malawi" OR "Mali" OR "Mauritania" OR "Mauritius" OR "Morocco" OR "Mozambique" OR "Namibia" OR "Niger" OR "Nigeria" OR "Rwanda" OR "São Tomé and Príncipe" OR "Senegal" OR "Seychelles" OR "Sierra Leone" OR "Somalia" OR "South Africa" OR "Sudan" OR "Swaziland" OR "Eswatini" OR "Tanzania" OR "Togo" OR "Tunisia" OR "Uganda" OR "Western Sahara" OR "Zambia" OR "Zimbabwe")*** AND ***("health" OR "healthcare")***.

For filtering out the results in order to obtain preferred outcomes that are in line with our research goals, the following criteria was employed: (a) all articles published in English; (b) papers that highlighted the concept of blockchain and its application (or potential application) within healthcare in Africa. The excluded papers were primarily focused on research with respect to proposals and experiments on blockchain in healthcare frameworks which were mostly performed by researchers affiliated with African universities (a vast majority from Egypt) but were not directly focused on African case studies. Figure 5 highlights the first phase of the research methodology where data was collated for further analysis and knowledge extraction.

Quality Assessment

In assessing research quality, we relied on the work of Dybå, T., & Dingsøyr, T. (2008). Criteria such as relevance, accuracy and plausibility are the cornerstones on which we screened each research (Greenhalgh 1997; Greenhalgh and Taylor 1997) . For this purpose, we delineated tiers of selection for each study, as depicted in Table 1.

Table 1. Research Quality Assessment Table

Quality Criteria	Assessment Questions
Empirical Investigation	Is this research-based or merely an expert appraisal?
Clarity of Purpose	Are there any incentives for conducting the investigation?
	Does the work pertain predominantly to blockchain or to its inherent transformative capabilities within the African health sector?
	Is there any experimental evidence for this research?
	Are the core findings clearly articulated in this research?
Environmental consideration	To whom are we appealing?
	Under what surroundings has the research been performed?
Research Design	Has the researcher characterized and/or rationalized the research design?
Data Collection	Is there transparency surrounding the way in which data are being compiled?
	Has the researcher articulated his/her approaches?
Data Analysis	Were sufficient data reported to substantiate the inferences?
Findings	Are the limitations to the study being explicitly debated?
Research Merit	Is the researcher arguing about whether the research adds substantially to the body of knowledge?
	Do researchers pinpoint emerging areas in which research is warranted?

The detailed findings from individual database searches are outlined in figure 6. These are published and indexed results across databases from 2017 to 2022, with an average citation of 2.067 per paper. A total of 71 individual authors were deciphered in the search collections. The results were obtained by screening of relevant papers in the selected accredited databases by applying the quality assessment criteria and eligibility criteria to select relevant papers.

Fig 7. illustrates the second phase of the research methodology where we applied natural language processing (NLP) algorithms to extract knowledge from selected articles. The abstracts and keywords of articles gathered from our systematic review search process were manually collated into text files and arranged in their respective folders, as per the year of publication. For conducting the NLP procedure, Python was used. The textual data was loaded and the Natural Language Toolkit (NLTK) together with spaCy libraries were used for the text pre-processing stage where the corpus was broken down into tokens (tokenization), lemmatized to obtain the root words of verbs and nouns, as well as removing stopwords (including country names in order to obtain pure keywords) (Bird et al., 2009). These tools are well-adopted within the computational linguistics community for performing knowledge extraction tasks. The clean data was merged into a corpus and the gensim library (Rehurek & Sojka, 2010) is used in generating bi-grams, which is defined as a pair of consecutive tokens or terms (Amensisa et al., 2018). Bi-grams are relevant in the sense that they are capable of capturing relevant phrases and provide more meaning than single terms or unigrams (Wilson et al., 2018; Wisdom & Gupta, 2016). Furthermore, a bag-of-words model which is defined as the representation of a corpus of text as a set of tokens (words) with the frequencies of their occurrences (Ishihara, 2021). The product of the bag-of-words model is a document-term-matrix which is a large matrix consisting of documents (the articles in our case) and terms (the tokens from all articles), as well as their frequency of occurrence (Manďák, 2016).

Topic modeling was undertaken using latent semantic analysis (LSA). LSA is a methodological approach for the extraction and representation of the meaning of words (from a contextual standpoint) by applying statistical computations to a corpus of text (usually large) (Miles et al., 2016). Dimensionality reduction occurs due to the fact that the document-term matrix is highly sparse and our goal is to obtain the latent terms within the matrix. LSA can be likened to factor analysis since it aims at dimensionality reduction through singular value decomposition (SVD) (Sidorova, 2008).

LSA has been applied by numerous researchers and practitioners in identifying and mapping key themes to the primary information systems (IS) research topics; for extracting the distinct research agenda within health information (IS) research articles; in extracting knowledge regarding skills and competencies with respect to business intelligence and big data related job advertisements (Debortoli et al., 2012; Chen et al., 2019; Nguyen et al., 2022). Sidorova et al. (2008) briefly described the history of LSA and indicated that LSA is geared towards gathering all the contexts within which words appear as well as establishing the common factors that represent underlying concepts. As a means of supporting the systematic review results presented in our study, we adopted the LSA algorithm as a vehicle for highlighting the key themes in blockchain technology research with respect to healthcare in Africa.

4. Findings

4.1 Descriptive Analysis

In this section, we present the findings from our systematic review (bibliometric and thematic analysis) as well as latent semantic analysis based on the selected research papers. Figure 8 illustrates the publication distribution over time as well as the relative growth rate of publications on blockchain in healthcare with respect to Africa. Research on blockchain in African healthcare has an annual scientific production growth rate of 18.92%. This is indicative of a steady rise and diffusion of the understanding of blockchain as not only related to cryptocurrencies and non-fungible tokens (NFTs), but also an asset for driving economic development via supporting decision making systems within healthcare.

4.2 Co-occurrence Network Analysis

Figure 9 is indicative of a co-occurrence network analysis where frequent terms are represented as nodes (the larger the node, the more frequent the term) and edges represent the relationship between nodes (the thicker the edge, the stronger the connection).Core thematic identifiers are an invaluable stage in gaining an accurate picture of a phenomenon. Co-occurrence network analysis therefore enables scholars to pinpoint various tendencies within a given research topic. It is a scientometric exercise that offers scholars an appraisal of commonalities and key areas of interest in the literature (Zupic and Čater 2015). The approach glosses over an article's substance and associated supporting details, such as its methodology, author's scientific claims, as well as the underlying problematic that it addresses. It comprises three (3) clusters, with the green cluster (hospitals, and health) isolated. The co-occurrence network highlights blockchain (red cluster) as a central theme, where health care (another central) theme is connected to. The red cluster (blockchain, security, health information, records management, and mhealth) are indicative of the importance of blockchain in mobile healthcare (mhealth), within healthcare record management, and security as a key theme in blockchain for healthcare (B4HC) initiatives.

The blue cluster (health care, healthcare providers, electronic health record, and decentralized) highlights the desire for decentralization of digital/electronic health records (EHR) within the African healthcare sector in order for healthcare providers to easily establish interoperability and the smooth flow of immutable data.

The green cluster - isolated from the network - consists of two nodes with the keywords hospitals, and health.It is a major area of focus, at the core of the African blockchain agenda within healthcare. Additionally, it outlines the path mapped by numerous research studies on blockchain implementation within the healthcare industry. In summary (as pointed out in Table 3 below), most researchers have discussed the need for blockchain technology integration within healthcare in Africa to focus on healthcare records within health facilities (primarily hospitals) for the purpose of data interoperability, immutability and integrity.

4.3 Trending Topics

Figure 10 highlights the trending topics within blockchain and healthcare research with respect to Africa consisting of the topics (with a frequency >= 5): data privacy, health records, blockchain technology, healthcare providers, birth registration, and emerging technologies respectively. Data privacy being the most relevant topic is indicative of the caution with which researchers are approaching the potential implication of blockchain technology where blockchain is believed to be a solution to numerous data interoperability issues, but data privacy must be a topmost priority for government agencies in order to ensure trust. An interesting revelation is with regards to birth registration which has been regarded as a slow and painful process in some countries and linked with issues of record falsification (Bequele, 2005; Makinde et al., 2016). In order to prevent any human-level manipulation at later dates, blockchain has been recommended as a sure data integrity provider.

4.4 Word Cloud

As part of performing content analysis for this study, Figure 11 is a word cloud that highlights the relevant and frequent keywords obtained from the abstracts; where the font-size is indicative of the prevalence of that keyword.

4.5 Topic Modeling

Table 2. Top 5 Topics in Blockchain in African Healthcare Literature - Latent Semantic Analysis

#	Topic Label	Top Terms
1	Blockchain as a Solution for Patient Health Record Sharing	"care" + "patient" +"quality" + "health_record" + "record" + "sharing" + "health" + "solution" + "medical" + "sector"
2	Blockchain as a Secure Channel for Ensuring Quality Healthcare Record Storage and Access	"care" + "record" + "health_record" + "security" + "health" + "medical" + "patient" + "electronic" + "quality" + "hospital"
3	Blockchain as a Means of Lowering the Cost in Health Record Storage and Transmission	"security" + "patient" + "health_record" + "medical" + "record" + "network" + "process" + "low" + "use" + "cost"
4	Blockchain as a Safeguard for Patient Record and Medical Process Privacy	"health" + "security" + "sharing" + "medical" + "patient" + "process" + "privacy" + "service" + "context" + "record"
5	Blockchain as a Tool for Providing Trust in Health Information Service	"process" + "medical" + "health_information" + "trust" + "sharing" + "context" + "privacy" + "transaction" + "service"+ "potential"

The results of the LSA are represented in table 2, containing the top five (5) topics made up of the top nine (9) terms generated from the 15 pre-processed abstracts. The top nine (9) terms are a combination of most salient bigrams and unigrams. Owing to the fact that the dataset was made up of 15 abstracts, we thought it wise to limit the number of terms and topics in order to eliminate noise within the results. In addition to that, we formulated the research agenda (within the topic label column) by inferring from the top terms.

4.6 Blockchain for Health within Africa

From Table 3, we infer that from research, it is evident that currently very few forms of blockchain implementation in healthcare with respect to Africa and that all the studies have made propositions which have the potential of solving pertinent issues. With respect to countries, research on blockchain in healthcare has mostly made propositions for the South African experience, followed by Kenya, and Nigeria respectively.

Table 3. Summary of Research on Blockchain in Healthcare in Africa

Reference	Context	Findings	Key Drivers						
			Data security	Interoperability	Standardization	Data Integrity	Monitoring	Auditability	Energy Conse
(Weiss et al. 2017)	MHealth (South Africa)	The paper **made a case for** the need for blockchain technology to be integrated into **South Africa**'s mobile health services (mHealth) on the basis of the following: • The need for an improved security model • Blockchain has the capability of lowering the cost of trust (i.e. securing P2P transactions and eliminating the need for a trusted third party). Blockchain is capable of solving the burden of proof for the National Department of Health (NDOH) by providing the required security necessary to allow compliance with the South African Protection of Personal Information Act (POPI).	X			X			
(Jita and Pieterse 2018)	In-Home Care Systems (South Africa)	Due to South Africa's rising costs in medical care for the aged (as well as all over the world), researchers **proposed** the use of micro-services architecture in conjunction with Blockchain technology for the design of in-home care systems. The goal is to enable caregivers to monitor patients remotely and securely thereby resulting in independence, cost reduction and a remove burdens of worry from loved ones.	X						

Reference	Context	Findings	Key Drivers						
			Data security	Interoperability	Standardization	Data Integrity	Monitoring	Auditability	Energy Conse
(Kamau et al. 2018)	Electronic Medical Records (Kenya)	Researchers proposed blockchain as an appropriate platform to overcome interoperability and security challenges of EMR (electronic health/medical records) systems in developing economies. The authors proposed blockchain for Kenya's healthcare system to guarantee patients' privacy and to ensure that the data is stored securely.		X					

Reference	Context	Findings	Key Drivers						
			Data security	Interoperability	Standardization	Data Integrity	Monitoring	Auditability	Energy Conse
(Osebe et al., 2019)	Digital Health Wallet (Kenya)	According to the researchers, observing **Kenya**'s referral care highlighted the need for reliability and efficiency improvements. The authors **proposed** and experimentally deployed a Digital Health Wallet (a patient-centric system) for Kenya which is a blockchain-enabled system that enables seamless clinical workflow orchestration and patient-mediated data exchange through consent management in a privacy-preserving manner. The proposed system was asserted to be used to improve the efficiency of care coordination and patient referrals by supporting communication between care providers, eliminating unnecessary paperwork and reducing duplicate services. The perks of such a blockchain-based system include patient engagement, improved medication adherence, safety and efficacy, and the ability for patients to monetize their health data.	X			X			

Reference	Context	Findings	Key Drivers						
			Data security	Interoperability	Standardization	Data Integrity	Monitoring	Auditability	Energy Conse
(Ndayizigamiye and Dube 2019)	Interoperable Public Healthcare (South Africa)	At a time when South Africa was preparing to roll out their National Health Insurance (NHI), researchers made a case for the use of blockchain within South Africa's public healthcare in order to curb fraudulent activities. Thus promoting accountability, trust, traceability, immutability with respect to transactions, and transparency. The authors indicated challenges such as the non-existence of interoperability (which is a crucial enabler of blockchain technology) between public healthcare services. Another challenge the authors addressed for recommendation is the necessary regulatory framework and standards to spell out the terms and conditions regarding patient data access and incorporating external data into the blockchain respectfully.	X	X					

Reference	Context	Findings	Key Drivers						
			Data security	Interoperability	Standardization	Data Integrity	Monitoring	Auditability	Energy Conse
(Azogu et al. 2019)	Health Information Systems (Nigeria)	The authors drew lessons from early adopters of blockchain technology (Dubai, Estonia, and The Netherlands) - all developed economies. They highlighted the following challenges that prevent quality and efficient decision making within the Nigerian Healthcare sector: missing files (records), non-interoperability between healthcare providers, lack of secure records and also inaccessibility of patients' health information for healthcare providers.	X	X					
(Mashamba-Thompson and Crayton 2020)	Self-Testing and Tracking System for Infectious Diseases (Sub-Saharan Africa)	As a result of the SARS-COV-2 pandemic that hit the entire world in 2020, researchers **proposed** a low cost community-based blockchain and artificial intelligence-coupled mobile-linked self-testing and tracking system in order to monitor and treat emerging infectious diseases within the **sub-region**.					X		

Reference	Context	Findings	Key Drivers						
			Data security	Interoperability	Standardization	Data Integrity	Monitoring	Auditability	Energy Conse
(El Kassmi and Jarir 2021)	National Healthcare (Epidemiological) Interoperability System (Morocco)	Studies proposed an approach that integrates blockchain transactions and smart contract executions, in order to enhance collaboration as well as interoperability between entities while ensuring trust and auditability. The solution was built on the Hyperledger Fabric platform (a permissioned architecture) with a RAFT consensus algorithm. They then applied the initiative by integrating healthcare providers and epidemiological entities (national scale) during the COVID-19 pandemic.		X		X		X	
(Crump et al. 2021)	Veterinary Vaccine Supply Chain System (Mali & Côte d'Ivoire)	The BlockRabies application is a blockchain secured (based on an ethical design framework) One Health intervention aimed at providing post-exposure prophylaxis for dog-mediated rabies infected people. It combines public health sector, the veterinary sector, the Health Information system and the vaccine supply chain. The system enables trusted communication between veterinary and healthcare authorities and takes into consideration data security and confidentiality.	X	X		X	X		

Reference	Context	Findings	Key Drivers						
			Data security	Interoperability	Standardization	Data Integrity	Monitoring	Auditability	Energy Conse
(Chuma and Ngoepe 2021)	Secure Electronic Personal Health Information (ePHI) (South Africa)	Researchers indicated that due to the potential of security protocol compromisation, electronic personal health information (ePHI) in **South Africa** could be exposed to threats and cyber-attacks. As such blockchain would safeguard the integrity of sensitive healthcare data.				X			
(Ngoepe and Marutha 2021)	Interoperable Healthcare Records across Healthcare Organizations (South Africa)	Researchers proposed a blockchain framework in order for **South African** healthcare organizations are able to share responsibilities with the use of shared patient medical and health history in enhancing the quality of care		X					
(Smidt and Jokonya 2021)	Proposal of Digital Solutions to COVID-19 Pandemic (South Africa)	In the case of **South Africa (SA)** and COVID-19 lockdowns, the researcher proposed a list of requirements for the SA government to deploy digital solutions (of which blockchain was listed) in order to build and safeguard public trust.				X			

Reference	Context	Findings	Key Drivers						
			Data security	Interoperability	Standardization	Data Integrity	Monitoring	Auditability	Energy Conse
(Guo et al. 2021)	Smartphone-based DNA diagnostics for malaria detection (Uganda)	To detect malaria, a smartphone-based DNA diagnostics system was **developed** and implemented with Convolutional Neural Networks inference and a blockchain network. The implemented solution has been purported to provide a secure mechanism to connect actionable information from low-resourced healthcare infrastructures (rural and urban) with governments and healthcare services in order to implement and improve care provision strategies and outcomes.	X		X	X	X		
(Walcott-Bryant et al. 2021)	Digital Health Platform (Kenya)	With respect to the **Kenyan** private health care sector, researchers proposed a digital health platform developed for the purpose of providing hypertension care support as well as coordinating clinical workflow orchestration. Such a decision support system makes use of patient-mediated data sharing with an end product of auditability and privacy preservation, thus delivering a trust enabled blockchain technology.	X	X		X		X	

Reference	Context	Findings	Key Drivers						
			Data security	Interoperability	Standardization	Data Integrity	Monitoring	Auditability	Energy Conse
(Mnyawi et al. (2022)	Hyperledger Blockchain Architecture for EMR system (Tanzania)	Researchers revealed the ability to improve data storage security in health information systems utilizing the Hyperledger Fabric blockchain framework (Execute-Order-Validate architecture). This was implemented in the Arusha region (Mount Meru Referral Hospital); a blockchain system was integrated with the Electronic Medical Record (EMR) system (GoT-HOMIS) for protection against cyber-security breaches and hacks. Fabric implements a private data policy which utilizes private data collection addresses; it compensates for flexibility, security, scalability, resiliency lapses faced by Ethereum.	X			X			X

The WHO reports that approximately 30% of the medicine sold in Africa, Asia, and Latin America is counterfeit; in light of this statistic, researchers affirm the necessity of a decentralized supply chain system with comprehensive logs for integrity management (Jamil et al., 2019). From our study, we gathered that three (3) major factors are at the core of propositions for blockchain in healthcare with respect to Africa: Interoperability, Security and Public Trust. Figure 12 summarizes the key driving factors for blockchain technology adoption within the African healthcare sector. The numerous potentials of blockchain implementation in other spheres have been observed as key drivers for its desire to be implemented within the healthcare sector. In summary, the key antecedents to blockchain implementation in healthcare are mainly interoperability, data integrity, trust, and security.

5. Discussion

For the purpose of discussing our findings, we have delineated some thematic areas of consideration. In view of increased clearness in classifying research themes, we clustered them in a strategic diagram. The thematic map, as depicted in Figure 13, is based on both density (y axis) and centrality (x axis) (Cobo et al. 2011b). It is a tool for organizing and representing knowledge as well as concepts incorporated within them, which is used to identify, analyze, and report salient themes within a collection of text data (Matt et al., 2019). Centrality refers to the extent to which a specific network interacts with others as a proxy for thematic relevance in a field of study (Cobo et al. 2011a) . As for density, it reflects the breadth of coverage of a theme while gauging its internal relevance within a network.

The effectiveness of co-occurrence networks by itself is not high enough to visualize contemporary scientific patterns and prospects. Therefore, the thematic map plays an important supporting role in analyzing current topics, depending on their classifications (centrality and density).Thematic analysis is one of the preferred tools since it provides a theoretical foundation as well as a methodological approach for the analysis of textual data or documents for contributing to a better understanding of publications (Ruhode 2016). The description of the thematic map shown below is as follows:

- Upper right quadrant: motor themes - this portion is devoted to well-elaborated thematic areas that define our research structure. Topics in this area are distinguished by a high degree of centrality and density.

- Lower right quadrant: basic themes - within this portion, there is a high degree of divergence between the keywords. It refers to promising themes, or themes that have been extensively explored within the literature.
- Upper left quadrant: high specialized/niche themes -this stretch deals with heavily expanded and specialized themes, which nevertheless remain fringed in the literature.
- Lower left quadrant: emerging or disappearing themes - These topics are prone to either increasing in centrality, i.e. shifting to the right, or growing in density, i.e. Shifting upwards.

Therefore, the following points can be drawn from the thematic map in Figure 13:

- Electronic Health Record, security, blockchain technology are among the central themes under continuous scrutiny in Africa. This finding is borne out by the sheer importance of these themes within the healthcare field.
- Moreover, topics such as blockchain technology as well as health records, patient care and decision support systems are at the crossroads between the basic themes, motor themes and niche themes. This intersection reflects the extent to which these themes can reshape the field of study.
- Topics such as Patient Care and Decision Support Systems might evolve towards the motor themes, considering their prominence within the African health sector.
- Decentralization of the health system (Emerging or Declining Themes) constitutes a topical interest in Africa. Our analysis indicates that the theme is categorized as an emerging theme, given governments' attempts to reinforce their health systems, as well as the challenges they face in doing so.

Just like every other developing economy, countries in Africa are not strangers to the shortcomings within the healthcare sector. Studies from other countries indicated a number of these challenges: (a) healthcare supply chain (challenges with drug intake supervision and distribution); (b) the absence of a unified access to patient data (i.e. interoperability); (c) issues regarding data integrity (confidentiality and protection); (d) a lack of a centralized approach to financing, promoting and disseminating high quality medical research (Prokofieva et al., 2019.). These gaps have birthed opportunities for African economies to leverage on the potential of blockchain technology in curbing such issues. Despite the opportunities, one cannot ignore a number of barriers are capable of slowing down and killing the integration of blockchain in healthcare, and these include: corruption and poor leadership (not solely limited to governmental levels), change management issues, resistance to change, lack of skilled workers in certain industries, and many others (Leesakul et al., 2022.; Pathak et al., 2014; Beni, 2011). These crucial barriers must be considered, monitored and disarmed in the process of implementing blockchain in healthcare so as to ensure the maximum benefit of the technology.

The African technological landscape has in recent years slowly gained momentum and is on the verge of catching up with the global pace in a few decades (Mungai, 2018). With the emergence of technological hubs and colaboratory ecosystems, the level of value creation is set to improve with the current generation of technologists within the region (Atiase et al., 2020). In addition, Foreign Direct Investments (FDI) is contributing to the development of infrastructure, enabling knowledge and technology transfer as well as eliminating bottlenecks (Hu et al., 2021; Rasoanomenjanahary, 2021). As such, inferring from studies undertaken across the globe as well as propositions made by researchers in Africa, it is possible to transfer and develop such experiences in order to catapult the African digital healthcare landscape.

5.1 Blockchain as a transformational driver for health data protection / Trust

African governments are gradually gaining consciousness about the vulnerability of their data when considering the way it is being stored and managed. While Africa is often referred to as a "digital colony", blockchain technology has the potential to tackle various sovereignty challenges related to data protection. When analyzing the global storage capacity map, the African continent stands at the bottom (oxfordbusinessgroup 2021). This reality mirrors the inability of African governments to afford appropriate data storage infrastructure to mitigate data outsourcing and minimize any potential threats on data confidentiality, availability and integrity. Blockchain technology has the potential to incrementally bolster the continent's storage capacity by supplying a guarantee on data security, including the data being housed in offshore servers. Blockchain carries significant opportunities to revolutionize health record management systems, as well as improve the biomedical and health data ledger (Attaran 2022). The technology can confer on patients an ownership role in accessing their medical records, and even connect them to other hospitals (Abu-Elezz et al. 2020; Yoon 2019).

5.2 Building capacities of public health organizations

From the findings, the case of Uganda indicated the realization of the prospects of Blockchain technology at the national level. This manifested in connecting information from the healthcare infrastructures in rural and urban areas with limited resources to governments, in order to improve healthcare strategies and outcomes in detecting Malaria disease early (Guo et al. 2021). This corroborates with what the existing literature has acknowledged that Blockchain technology has potential to strengthen the capacity of healthcare systems in African countries, where there is high chance of epidemic and pandemic to occur, through early warning surveillance for diseases of epidemic potential; thus, reducing the mortality, spread of diseases, and economic costs (Bhattacharya et al. 2019). However, Blockchain technology has also the potential to leverage international medical and scientific cooperation, knowledge sharing, and capacity building globally (Resiere et al. 2020). This is a lesson learned from COVID-19 pandemic, where coordinated actions focused on connecting developing countries to international medical entities, in order to address the immediate needs of developing countries to access medicine, medical services, and vaccines (Resiere et al. 2020). Therefore, more studies are needed to examine the prospects of Blockchain technology for African countries, in terms of capacity building at a global scale and taking into consideration the limited resources specific to African countries.

6. Implications

This research hinges on charting blockchain technology within the African healthcare landscape. Given the rapid spread of technology to curb health calamities affecting the global health system, research fields are undergoing a rapid expansion as well. Therefore, an appreciation of what exists when it comes to the operationalization of blockchain technology in the African health system offers an avenue for comprehending burgeoning research streams and charting diverse research discourses and themes within the emerging literature. This reinforces a new research dynamic in a systemic, scientific and informed way, through a substantial theoretical input to the body of knowledge. Building upon the prospects of strengthening the healthcare system in the global south, instances of blockchain implementation in healthcare are drawing increasing interest from governments, scholars and practitioners around the world. Several experiments were performed to reveal the prowess of such cutting edge technology in the healthcare industry. The development of numerous applications and digital tools have largely expedited transformation of the African health landscape, contributing to improved human living conditions. While this innovation holds tremendous potential for the African health system, since it has the ability to leverage several spheres simultaneously such as governance, administration, education, and health, substantial unresolved and complex problems such as data protection and capacity building have yet to be resolved.

The results of our research have highlighted the transformation of the health system in several African countries through the use of Blockchain, and the development of new innovative technologies. Our contribution spans across a range of theoretical and scientific arguments around blockchain technology at the nexus of the African health system. It also addresses the dynamics behind the resulting themes, pointing to substantial breadth in research and applications. Additionally, we document the diversity of research surrounding the core focus of this project, including extensive review, evaluation, and future theoretical openings. Finally, our article is the first of its kind to coin the acronym B4HC which stands for “blockchain for healthcare”, which we recommend for wider adoption by the research community.

Our contribution has a methodological edge. Indeed, we deliver science-based rationale through a consistent and stringent blend of unique methodologies. This combination yields a well-rounded interpretation of health information systems research. The use of a multi-methodological design affords an incentive for future research to meaningfully engage in the expansion of information systems through multilevel analysis. One practical implication of the study is the use of latent semantic analysis (LSA), which considers the context of terms, in extracting knowledge from large bodies of text as well as outlining core thematic areas within a given domain of discourse.

7. Limitations

The main contribution of this research is to supplement and broaden the literature on blockchain technology and health information systems in developing countries. In our research, we followed stages for doing research that embodies multiple analytical perspectives (Beydoun et al. 2019; Evangelopoulos et al. 2012; Gefen et al. 2017). However, this study exhibits a couple of shortcomings that should be acknowledged when assessing the findings and should be reflected in future research. First and foremost, we propose a structured research design that embeds multiple analytic efforts by keyword. This keyword oriented methodology demonstrates its inherent drawbacks regarding the exclusion of specific keywords that may result in some articles not being deemed for inclusion. Furthermore, the research area of “blockchain technology” or “distributed ledger technology” is in itself a young field as such combining keywords such as healthcare/health as well all African countries furthermore limits the possibility of obtaining a large well of research publications in Scopus, Web of Science and PubMed. The earliest papers from our results are dated 2017. As such we strongly recommend researchers within the African sub-region to innovate and explore novel means of applying blockchain technology within the healthcare sphere.

Furthermore, our study employed bibliometric analysis and latent semantic analysis to support the systematic literature review process. Since bibliometric analysis purely provides a general overview of bibliography, abstract and keyword-related observations, the findings obtained do not provide in-depth analysis and elucidation. As such, our study furthermore explored each research paper by performing content analysis on the applications of blockchain technology within the African healthcare scope.

8. Research Recommendations

8.1 Theoretical frame

The adoption of blockchain in most emerging industries in Africa is highly innovative for many institutions, as some technological, structural and institutional prerequisites are absent. This newness in an ever-penetrating technology environment poses challenges in assessing factors shaping how cutting-edge technologies can operate in developing countries. Thus, emerging theories could initiate the theoretical conversation on the role of cutting-edge technologies such as blockchain in the transformation of high-potential fields in Africa (Frizzo-Barker et al. 2020). The point here is to blend theoretical arguments to address unresolved challenges (Dwivedi et al. 2022; Sharma and Kshetri 2020).With the aim of probing the theoretical underpinnings which will be contextualized for blockchain technology within the African healthcare landscape, future studies may converge on the following research directions:

- How have emerging theories in information systems been reflected in research on blockchain within the African health industry? What has been the relevance and issues identified?
- Should health research in Africa engage in new theoretical frameworks that address the contexts?
- Within African health, which areas warrant further scrutiny even beyond the technology component?
- How should scholars engage in theoretical musings towards a context-based lens that would accurately portray the current trajectory of blockchain adoption in developing and empowering health information systems in Africa.

8.2 Context

A variety of blockchain applications within the healthcare industry in Africa have underlined the merits of such a technology. For example, scholars have provided an alternative approach that embeds blockchain transactions and smart contract enforcement to enable improved collaboration as well as interoperability between entities while guaranteeing trust and auditability (El Kassmi and Jarir 2021). Future research can thus look at different typologies of systems in Africa, specifically in countries that are still in a process of understanding and prototyping. Hence, future research may consider different typologies of systems in Africa, especially in countries that are still in a process of understanding and prototyping. For instance, research could address the drivers of decision making in public health organizations once they have opted for a blockchain-based system. Therefore, they can tackle theses topics as follows:

- What distinguishes health information systems that are based on blockchain in Africa?
- At which degree can these systems be classified?
- What are the mechanisms for the development or breeding of blockchain-based health information systems in African health organizations?
- How does context and culture shape the selection of such systems?

8.3 Content

Considering blockchain in healthcare is in its nascent stage in Africa regarding adoption, understanding and implementation in various areas, opportunities are boundless (Prokofieva and Miah 2019). Thus, it would be compelling for future research to explore blockchain implementation scenarios for healthcare. Research can therefore address the following issues:

- What bearing do organizational capabilities have in deciding to enact a blockchain-based system within the healthcare industry in Africa?
- Why do public health organizations endorse or disregard the implementation of blockchain-based health systems in their efforts to strengthen the health information system?
- What are the socially accountable principles that public health organizations ought to enact to secure patient data through the use of blockchain-based systems?

8.4 Methodology

Notwithstanding the intriguing potential of embedding emerging technology within health information systems management processes in Africa, there are many variables influencing their adoption in public health organizations. Thus, forthcoming research efforts should consider the following thematic areas:

- Which methods are most pertinent in assessing blockchain enabling factors in African health systems? What theoretical framework best supports the methods?
- How can we develop an analytical framework that would optimally appraise blockchain's impacts on health data management between public health organizations that have adopted the technology, and others that have not?

9. Conclusion

Our research builds a theoretical, methodological and practical grounding on the acceptance of a disruptive technology such as blockchain in the African healthcare industry, while outlining various emerging initiatives. Contextual constraints such as a common regulatory framework across states, infrastructure limitations are some of the main challenges hindering the expansion of blockchain technology in Africa. Regarding different use cases in the African context, we conducted a multi-method analysis from a situational, thematic, and prioritization standpoint. The details of this analysis are recorded in Figures 8, 9, 10, 11, demonstrating the limited use of blockchain in the health industry in Africa, which is an under-exploited niche with great potential. Furthermore, we developed a thematic rationale using Latent Sematic Analysis to categorize the reflections that drive the emerging literature on blockchain within the healthcare industry in Africa. This categorization has brought to light a picture of both the technological orientation and vision of blockchain research in Africa, leading to a Strategic Agenda. This Agenda aims at strengthening weak areas in healthcare, including data protection, data security and interoperability between systems.

A number of scientific and practical insights on blockchain adoption in the African health industry surfaced. One of the recommendations for future research is to undertake an in-depth mapping of disruptive designs and practices being implemented / used. This will enable a unique context-based framework to be developed within the African continent, considering a common set of metrics across implementation settings.

Declarations

The author(s) declared no possible conflicts of interest regarding the research, writing and/or publication of this article.

Ethics approval and consent to participate

Not applicable. All methods were undertaken in accordance with the relevant guidelines and regulations.

Consent for publication

Not applicable

Availability of data and materials

This literature review did not involve gathering empirical data or identifiable personal information. The datasets generated and/or analyzed for the purpose of this study were gathered from online sources as indicated in the study and are available at the following sources: https://coinmarketcap.com/view/health/ and https://www.scopus.com/home.uri

Competing interests

Not applicable

Funding

Not applicable

Authors' Contribution

JKW and EA conceptualized the topic initially. RE and JKW was responsible for the research design. JKW conducted the background study and performed the systematic review. EA conducted the analytical tasks. RE refined the research questions, framed the findings on the studies, and contributed to the discussion of the findings. All authors wrote, read and approved the final manuscript.

Acknowledgements

Not applicable

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Figures

Figure 1

Global Google Trends Analysis on Blockchain (2004 – 2022)

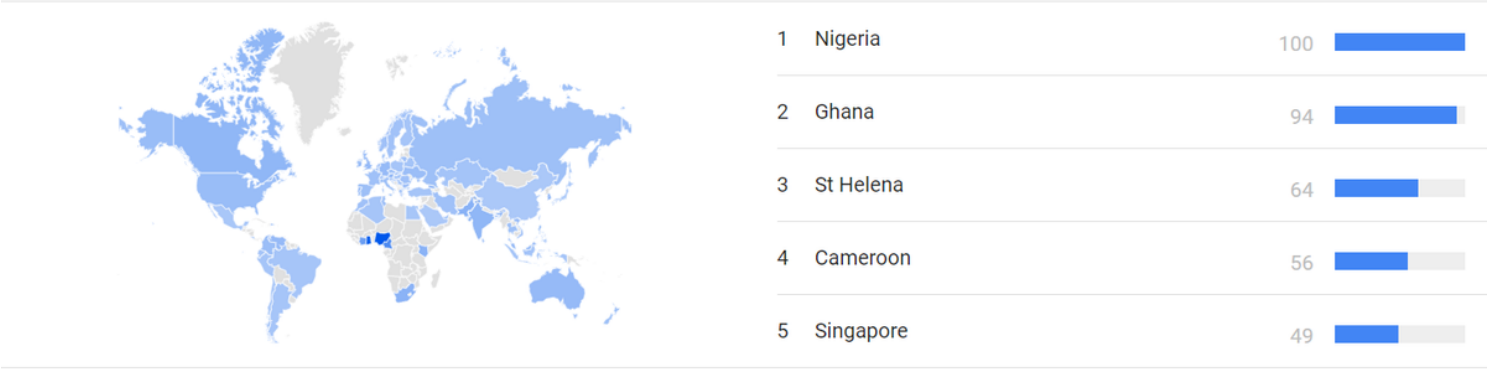

Figure 2

Interest by Region – Blockchain (2004 – 2022)

Figure 3

Blockchain for Sustainable Development Goals, adapted from (Fraga-Lamas and Fernández-Caramés 2020)

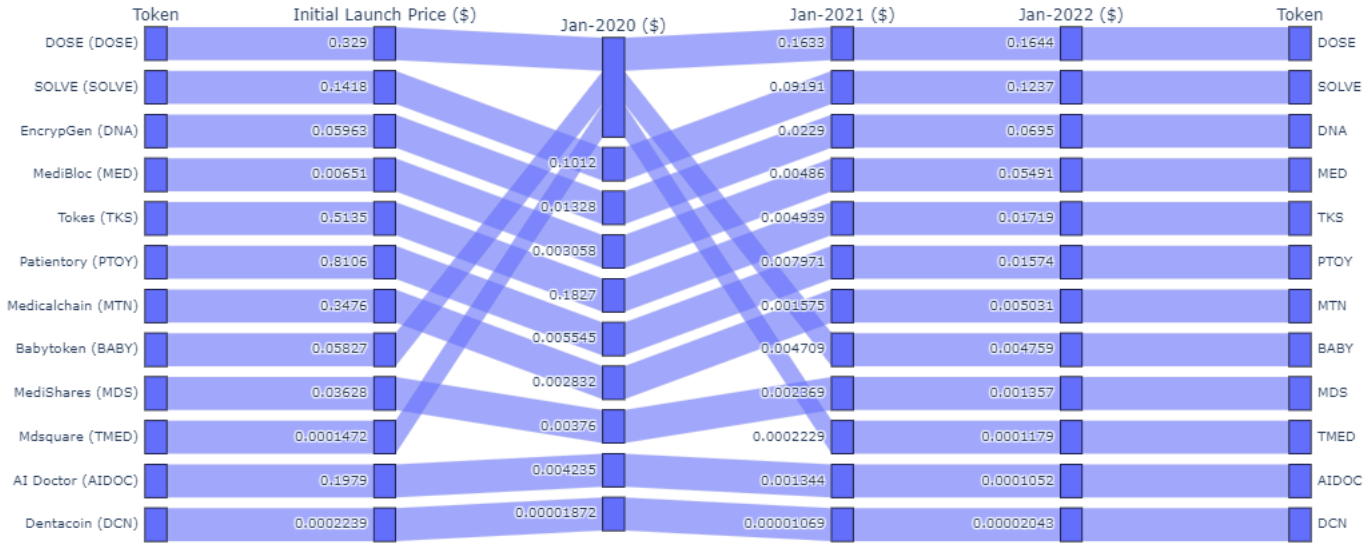

Figure 4

Parallel Coordinate Plot of Health Tokens by Market Price

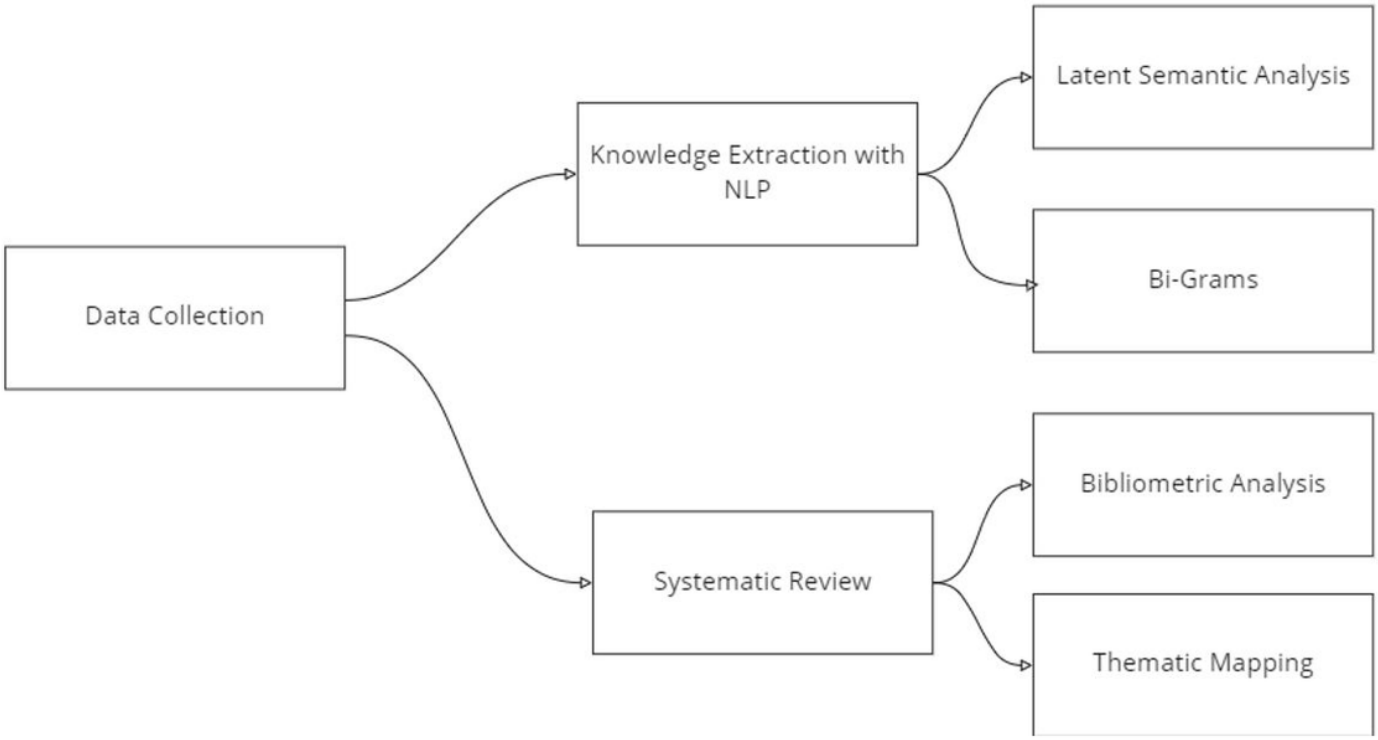

Figure 5

Research Methodology

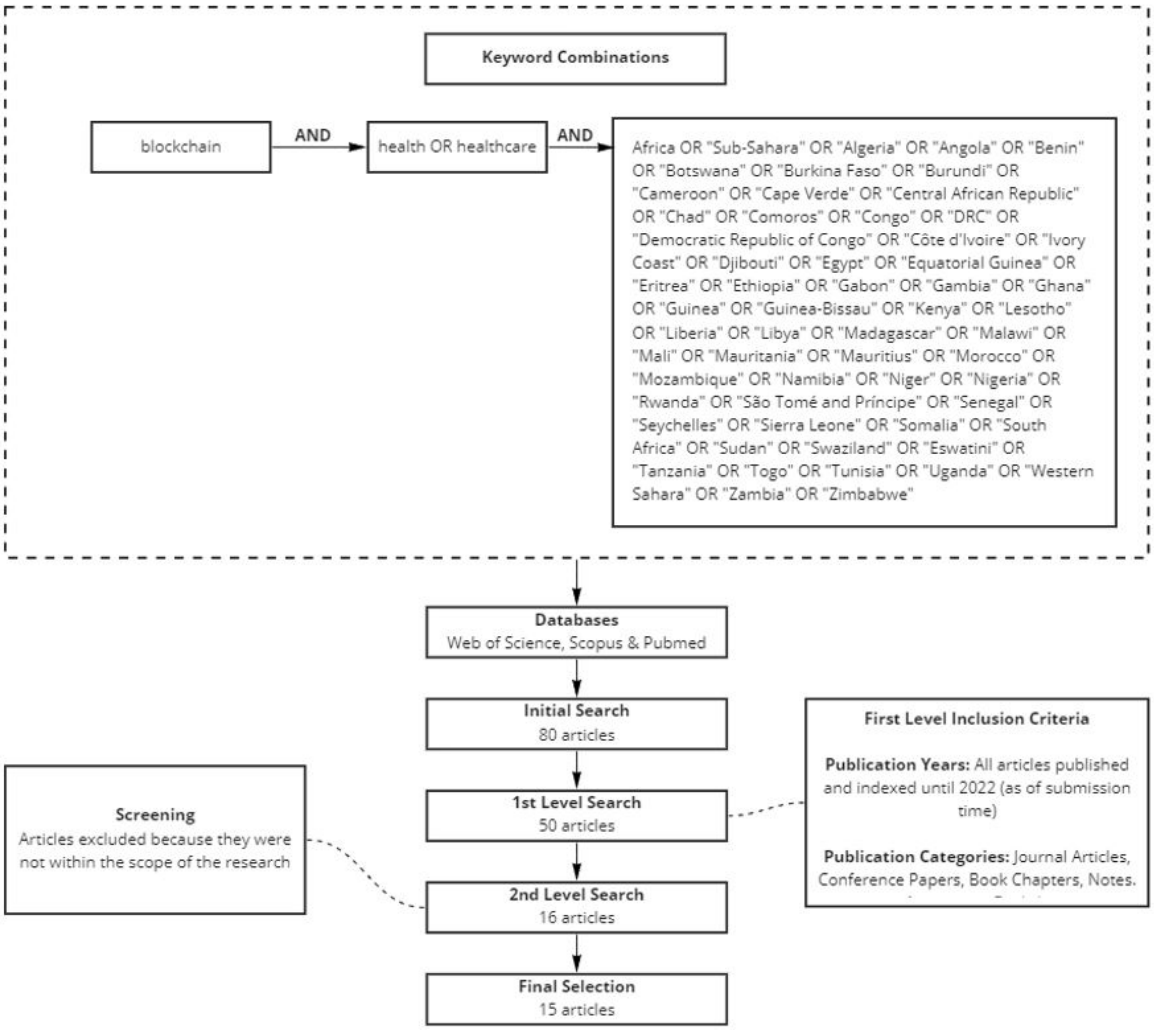

Figure 6

Systematic Review Methodology - Data Collection Process

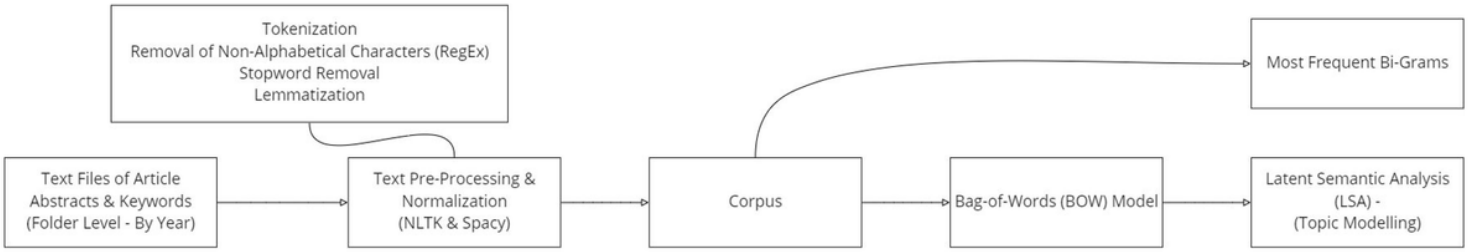

Figure 7

Research Methodology (Phase 2) - Natural Language Processing

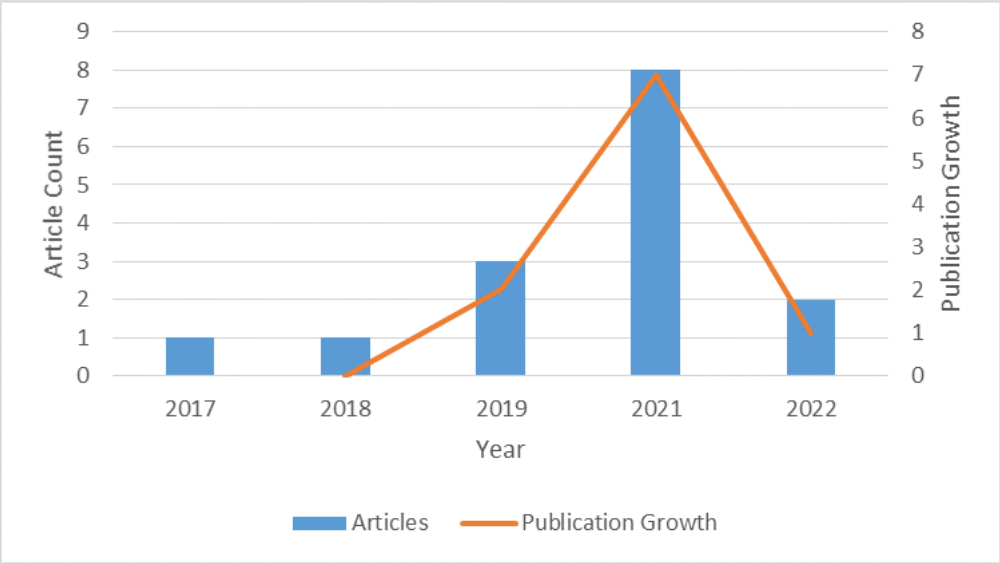

Figure 8

Publication Distribution and relative growth rate

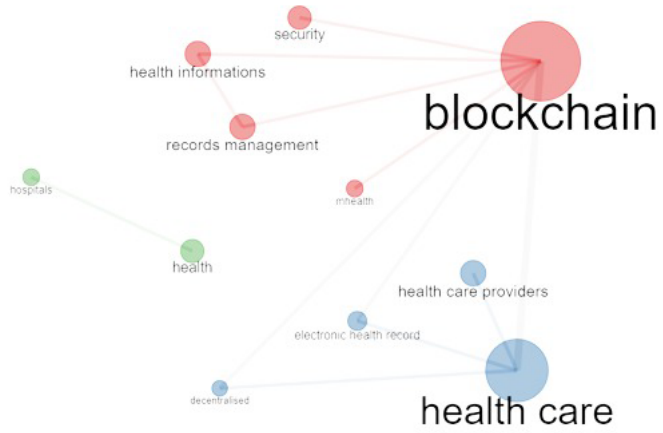

Figure 9

Co-occurrence Network Map (based on Authors' Keywords)

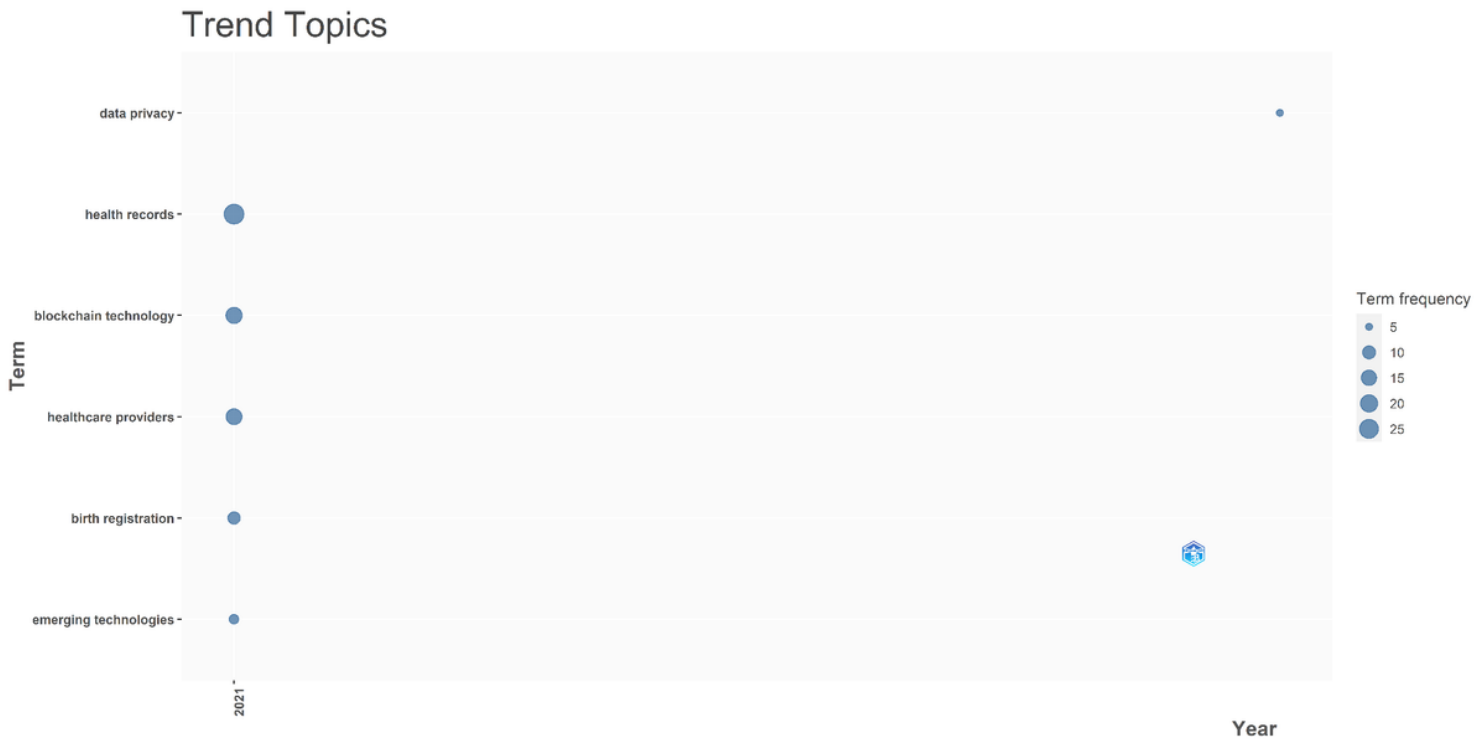

Figure 10

Trend Topics in Blockchain and Healthcare Research (Africa)

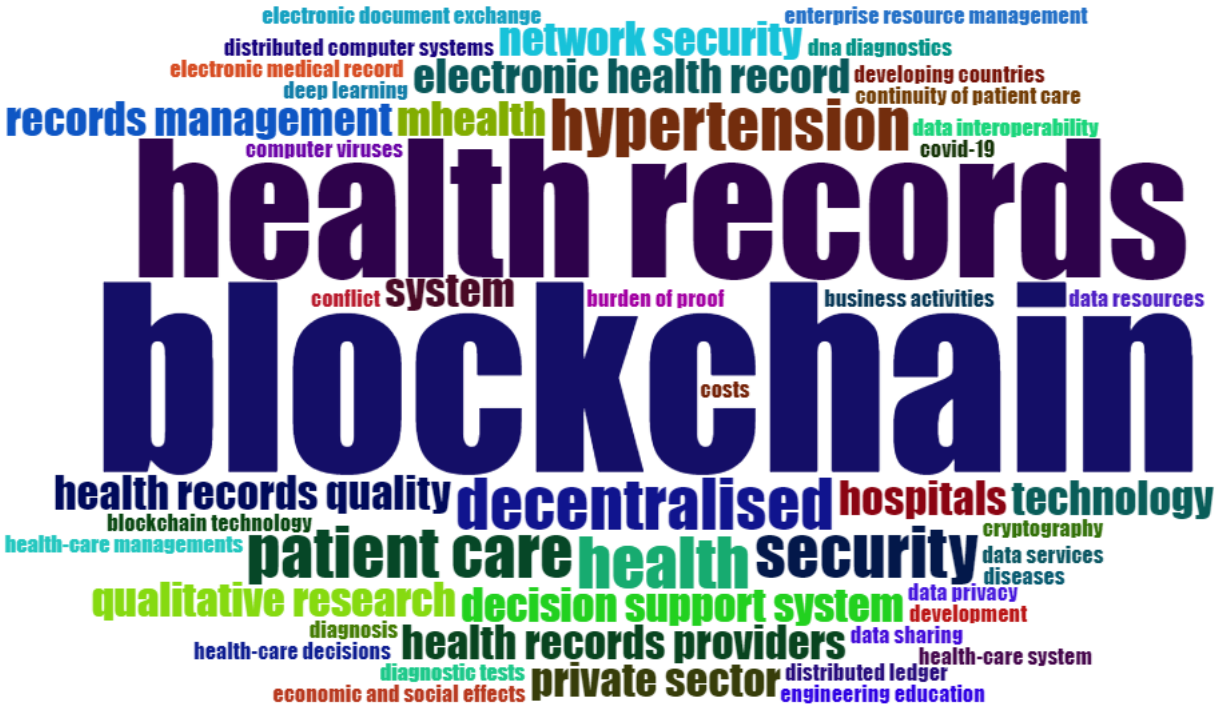

Figure 11

Word Cloud of Keywords in Blockchain and Healthcare Research (Africa)

Figure 12

Driving Factors for Blockchain Technology Acceptance in the African Healthcare Sector (Source: Authors' own Elaboration)

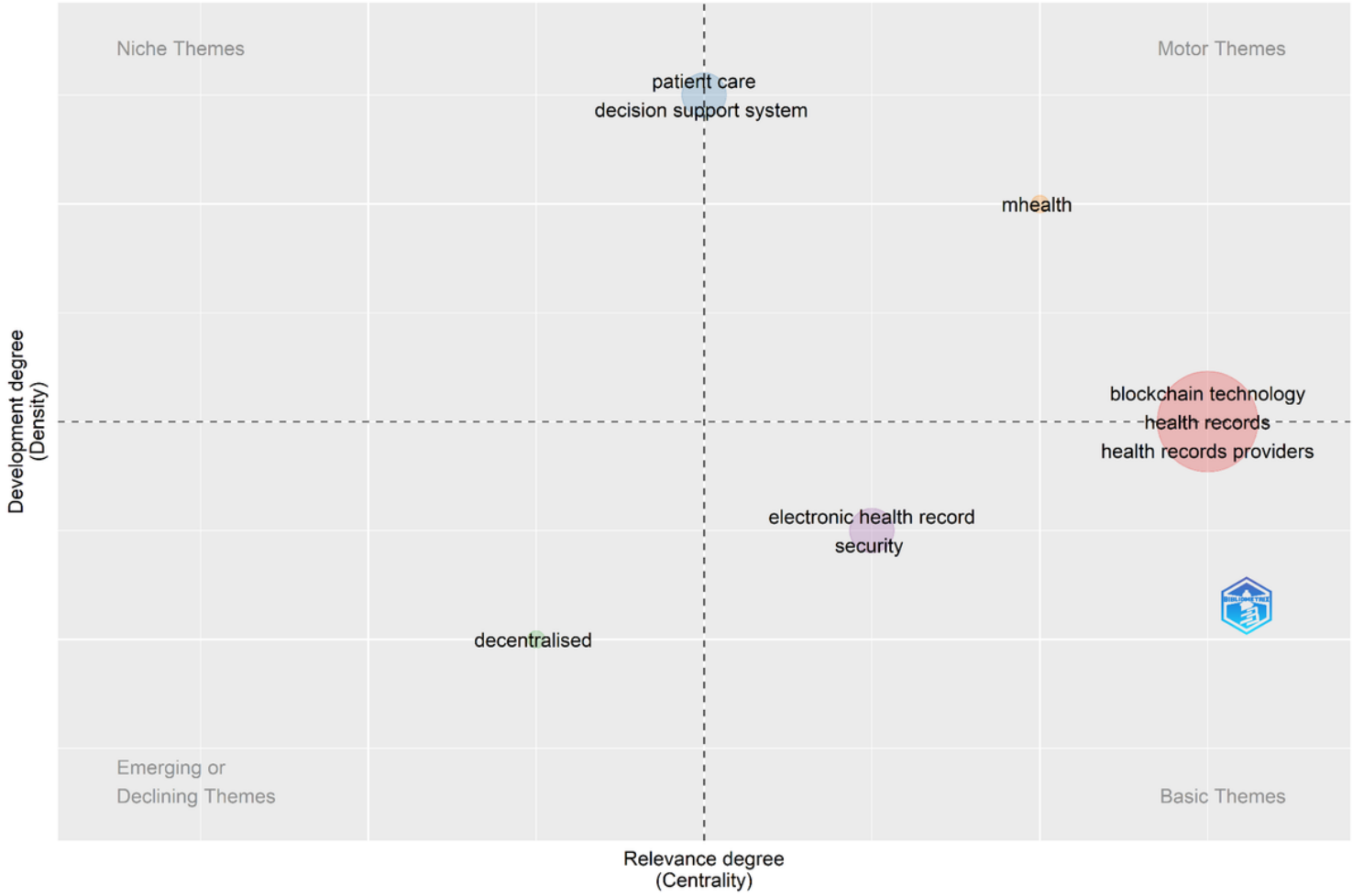

Figure 13