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Towards Smart and Green Features of Cloud Computing in Healthcare Services: A Systematic Literature Review

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Abstract

Background: The healthcare sector has been facing multilateral challenges regarding the quality of services and access to healthcare innovations. As the population grows, the sector requires faster and more reliable services, but the opposite is true in developing countries. As a robust technology, cloud computing has numerous features and benefits that are still to be explored. The intervention of the latest technologies in healthcare is crucial to shifting toward next-generation healthcare systems. In developing countries like Ethiopia, cloud features are still far from being systematically explored to design smart and green healthcare services.
Objective: To excavate contextualized research gaps in the existing studies towards smart and green features of cloud computing in healthcare information services.
Methods: We conducted a systematic review of research publications indexed in Scopus, Web of Science, IEEE Xplore, PubMed, and ProQuest. 52 research articles were screened based on significant selection criteria and systematically reviewed. Extensive efforts have been made to rigorously review recent, contemporary, and relevant research articles.
Results: This study presented a summary of parameters, proposed solutions from the reviewed articles, and identified research gaps. These identified research gaps are related to security and privacy concerns, data repository standardization, data shareability, self-health data access control, service collaboration, energy efficiency/greenness, consolidation of health data repositories, carbon footprint, and performance evaluation.
Conclusion: The paper consolidated research gaps from multiple research investigations into a single paper, allowing researchers to develop innovative solutions for improving healthcare services. Based on a rigorous analysis of the literature, the existing systems overlooked green computing features and were highly vulnerable to security violations. Several studies reveal that security and privacy threats have been seriously hampering the exponential growth of cloud computing. 54 percent of the reviewed articles focused on security and privacy concerns.

Keywords: Cloud computing, Consolidation, Green computing, Green features, Healthcare services, Systematic literature review.

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I. INTRODUCTION

The population of the world is expected to reach 9.7 billion by the year 2050 [1]. Accordingly, the African population is expected to double by 2050. Every sector needs faster services as the population grows in order to serve the community as quickly as possible. However, the healthcare sectors in developing countries are still struggling to sustain their ICT needs for better healthcare services. One of the major problems is the lack of accessibility to healthcare services. Research studies [2]–[5] revealed that healthcare services in developing countries lack faster and more reliable access to health care data and information services. The quality of healthcare services and the population to be served are disproportionate in these countries, such as Ethiopia. According to a reference [6], in Ethiopia,

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hospital-based services are categorized and clustered in a Three-Tier healthcare delivery model, i.e., 1) Primary, 2) General, and 3) Specialized hospitals. However, healthcare services and accessibility to patients' health care data and information across hospitals are difficult due to their scattered nature, storage over disparate systems, and lack of health care data consolidation. Hence, the intervention of ultra-modern facilities like ICT-enabled systems is crucial to minimize the challenges and enable easy access to patient's health care data and information services to avoid the medicines' adversities and reaction consequences in case of emergencies.

The research studies [2], [3] revealed that the judicious intervention of information and communications technologies (ICT) in healthcare services in developing countries is still lacking in terms of investigation and exploration of modern ICT-enabled technologies such as Machine learning (ML), Artificial Intelligence (AI), Big Data analytics, the Internet of Things (IoT), and Cloud Computing. As per reference [7], the use of Cloud-native technologies will be the centerpiece (i.e., the center of attention) of new digital experiences. It [7] estimated that by 2025, over 95% of new digital workloads will be deployed over cloud-native platforms. This implies that cloud computing has grown to become an indispensable aspect of modern information technology (IT) infrastructure across a variety of industries, such as the healthcare industry.

Studies reveal that advancements in cloud computing require the application of green cloud computing technologies, which focus on sustainable development and efficient utilization of resources (i.e., environmentally friendly practices). Green computing, or green IT, is a technology strategy aimed at reducing environmental impact through energy-efficient systems and services. A study [8] defines green computing as "the study and practice of designing, manufacturing, using, and disposing of computers, servers, and subsystems efficiently and effectively, with minimal or no environmental impact". Usually, e-waste, greenhouse gases (GHGs), and carbon dioxide (CO_2) emissions are the terms that are used to measure sustainable or green practices (i.e., reducing carbon footprints).

This study identifies research gaps in the smart and green features of cloud computing in healthcare services from prior research studies. Author Uecke, O. [9] discusses a research gap identification strategy. Accordingly, a research gap is a defect or deficiency in prior studies identified through rigorous literature surveys. It is summarized after analyzing the strengths and weaknesses of existing studies in the domain.

Through a systematic and rigorous literature review, this paper investigates, analyzes, and maps the applications, interventions, and practices in previously accomplished healthcare studies so that researchers and practitioners can get comprehensive conclusions and contributions in a single paper to find out the research gaps for further improvements in the domain-specific research.

II. LITERATURE REVIEW

A. An Overview of Cloud Computing

Cloud computing has emerged as one of the umbrella technologies for transforming current systems into next-generation systems as a result of the rapid advancement of ICT. According to Simson G. [10], in the 1960s, John McCarthy envisioned that cloud computing facilities would be provided to the general public like a utility, just as the telephone system is a public utility. The authors of [11] define Cloud computing as a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction. Accordingly, Cloud computing has five essential characteristics: on-demand self-service, ubiquitous network access, rapid elasticity, location-independent resource pooling, and metered services; three basic service models (software as a service (SaaS), platform as a service (PaaS), and infrastructure as a service (IaaS); and four deployment models (i.e., public, private, hybrid, and community).

Cloud technologies provide effective service delivery and deployment models that can lead to substantial cost reduction, time-savi ngs, service rendering, and energy conservation with assured uptime. It offers hardware, software, network, storage, virtualization, containerization, applications, and almost anything as a service, i.e., XaaS.

B. Cloud Service Models

In the SaaS model, software and applications are provided by cloud service providers (CSPs), and end-users can use the cloud service provider's applications through a web browser, mobile apps, or website links. The consumer does not control or manage the underlying cloud infrastructure. In the PaaS model, cloud service providers deliver computing platforms to the consumer in an on-demand fashion. In the PaaS model, cloud service providers deliver computing platforms to consumers on-demand fashion. According to references [11], [12], the PaaS scheme provides flexibility in installing software on the system and scalability. Using PaaS, application developers can develop, run, and host their applications on the Cloud platform without the cost and complexity of buying and managing the underlying infrastructure. The IaaS model comprises the underlying infrastructure, such as virtual machines (VMs), storage, etc. The Cloud service models are not limited to the listed models; i.e., other additional service models incorporate security as a service (SECaaS), database as a service (DBaaS), and anything as a service (XaaS).

C. Cloud Deployment Models

According to [11], (1) Private cloud: the Cloud infrastructure is provisioned for exclusive use by a single organization comprising multiple consumers. This model can be owned, controlled, and managed by the internal organization itself, a third party, or possibly a combination of both. (2) Public cloud: The infrastructure and services are being used by the general public, and the infrastructure is owned and managed by the CSPs. (3) Community cloud: the infrastructure is provisioned for exclusive use by a specific community of consumers from organizations that have shared concerns (e.g., mission, security requirements, policy, and compliance considerations); and (4) Hybrid cloud: the infrastructure is a composition of two or more distinct cloud infrastructures that remain unique entities.

In addition to the Cloud models, there are Cloud-enabling technologies such as virtualization, containerization, load balancing, free and open source software (FOSS), replication, service level agreements (SLAs), and identity and access management (IAM), as shown in *Fig. 1*. Figure 1 depicts various aspects of Cloud computing, which are drawn based on the reviewed studies [11]–[13].

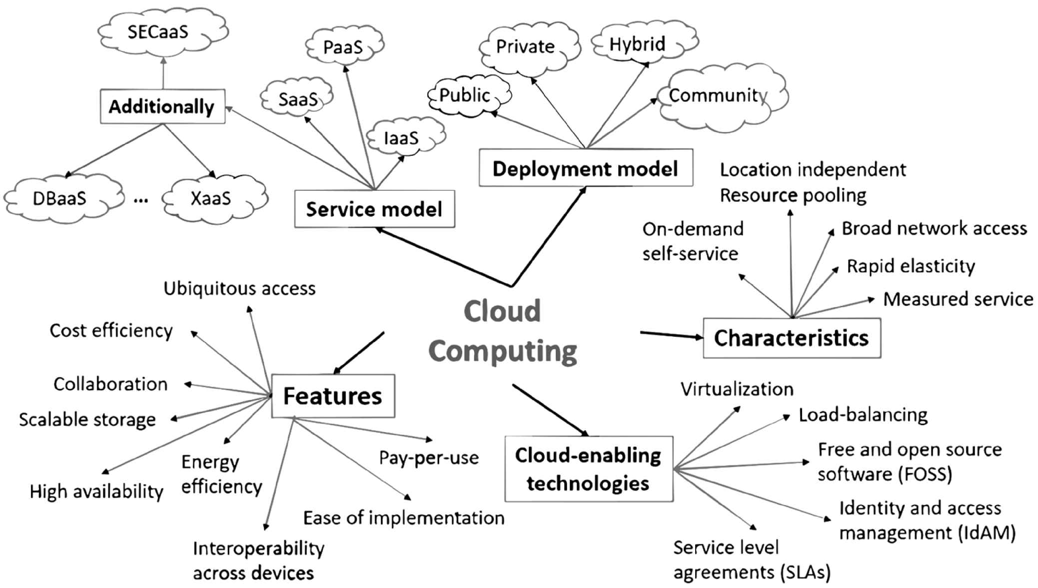

Fig. 1 Various aspects of cloud computing

According to references [11]–[13], cloud computing offers numerous features: ease of implementation, cost efficiency and effectiveness, on-demand access and self-service, collaboration, ubiquitous access, scalable storage, high availability (uptime), performance, security, and reliability, scalability and flexibility, energy efficiency, and interoperability for different domains. Other authors [14] argued with the convenient and economic features of the Cloud and stated that healthcare services require reliable data and information sharing from anywhere at any time. However, these features are still not being systematically explored and adopted at their full potential to provide smart and green health care data and information services in developing countries, particularly in Ethiopia.

According to [2], [3], [15], developing countries' healthcare institutions still depend on manual work or manual methods; however, this method hinders health data sharing, collaboration, access to patients' data from distant locations, and coordination among patients, professionals, and hospitals. Solving such limitations with traditional IT requires high capital expenditure (CAPEX) [16] and contributes to high carbon dioxide (CO_2) emissions from many data centers. On the other hand, numerous research studies [12], [17], [14], [21], [18], [19], [20] have identified various smart and green features of cloud computing, such as energy efficiency, cost efficiency (operational expenditure, OPEX), storage scalability, resource-saving (optimal resource usage), location-independent access, reducing paperwork, and a pay-per-use model to eliminate the shortcomings of traditional IT infrastructures. Based on the references [19], [18], [20] virtualization, containerization, automation, environmental sustainability, multi-tenancy, reduction of greenhouse gas emissions (carbon footprints), health data consolidation, and reduced paper consumption (paperless) can be considered smart and green features of cloud computing in healthcare services. As per reference [8], the green computing technology strategy is aimed at reducing environmental impact through energy-efficient systems and services. According to [17], virtualization technology offers a new method to enhance resource utilization and cloud services. i.e., optimal resource usage in green cloud computing. Also, according to [19], integrating cloud technology with IoT-Fog-based computing can provide smart and green healthcare services.

A systematic review paper [5] discusses the need for digital health technologies (DHTs)-enabled randomized controlled trials on emerging DHTs, including AI, cloud, Big data, cyber security, Telemedicine, and Wearable devices to provide robust evidence and materialize the WHO's global strategy on digital health. The study [5] explores six DHTs, such as mobile health (mHealth), EMR, Telemedicine, Cloud-based applications, AI, and ICT. These DHTs were focused on improving clinical and public health practices. A review paper [18] classified cloud-enabled healthcare in three dimensions: (1) opportunities; (2) issues; and (3) applications. This study [18] designed a classification framework for cloud computing in healthcare. Another review paper [21] listed cloud computing's opportunities like scalability, flexibility, on-demand delivery, pay-per-use, and resource pooling, but still faces challenges such as security, regulation, privacy concerns, and loss of control in emerging cloud-based technologies. Also, a review study [22] examined the criteria that offer a roadmap to decision-makers before cloud computing adoption in the healthcare sector, such as organization, the external environment, technology, economic, social, human-environment, and trust. Even though these review papers focus on the usage of digital technologies in the healthcare sector, none of these review studies considered the smart and green features of cloud computing to build smart and green healthcare services. This systematic literature review (SLR) focuses on the study context of existing studies, proposed solutions, and the identification of research gaps towards smart and green features of cloud computing in healthcare services.

III. METHODS

Based on reference [9], the research gaps or defects identified through a thorough literature review can be summarized by examining the shortcomings in previous studies. This leads to the general research question of this study: What are the contextualized research gaps in the existing research studies on the smart and green characterizations of cloud computing in the current healthcare data and information systems and services? This general research question (RQ) can be broken down into the following three research questions (RQs):

Research Question (RQ1): What are the existing contextualized research gaps in the current legacy healthcare data and information systems in Ethiopia?

Research Question (RQ2): Which cloud computing features/characterization and models are suitable for adoption in healthcare for smart and green health care data and information services?

Research Question (RQ3): What are the cloud-based solution models/Frameworks and their research gaps in the existing research studies towards smart and green health care data and information services for synthesizing the results?

Research objective: The prime objective of this study is to conduct a systematic literature review to identify contextualized research gaps in the existing research studies towards smart and green characterization of cloud computing in healthcare data and information services and synthesize the results based on the rigorous analysis of the literature review.

To achieve its prime goal, this review paper conducted a systematic literature review of contemporary and relevant research articles to identify research gaps. We considered the research publications indexed in Web of Science, Scopus, IEEE Xplore, PubMed, and ProQuest. From the numerous indexing databases where researchers can retain and share their research findings, the aforementioned indexing databases were selected due to their high reputability, high quality, and global acceptance. In addition, Google Search and Google Scholar have been used for additional searches.

In this systematic literature review, our general search strategy is delimited by the following research string: ("Cloud computing" AND "Healthcare") OR ("Cloud computing" AND "Health care") OR ("Cloud computing" AND "Health"), ("Cloud-based" AND "Healthcare") OR ("Cloud-based" AND "Health care") OR ("Cloud-based" AND "Health"), ("Cloud-enabled" AND "Healthcare") OR ("Cloud-enabled" AND "Health care") OR ("Cloud-enabled" AND "Health"), ("Cloud computing" AND "Hospitals") OR ("Cloud-based" AND "Hospitals") OR ("Cloud-enabled" AND "Hospitals"), ("Cloud computing" AND "Healthcare" AND "Ethiopia") OR ("Cloud computing" AND "Health care" AND "Ethiopia") OR ("Cloud computing" AND "Health" AND "Ethiopia"), ("Cloud-based" AND "Healthcare" AND "Ethiopia") OR ("Cloud-based" AND "Health care" AND "Ethiopia") OR ("Cloud-based" AND "Health" AND "Ethiopia"), ("Cloud computing" AND "Healthcare" AND "Africa") OR ("Cloud computing" AND

"Health care" AND "Africa") OR ("Cloud computing" AND "Health" AND "Africa") OR ("Cloud-based" AND "Healthcare" AND "Africa") OR ("Cloud-based" AND "Health care" AND "Africa") OR ("Cloud-based" AND "Health" AND "Africa") OR ("Cloud-enabled" AND "Healthcare" AND "Africa") OR ("Cloud-enabled" AND "Health care" AND "Africa") OR ("Cloud-enabled" AND "Health" AND "Africa"), ("Cloud computing" AND "Healthcare" AND "developing countries") OR ("Cloud computing" AND "Health care" AND "developing countries") OR ("Cloud computing" AND "Health" AND "developing countries") OR ("Cloud-based" AND "Healthcare" "developing countries") OR ("Cloud-based" AND "Health care" AND "developing countries") OR ("Cloud-based" AND "Health" AND "developing countries") OR ("Cloud-enabled" AND "Healthcare" AND "developing countries") OR ("Cloud-enabled" AND "Health care" AND "developing countries") OR ("Cloud-enabled" AND "Health" AND "developing countries").

Based on the search string, initially 142 articles were shortlisted. However, based on the selection criteria, 90 articles were excluded due to various reasons, and finally, 52 relevant articles were included for the rigorous review.

The Preferred Reporting Items for Systematic Review and Meta-analysis (PRISMA) flow diagram and checklist were used for this study, a systematic review that included searches of databases. According to [23], the PRISMA 2020 statement provides updated reporting guidelines for systematic reviews, incorporating advancements in methods for identifying, selecting, evaluating, and synthesizing studies. As per the study [23], an R package and Shiny app allow users to produce systematic review flow charts. The layout in this paper is based on the PRISMA 2020 flow diagram, which was designed using the Shiny app, a web-based tool for the identification of new studies via databases. *Fig. 2* depicts the complete flow diagram that shows the articles' selection procedures for this review paper. On the flow diagram, N stands for the number of records.

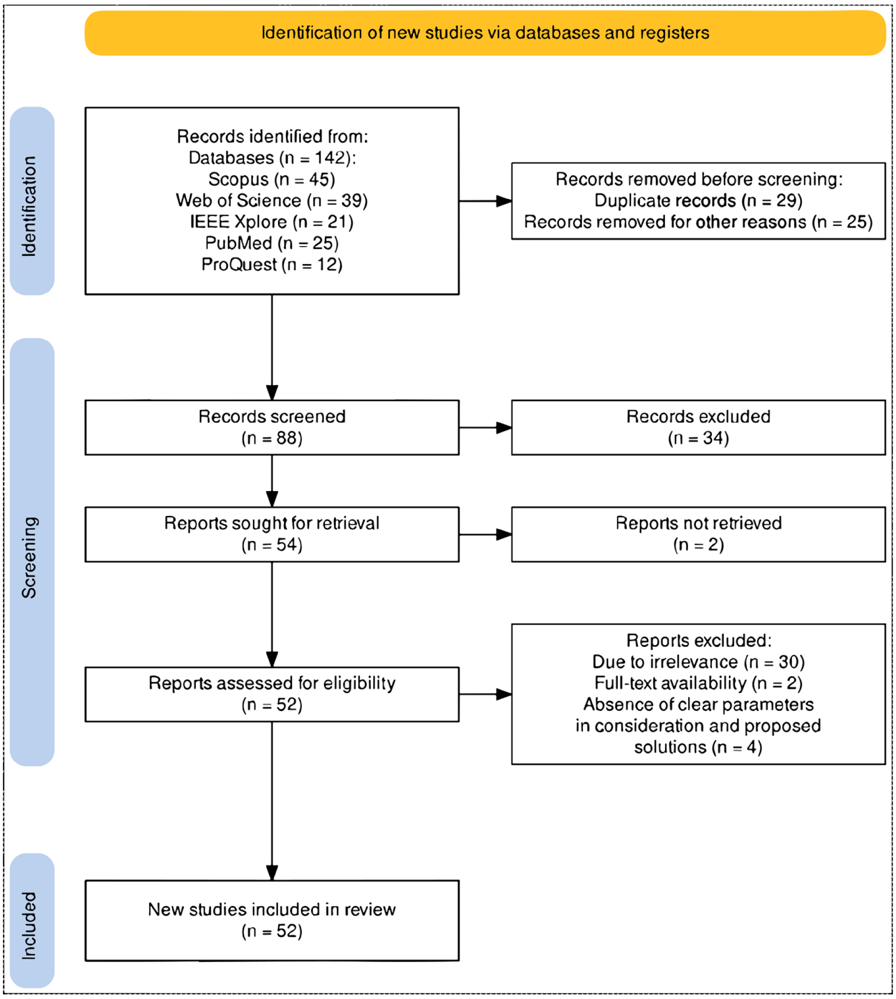

Fig. 2 The articles' inclusion and exclusion procedure (based on PRISMA 2020 flow diagram [23])

The PRISMA 2020 statement is designed to help systematic reviewers transparently report the purpose, authors' actions, and findings. It has three essential steps in records: (1) identification; (2) screening; and (3) inclusion. Thus, based on the PRISMA 2020 statement, 142 records are primarily identified from five databases, i.e., Scopus (n = 45), Web of Science (n = 39), IEEE Xplore (n = 21), PubMed (n = 25), and ProQuest (n = 12). However, at this step, 54 records (articles) were removed due to duplication (n = 29) and other reasons, such as articles published earlier than the year 2017 (n = 25). During the screening stage, 36 records (articles) were removed due to irrelevance (n = 30), full-text availability (n = 2), and the absence of clear parameters in consideration and proposed solutions (n = 4). Lastly, 52 new studies are included for a rigorous systematic literature review.

As shown in Fig. 3, 27% of the articles were published in 2020 and 19% in 2021. In terms of indexed databases, as depicted in Fig. 4, 35% were indexed in Scopus and 31% were indexed in Web of Science.

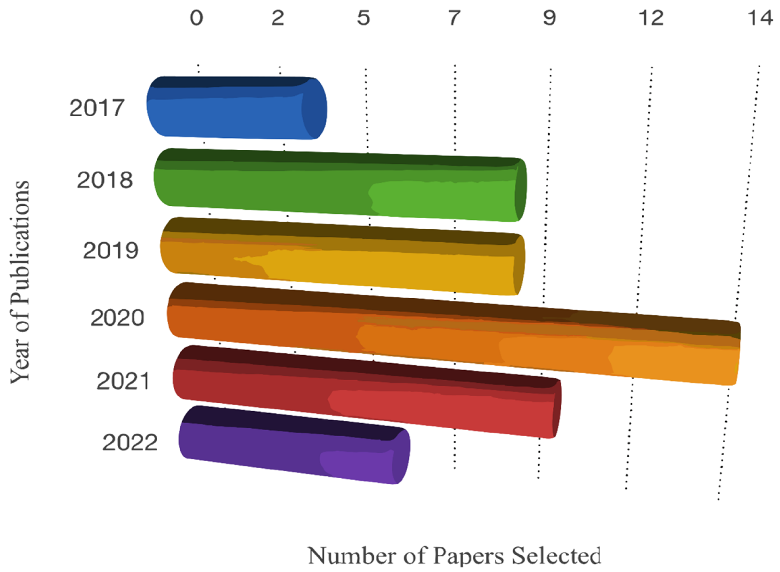

Fig. 3 The articles statistics status- year based

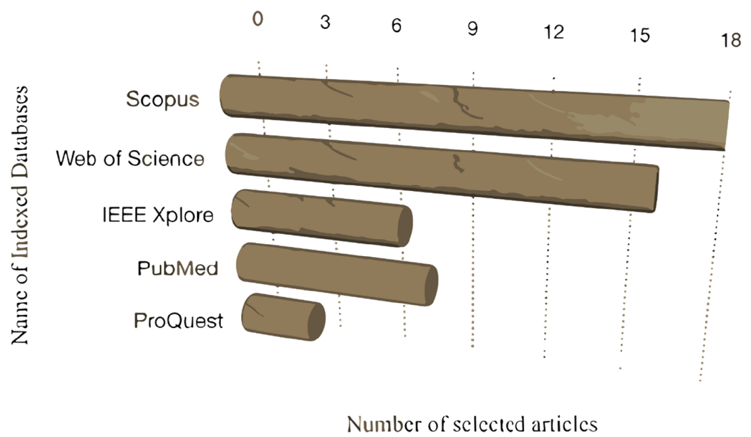

Fig. 4 The selected articles' indexed databases

A. Articles Selection Criteria

1) The articles inclusion criteria:

The research papers from the aforementioned sources were assessed based on the predefined eligibility criteria, such as the relevance of 'research title', 'abstract', 'availability of full-text, and 'recentness, i.e., year of publications from 2017 to 2022'.

2) The article's exclusion criteria:

Articles published earlier than 2017, duplications, irrelevance, absence of proposed solutions, and non-English language articles were used to exclude the articles.

IV. RESULTS

The data collection is focused on cloud computing in healthcare in general and in developing countries such as Ethiopia in particular, which is one of the developing countries in Africa. However, due to the small number of papers (i.e., 10%) discussing cloud computing in Ethiopian healthcare systems, it is important to consider and study the situation of other developing countries on the African continent.

The details of the current studies' study context (parameters), cloud-based proposed solution models, and their research gaps are synthesized under RQ3 (see Table 2) from other countries' perspectives. Thus, the data collection addresses RQ1 in particular and RQ2 and RQ3 in general under this study's general RQs and goals.

A. RQ1. What are the Existing contextualized research gaps in Ethiopia's legacy of current healthcare data and information systems?

Even though numerous research studies have indicated that paper-based or manual procedures in the processing of healthcare data and information are widespread problems in many developing countries in Africa in general and Ethiopia in particular, which serves as the baseline for the analysis in this section.

The first question relates to identifying the contextualized research gaps that exist in Ethiopia's current healthcare data and information services. We only found a relatively small number of papers—10% of all papers—that discussed cloud computing in Ethiopian healthcare. As the authors of [2] revealed, most health care practitioners and healthcare institutions still rely on paper-based medical records and paper-based information processing. One major concern is that the country's population is outpacing the level of healthcare and healthcare services already available. Currently, there are over 120 million people in Ethiopia, but that number is dramatically increasing. However, the current healthcare data and information systems are not up to par. As the volume of healthcare data and information is continuously increasing, the current manual methods cause slowness in data or information retrieval and processing.

In this paper, we investigated that the paper-based or manual method of healthcare data and information handling is one of the serious causes of (a) erroneous health care information repositories, (b) delay in information delivery, (c) poor mechanisms of accessing patient information in case of emergency, (d) security and privacy concerns of health care information (prone to unauthorized access), (e) high carbon emissions, and (f) unnecessary information access congestion in hospitals. Table 1 depicts existing research gaps in the current healthcare information systems.

TABLE 1
EXISTING RESEARCH GAPS IN THE CURRENT HEALTHCARE INFORMATION SYSTEMS

References	Existing contextualized research gaps in current healthcare information systems
[2]	Paper-based medical records and paper-based health care information processing methods have limitations– in data sharing, collaboration, easy accessibility (i.e., slow access to patients' history), data filing (i.e., misfiling), and poor quality of information.
[3]	Record health data both on paper-based and electronic data entry (i.e., dual system). The dual systems cause redundancy, consuming time and costly resources with high power consumption and poor environmental sustainability. It also lacks sustainability, scalability, storage capacity, and share-ability of health data across hospitals.
[4]	Collected health data from rural and resource-poor communities. Lack of technique(s) to share data across hospitals and poor control over their health results remotely.
[5]	People living in low-income countries such as Ethiopia are at a low level of exploration and adoption of modern technology-supported healthcare data and information services. Patients can't access their health data and information from anywhere in anytime manner. Difficulty in sharing health data among hospitals, poor data standardization, and collaboration.
[16]	Sharing of composite personal health information in Ethiopian health care centers. Traditional IT contributes to carbon footprint and emission of carbon dioxide (CO_2). Secure data sharing, and patients' own data access control.

B. RQ2. Which Cloud Computing Features/characterizations and Models are suitable for adoption in healthcare for Smart and Green health care data and information services?

This part focuses on scrutinizing the reasons to embody Cloud computing in smart and green healthcare services. Each reviewed research article is focused on cloud computing in health care. Various research studies [24],[25],[22], [26], [27] have shown that cloud computing models offer critical benefits, such as resource-savings over traditional IT/on-premises solutions and paper-based/manual methods in healthcare systems. Inextricably, cloud computing features and significant benefits have been mentioned in the reviewed research articles. Identifying existing contextualized research gaps, scrutinizing the reasons to embody Cloud in healthcare, and synthesizing the results are interrelated and inseparable under the scope and aim of this study.

For a high-level understanding and use of the important features and models of cloud computing in healthcare data and information services, perceptive of the crucial features and suitable models is so important.

In *Fig. 1*, we presented various aspects of cloud computing. According to research studies [12], [28], [29], in the software as a service (SaaS) model, end-users can use the cloud applications through a web browser, mobile apps, or website links over any type of digital device (i.e., interoperable). The community cloud deployment model is provisioned for exclusive use by a specific community of consumers from organizations that have shared concerns. This can be one of the deployment models for healthcare institutions (hospitals). Other additional Cloud service models include security as a service (SECaaS) and database as a service (DBaaS). Virtualization, containerization, load balancing, free and open source software (FOSS), replication, service level agreements (SLAs), and identity and access management (IAM) are the underlying cloud-enabling models and services.

Several research studies [18], [20]–[22], [30] discovered several features/characterizations of cloud computing, such as cost efficiency, easy implementation, on-demand access, collaboration, scalable storage, high availability, energy efficiency, interoperability, security, and reliability, time savings, unlimited resources, global access, and pay-per-use features.

Based on several research studies, we investigated the most preferred characterizations/features for building smart and green healthcare services:

Virtualization	Automation
Energy efficiency (reduced energy consumption)	Sustainability
Multi-tenancy	Reduce greenhouse gas emissions
Consolidation	Reduced paper consumption (Paperless)

These days, paper consumption is very high; however, to date, hospitals in Ethiopia consume huge amounts of paper for recording information, prescriptions, lab results, etc. The current paper-based systems are lacking in terms of multiuser access, anytime-anywhere remote availability, quick dissemination, centralized security and privacy maintenance, high reliability, smart access, and energy efficiency. Alternatively, new modeling of healthcare data and information is anticipated to achieve the aforementioned features/characteristics in healthcare data and information over emerging technology systems like the cloud.

C. RQ3. What are the cloud-based solution models/Frameworks and their research gaps in the existing research studies towards Smart and Green health care data and information services for synthesizing the results?

As per PRISMA, synthesis involves the collation, combination, and summary of the findings of individual studies included in the systematic literature review, which is an essential part of a systematic review. This study uses the tabulation technique and a textual approach to synthesize the results. As synthesized in Table 2, this review paper identified crucial research gaps that are significantly important upon rigorously reviewing 52 research articles that are brought together and tabulated with review remarks. The study revealed and listed the reviewed articles' study context (parameters), proposed/designed solutions, and identified key research gaps in each research article. The details of this study's findings and the excavated research gaps are presented in Table 2.

V. Discussion

The analyses of the reviewed papers are categorized into multiple sections based on the challenges observed, reported, and considered as proposed solution models in healthcare services, as follows:

A. Manual methods and disparate systems

According to [2], Ethiopia's healthcare institutions still rely on paper-based methods that limit sharing, collaboration, and coordination among patients, staff, and hospitals. The increasing volume of healthcare data affects storage capacity, slows data retrieval, and lacks interaction between professionals and patients. A mobile cloud computing architecture (MCC) is suggested as a solution, but it lacks health data standardization and secured access features. As per a study [15], developing countries like Ethiopia still use paper-based methods, causing accessibility issues, poor information quality, and misfiling. An integrated cloud-based electronic medical records (ICBEMR) system is proposed; however, it lacks security and green features. According to [3], Ethiopian health extension workers are expected to record paper-based and electronic data entry for a dual system, which is redundant, time-consuming, resource-intensive, and environmentally unsustainable. Accordingly, barriers include inconsistent electricity access, low e-health literacy, data governance, technology infrastructure adaptability, smartphone costs, service management

TABLE 2
THE RESEARCH FINDINGS AND THE EXCAVATED RESEARCH GAPS

Research works	Study Context (Parameters)	Proposed/designed Solutions (RQ3)	The Identified Research gaps (RQ3)
Lijalem M. et al. [2]	Paper-based health data Lack of interaction	Mobile Cloud Computing (MCC) architecture	Lacks health data standardization, share-ability, interoperability, and collaboration. No control of patients over health data.
Kimberly H. et al. [3]	Data redundancy Limited access to health IT	mHealth architecture	Lacks sustainability, scalability, storage capacity, and share-ability of health data across hospitals.
Felix J. et al. [4]	Cervical cancer screening	Cloud-based info. Systems	Doesn't allow patients to access their health data.
Tsegahun M. et al. [5]	Limited Access to health innovations	Suggested digital health technologies	Lacks health data standardization and experimental analysis.
Minh Pham, et al. [31]	Human functionalities likely to be impaired at an older age	Cloud-based smart home environment (CoSHE)	Lacks integration/federation of health data. No considerations of energy-efficiency.
Jai-Woo Oh. et al. [32]	Disparate/independent HIS Low interoperability	Cloud-based health info. systems (cHIS)	Lacks access to patient health data across hospitals, and greenness.
Seham S. Almubarak [33]	The complexity of hospital information systems	Suggested Cloud Solutions in healthcare service	How can paper-based systems be shifted to Cloud? Smart and green features are overlooked.
Siti D. et al. [14]	Privacy and Integrity of health and medical data	Cloud-based secured healthcare Framework	Lacks health data share-ability among healthcare institutions (hospitals).
Jiunn-Woei Lian [28]	Information quality, system quality, and service quality	Integration of Trust into info/system success model	Smart and green features are ignored.
Mayank S. et al. [24]	Security, interoperability, support, and quality of CSPs	No	No other parameters (accessibility, collaboration, energy, greenness, share-ability) are considered.
Hina Kunwal, et al. [29]	Privacy and security, service reliability, integration and interoperability, data standards	Hybrid cloud computing conceptual framework	Overlooked greenness, energy-saving, and carbon footprint. No security solution was provided.
Mbarek M. et al. [30]	Interoperability, operating costs, security, and privacy	Secure collaborative working environment	Doesn't evaluate the efficiency of the algorithms, Energy efficiency/greenness is ignored
Omar Ali, et al. [18]	Opportunities (technology) Issues (technical, security) Applications	Cloud in Healthcare Classification Framework	Doesn't indicate how to incorporate data sharing across multiple systems features in the healthcare Still, fear & threats of data vulnerabilities exist.
Ali Vafamehr, et al. [20]	Energy management/saving	Energy-aware Cloud hierarchy market structure	Greenness, collaboration, accessibility, and share-ability are overlooked.
PATIENCE E. IDOGA et al. [34]	Data security, information sharing, cloud-based health knowledge, performance, effort & facilitating conditions	Cloud-based health system model (CBHS)	The targeted participants are not well-addressed Again overlooked greenness, energy efficiency, and carbon footprint.
Aparna Kumari, et al. [35]	Latency (Network) Privacy and security issues Resiliency against Cloud	Three-layer patient-driven Healthcare architecture	Didn't consider energy efficiency, carbon footprint, A solution for security issues is missing.
Masood I, et al. [36]	Data security & privacy Lack of standard architecture	Classification scheme (generic Framework)	Energy efficiency, green features, & performance for processing are not well presented.
Kumar V, et al. [37]	Security and privacy issues	A Mutual Authentication Framework for Healthcare	Green features, data sharing, integration, performance & energy-saving were not considered.
Masana N, et al. [15]	Paper-based systems (poor quality, access, & misfiling)	Integrated Cloud-based electronic record system	Missing security solution in the model. Greenness, collaboration & data sharing are ignored.
DINH C. NG., et al. [38]	Data privacy Network security	EHR sharing Framework that combines Blockchain	Doesn't consider QoS, energy, greenness, & collaboration among healthcare institutions.
AJAYI O, et al. [39]	Exchange of medical data Lack of expertise (locally) Lack of healthcare facilities	Cloud Federation for the healthcare support	No green features are considered. Security and privacy concerns are missing.
Rajabion L, et al. [40]	Healthcare big data receiving Healthcare big data sharing Storing patient information	Classification of Cloud computing applications in the healthcare big data	Greenness, energy-saving, and carbon footprint parameters are ignored.

TABLE 3 (CONTINUED)
THE RESEARCH FINDINGS AND THE EXCAVATED RESEARCH GAPS

Research works	Study Context (Parameters)	Proposed/designed Solutions (RQ3)	The Identified Research gaps (RQ3)
Idoga P, et al. [41]	Cloud-based knowledge, IT infrastructure, & data security	Cloud-based health center system architecture	Present security solution, energy-saving, & carbon footprint features are missing.
Omar A, et al. [42]	Security (data loss & theft) Data privacy, integrity, sharing	Patient-centric healthcare data management system	Other cloud features (interoperability, energy efficiency & collaboration) are missing.
SHEKHA C., et al. [43]	Security and privacy Cyber-security concerns	Classification of Privacy-preserving in e-health	Green/energy efficiency, collaboration, & accessibility features are not discussed.
Hao M, et al. [44]	Privacy threats Resource-saving	Privacy-aware resource-save collaborative protocol	Focused on deep learning, & no other issues were raised. Other Cloud features are overlooked.
Hafedh Ben H., et al. [45]	Patients' congestion in hospital Lack of resources in hospitals	Home hospitalization system architecture	Overlooked energy-saving, carbon footprint, collaboration, accessibility, & security concerns.
Sharm M, et al. [46]	Factors influencing cloud adoption in healthcare: organization, technology, trust	Suggested critical criteria that offer a roadmap to decision-makers	Didn't consider other cloud features in healthcare such as energy efficiency/ greenness, and accessibility.
Ogwel B, et al. [47]	Technological, organizational & behavioral context	Conceptual Framework	Didn't consider any other factors and features.
Balkrishna E., et al. [48]	Cloud-related issues (security), applications & Adoption	Structured Classification of Cloud in Healthcare	Smart, collaboration, greenness, across hospital access, and information-sharing features, are missed.
Chandrakar P, et al. [49]	Security threats (session key security attack, anonymity attack & impersonation attack)	New secure authentication protocol for cloud-based e-health system	Share-ability, collaboration, energy efficiency, and greenness features are overlooked.
M. Mamun-Ibn-A., et al. [50]	Security threats to patients' health data	The cloud-IoT-based smart healthcare system	Didn't consider green and energy-efficiency features.
Dr.Rajasekar Sundaram [16]	Emission of Carbon Dioxide Accessibility, secure sharing Patients' own data control	Green Computing System Architecture	Greenness considered, however, didn't consider other features such as energy-saving, collaboration, & security solutions.
Azath Mubarakali [51]	Content privacy Secure data transformation	The secure healthcare-based Blockchain approach	Performance, energy-saving, collaboration, accessibility, and greenness features are not considered.
Aceto G, et al. [52]	Opacity of infrastructure Data security & standards Heterogeneity of formats	Healthcare 4.0 applications scenarios (Cloud-based health information systems)	Doesn't consider how to apply in remote areas, and Doesn't indicate how to address the security & privacy concerns.
Prince P. Blessed, et al. [53]	Security & privacy (integrity, confidentiality & availability)	Privacy-enforced access control model	Doesn't consider share-ability, collaboration, greenness, or energy efficiency features.
Ahmad Al, et al. [54]	Financial Performance & Cost IT operational excellence	Cloud computing adoption model for HIS	Green, energy-efficiency, availability, reliability features, and present security solutions are missed.
Mbasa Joaquim M., et al. [21]	Challenge(security, regulation) Opportunities(scalability, pay)	No	Doesn't provide any solutions. Doesn't consider green, & energy-saving features.
Nermeen M., et al. [55]	Security risks Integration and transition	No	Did not provide any specific solution(s).
Nilesh Uke, et al. [56]	Data security Privacy-preserving in e-health	The architecture of Healthcare 4.0 data storage and sharing	Doesn't consider energy efficiency, greenness, collaboration, and carbon footprint.
Aarthi R. et al. [57]	Contextual, policy, and organizational factors	Recommendation for policymakers to Adopt Cloud	No other parameters are considered.
Mohammad M., et al. [25]	Security issues (data security, availability, and integrity)	Security solutions; data encryption, & authentication	Did not explain the details of the solution. Unclear parameters considered in the solutions.
Remya Sivan., et al. [58]	Security & privacy (availability, confidentiality, unsecured API)	Identity-based secure & encrypted data-sharing	The Greenness and energy efficiency of the models are either ignored or not considered.
Etikala Aruna., et al. [59]	Security & privacy (violations, forgery, & tempering)	Blockchain-based eHealth conceptual ecosystem	The Greenness and energy efficiency of their integration weren't considered/evaluated.
Khaldun G. Al-Moghrabi, et al. [26]	Quality (Information, service, system, and network) Perceived risk, and trust	Cloud computing success model	Doesn't have accessibility, interoperability, integration, energy efficiency & green features considerations.

TABLE 4 (CONTINUED)
THE RESEARCH FINDINGS AND THE EXCAVATED RESEARCH GAPS

Research works	Study Context (Parameters)	Proposed/designed Solutions (RQ3)	The Identified Research gaps (RQ3)
Bello M. Sule., et al. [60]	The volume of traffic in a network, security aspects, and accessibility	Healthcare architecture using Cloud computing	The framework requires to be refined by considering greenness, energy-saving, & collaboration.
Mamta Dhaka, et al. [22]	Energy-efficient, green, energy consumption, carbon emission	No	Didn't provide any specific model or show practically.
Anand K. M., et al. [61]	Security & privacy concerns	A GUI-based dashboard to support iCloud forensics	Specific to Apple devices (MacBook system). Not affordable in developing countries.
Mohd Javaid, et al. [62]	Advantages: scalable, access Drivers: cost, collaboration Challenge: security, downtime	No	Didn't provide a specific solution. Not considered energy-efficiency & green features.
Hemant B. Mah., et al. [63]	Privacy & security concerns	Blockchain-based healthcare system	Performance evaluation, energy-aware, greenness, and carbon footprints were not considered.
Billy Ogwel, et al. [27]	Economic, operational, and functional benefits	No	The sample size is very small to generalize the results. No suitable solution was provided.

costs, and local IT human resource constraints. A study [3] developed a mobile-health architecture as a viable solution; however, its sustainability, scalability, storage capacity, and shareability remain unanswered. Based on reference [5], low-income countries have low adoption of modern technology-supported healthcare services. This study [5] involved six digital health technologies (DHTs), such as mobile health (mHealth), electronic medical records (EMR), telemedicine, cloud-based applications, AI, and ICT. However, none considered patient data access control, data standardization, data sharing, or collaboration among hospitals. As per a study [32], small and medium-sized hospitals often set up healthcare information systems (HIS) independently, resulting in low interoperability due to the heterogeneity of systems. A cloud-based (cHIS) system was designed, but it lacks sharing and access to patients' data and energy-aware solutions. The authors of [33] stated hospitals are shifting from traditional systems to modernized, ICT-enabled ones due to the complexity of information systems. Accordingly, factors influencing the adoption of cloud in hospitals include relative advantage, innovativeness, IT knowledge, compatibility, and top management support. However, it lacks discussion on individuals quick access to health data and cloud migration. According to a study [30], the healthcare sector faces challenges in reducing costs while delivering high-quality healthcare services. But lack of interoperability between disparate systems and operating costs are the major obstacles. Several studies reveal that the cloud has the potential to address interoperability issues and reduce operational costs (OPEX). This study [30] proposed a secure multiparty computation (SMC) algorithm to prevent the potential disclosure of confidential information. However, it didn't evaluate: (1) efficiency; (2) power consumption; and (3) security requirements, along with availability, data ownership, authentication, and access control.

B. Security, privacy, and interoperability issues

A study [14] reveals privacy and integrity challenges in healthcare and medical data sharing. A cloud-based secured healthcare framework (SecH) is proposed to offer safe access to healthcare and medical data by enhancing the cipher-text policy attribute-based encryption (CP-ABE) scheme, but details on secure sharing across hospitals and patient control remain unclear. A study [51] revealed that content privacy and secure data transformation affect healthcare systems. A secure and robust healthcare over blockchain (SRHB) approach with attribute-based encryption (ABE) is proposed to transmit healthcare data securely. However, model performance, energy consumption, service collaboration, accessibility, and greenness features were not considered. Blockchain enhances a decentralized system for patient data control, but increasing block sizes may cause delays. According to [24], the healthcare sector faces challenges in health care data digitization, accessibility, and IT infrastructure, especially in small hospitals. However, a study [29] advised that a cloud model can transform capital expenditure (CAPEX) into operational expenditure (OPEX). As per the study [24], the quality of services depends on IT infrastructure, skilled manpower, and technology transformation. The study [29] revealed factors influencing cloud computing in e-health, including security, privacy, interoperability, and data standards. It designed a hybrid cloud computing conceptual framework for e-health but neglected greenness, energy-saving, carbon footprint, and security concerns. According to [18], cloud-based systems can minimize typing mistakes or errors. The study identified cloud-based systems in healthcare as (1) opportunities, (2) issues, and (3) applications and designed a classified framework of cloud for healthcare, but it does not specify data sharing across multiple systems in the current healthcare facility systems. According to [35], healthcare 3.0 is hospital-centric, where patients suffer a lot due to several hospital visits for their routine check-ups, while healthcare

4.0 addresses these problems. This study [35] proposed a three-layer patient-driven healthcare architecture for real-time data collection, processing, and transmission, addressing latency, security, and privacy issues. The study [36] suggests securing healthcare data using cloud-based encryption technologies for confidentiality and integrity. A multi-biometric scheme and generic framework are suggested for patients' privacy and security. However, energy-efficient and green features and processing performance are not adequately addressed. A study [37] reveals that the security and privacy of the cloud have become a big concern for health care data. It proposed a new mutual authentication framework, but it neglected performance measurements, energy savings, and integration. A study [38] disclosed data privacy, security, and reliability concerns for e-health systems. It proposed a novel electronic health record-sharing framework that combines blockchain. However, the quality of services in terms of network latency, energy consumption, and collaboration has not been investigated. Another study [42] designed a patient-centric healthcare data management system using Blockchain to keep healthcare data secure. But neglected interoperability, energy efficiency, and collaboration features. A reference [43] reveals security, privacy, integrity, and confidentiality challenges in a cloud environment. This study classified privacy-preserving mechanisms in e-health systems as cryptographic or non-cryptographic techniques. However, greenness, collaboration, and accessibility features were not addressed.

According to [44], e-health systems manage patients' digital information effectively, but security and privacy threats are challenges. A privacy-aware and resource-saving collaborative learning protocol (PRCL) is proposed. However, this focused on deep learning without considering other cloud features. Another study [48] covered cloud-related issues such as security and privacy. It suggested a structured classification of cloud computing in healthcare. However, greenness, across-hospital access, and information sharing were not considered. According to [49], cloud-based authentication schemes are susceptible to security threats. The authors of [49] proposed a secure authentication system for healthcare monitoring over the cloud. However, cloud features are overlooked for energy efficiency, shareability, and inter/intra collaboration. According to [50], healthcare facilities in developing countries, like Ethiopia, are poor. Cloud technologies and the IoT revolutionize smart healthcare applications. IoT has limited storage and processing capacity, while cloud computing offers unlimited storage capabilities. This study [50] proposed a cloud-IoT-based smart healthcare system for enhanced performance for users. However, greenness and energy-efficiency features were overlooked.

To address the issues of health data security and privacy in the cloud, a study [53] proposed a privacy-enforced access control model. However, the model overlooks accessibility, energy efficiency, shareability, and collaboration in healthcare. According to [21], cloud computing offers opportunities like scalability, flexibility, on-demand,pay-per-use, and resource pooling but faces security, regulation, privacy, and control challenges. However, [21] lacks solutions for addressing these challenges. A study [55] reveals security, integration, and transition challenges in cloud computing deployment in e-health systems but lacks specific solutions. According to [55], countries with limited IT resources can modernize healthcare services using cloud computing. A study [56] identifies medical data security and privacy preservation challenges in e-healthcare systems. It [56] proposes a newly evolved architecture of healthcare 4.0. However, the architecture included a few parameters and excluded energy efficiency, greenness, service collaboration, and carbon emissions. According to [25], cloud-based systems face security challenges in data confidentiality, availability, integrity, and networks. The study suggests cloud security through encryption, authentication, a secure API, and data classification. However, the details of the proposed solution and parameters were unclear. Another study [58] confirms that confidentiality, integrity, unsecured APIs, and account hijacking are major security challenges in e-health systems. Also, [58] reveals security and privacy as critical concerns when sharing or accessing patient data. It [58] suggests identity-based secured, and encrypted data sharing techniques; however, it overlooks greenness and energy efficiency.

According to [59], smart healthcare systems are vulnerable to security violations, attacks (i.e., forgery and tempering), and privacy leaks. This study [59] suggests decentralized security policies in cloud environments and proposes a Blockchain-based eHealth ecosystem to improve security issues; however, greenness and energy efficiency are overlooked. According to [61], security and forensic concerns are linked to cloud environments. This study [61] developed a GUI-based dashboard to support iCloud forensics; however, it collects artifacts from MacBook systems, i.e., specific to Apple devices, and is not affordable for developing countries like Ethiopia. As per reference [63], security and privacy issues pose challenges for cloud-based patients' sensitive health data. Accordingly, blockchain technology may overcome the challenges by providing secure e-health services. Hence, [63] proposes Blockchain-based healthcare system; however, it ignores performance evaluation, energy awareness, greenness, and carbon footprints. This study [62] described the advantages of cloud computing in healthcare services, including scalability, collaboration, accessibility, efficiency, low cost, patient data ownership, and collaboration. On the other hand, it [62] reveals challenges like security, system downtimes, and less control over cloud computing. However, it lacks specific solutions for the challenges and completely overlooks energy efficiency and greenness.

C. Lack of information quality and IT resources

A study [26] reveals system quality, information quality, networking quality, service quality, and trust as the critical factors influencing the success of cloud computing in hospitals. It [26] proposes a cloud computing success model; however, the model lacks accessibility, interoperability, integration, and energy efficiency. Another study [28] suggests that cloud-based applications provide reliable and timely information for users. Also, it suggested information quality, system quality, and service quality as critical quality-related factors that affect cloud success in hospitals. As per reference [34], challenges arise from inadequate health institutions, a shortage of professionals, and IT resources in remote villages. Accordingly, rural dwellers have to travel very long distances to get healthcare services. This study proposes a cloud-based healthcare system (CBHS) model as a suitable solution, but the targeted participants are not well addressed. It [34] also reveals factors influencing healthcare consumers' attitudes towards cloud-based healthcare adoption: performance expectancy, effort expectancy, social influence, facilitating conditions, data security, information sharing, and cloud-based/IT knowledge. Another study [4] demonstrates community-based cervical cancer screening using a cloud-based information system in rural and resource-poor communities. However, it is device-specific and lacks remote patient control and sharing of vital indicators among hospitals. The authors of [39] argue that building world-class infrastructure can mitigate inefficient healthcare in developing countries like Ethiopia. Accordingly, the collaborative cloud model enables flexible, cost-efficient task execution. Thus, [39] proposes a cloud federation for healthcare support using collaboration models, but it overlooks green features, security, and privacy. A research study [60] described aspects that will be affected by cloud computing: volume of traffic in the network, security, business model, and accessibility. A healthcare architecture using cloud computing is proposed; however, the application framework requires refinement by considering energy savings, collaboration, and accessibility. According to [40], privacy and legal issues are major challenges in cloud computing. Hence, the study [40] categorized cloud applications in healthcare; however, greenness and carbon footprint are typically ignored.

A research study [41] proposed a cloud-based health center (CBHC) system architecture that can aid remote care for people in rural and remote communities. However, the present security concerns, energy conservation, and carbon footprint issues are still missing. Another study [45] stated that pandemics such as COVID-19 cause hospital congestion and resource shortages, affecting patient care. Thus, [45] proposes a low-cost, reliable home hospitalization system. However, it lacks consideration for energy savings, carbon footprint, collaboration, accessibility, security, and privacy concerns. Also, [41] reveals factors influencing healthcare professionals' acceptance of cloud-based health centers: cloud knowledge, IT infrastructure, data security, and information sharing. Another study [52] identifies technical challenges such as lack of infrastructure, performance monitoring, data privacy, heterogeneity of formats, and data standards for ICT pillars (IoT, cloud computing, and big data) for Healthcare 4.0. Thus, [52] suggests healthcare 4.0 application scenarios (i.e., personalized healthcare and cloud-based health information systems). However, the study overlooks how to apply these ICT pillars in remote areas and in developing countries' healthcare sectors, like Ethiopia. A reference [24] also clearly pointed out that small hospitals face challenges with high-cost IT infrastructures.

D. Energy efficiency and cost-efficiency issues

A research study [54] stated that health information systems (HIS) are increasingly essential for healthcare providers. Accordingly, the use of cloud computing in healthcare is enhancing the intelligence, reliability, availability, fault tolerance, and scalability of healthcare systems. However, a study [54] reveals three primary factors affecting HIS implementation in the cloud: (1) financial performance and cost (unexpected cost, unmonitored on-demand usage), (2) IT operational excellence and DevOps (vendor lock, skills, and experience, complexity in design), and (3) security, governance, and compliance (sharing security vulnerabilities with the vendor). As a solution, a cloud computing adoption model for HIS has been designed; however, green, energy-efficient features and the latest security solutions are still missing. According to [54], IT contributes to over 2% of global carbon footprints. This study [54] identified key issues in green IT responsibilities, including high CO_2 emissions, secure sharing accessibility, and patients' control over their data. A green computing system architecture is proposed considering greenness, i.e., diminishing CO_2 emissions; however, it does not address energy-saving, collaboration, or present security solutions. Another study [22] disclosed several aspects of secure and energy-efficient resource utilization strategies using green cloud services: secure, energy-efficient, energy awareness, and carbon emission. Accordingly, green cloud computing aims to save energy and reduce carbon footprints, but a study [22] lacks a specific model or framework for energy efficiency and greenness as a contribution. Another study [31] claims that the increasing elderly population is posing a significant challenge to existing healthcare systems, leading to impaired human functionalities and diseases like heart problems, strokes, and respiratory disorders. As a result, the authors of [31] developed a cloud-based smart home environment (CoSHE). However, it didn't consider a unified integration of health data, collaboration, energy efficiency, data standardization, and sharing across hospitals. Also, it's unaffordable for individuals to install all the required components in their homes in developing countries like Ethiopia. Research studies [18], [20], [30] also indicate that the cloud offers scalability, broad accessibility, and dynamic provision of computing resources with minimal capital investments. Also, a study [20] states that cloud computing can be achieved by establishing distributed data centers that consume a significant volume of energy. Other studies [20], [29], [34] reveal that cloud computing in healthcare sectors has witnessed major development in recent years due to its remote access capabilities and attracting abundant attention. The study [27], also discusses the economic (low capital investment, lower maintenance costs, reduced IT labor costs, energy savings), operational (unlimited resources, enhanced collaboration, and improved security), and functional (wider variety of services, interoperability, and integration) benefits of cloud computing in healthcare organizations. However, the study lacks a suitable solution, overlooks efficiency evaluation and green IT concepts, and the sample size considered is too small to generalize the results.

E. Technology-Organization-Environment (TOE) factors

The authors of [46] argue that cloud computing is the most viable option given the ever-increasing customer requirements and willingness to get on-demand resources. On the other hand, the same study [46] examines factors influencing healthcare decision-makers before adopting cloud computing in healthcare, such as organizational size (hospital), external environment (government policy), technology (security, confidentiality, and integrity), economic (financing of IT in hospitals), social (perceived visibility), human-environment (patients' attitude towards cloud), and trust. However, technology is revealed as the most critical criterion. The reference [47] claims that cloud computing has emerged as a technological paradigm to foster collaboration. This study [60] reveals factors significantly affecting cloud adoption in public hospitals, i.e., (1) technological context (readiness, service quality, and expert scarcity); (2) organizational context (top management support, policy, firm size, and individual difference factors); and (3) behavioral context (perceived usefulness, perceived ease of use, trust, and social influence). The authors of [47] designed a Conceptual Framework that integrates Technology-Organization-Environment (TOE) model, Technology Acceptance Model (TAM), and Theory of Planned Behavior (TPB) model but neglects green, energy-efficiency, and accessibility aspects. A study [48] also reveals cloud adoption challenges in Technology-Organizational-Environment (TOE). A research study [57] categorizes drivers and barriers to cloud adoption into contextual, policy, organizational, and human factors. Accordingly, the identified drivers are categorized into contextual factors (nature of healthcare and technology readiness), policy factors (national policy frameworks that promote digitization of healthcare), and human factors (public trust and acceptance). Also, the identified barriers are categorized into contextual factors (healthcare status and technology readiness), organizational factors (cost of adoption and technical expertise), and policy factors (lack of data standardization, strict data storage requirements, data privacy, and weak cyber-security infrastructure). This study [57] suggests recommendations for policymakers who are willing to adopt cloud technology in the healthcare sector, but it overlooks other key aspects or parameters. Several research studies [18], [40], [62] have shown that most medical errors are due to poor access to patient information in healthcare organizations. The research studies [62], [63] also indicate the crucial importance of cloud computing in other organizations, such as small and medium-sized industries. Accordingly, cloud computing is the latest model for offering ready-to-consume cloud-based IT services for small and medium-scale enterprises (SMEs). Another study [64] highlights the importance of cloud storage services as a crucial component in cloud-enabled IoT infrastructure and a backbone for IoT networks. This enhances the storage services aspects of SME data and the scalable processing of big data on the cloud, enhancing efficiency, cost reduction, information availability, and quicker access.

Generally, this review paper identified essential features and research gaps that the reviewed research studies overlooked. The research gaps identified and enlisted are crucial for designing, developing, and deploying the next generation of healthcare data and information management systems over the cloud as an alternative in healthcare institutions (hospitals) in developing countries in general and Ethiopia in particular. Several recent research studies typically overlooked secure shareability, secure communication, secure collaboration, and energy efficiency, performance, and accessibility standards in their research contexts. The current systems are found to be inefficient, vulnerable, and susceptible to security and privacy violations due to their lack of energy efficiency and smartness. This paper provides a comprehensive report on the research gaps based on rigorous investigation and analysis of the current proposed solutions in healthcare. With improved security and privacy, quality of service (QoS) can be boosted with instant access to health data. The paper contributed to consolidating research gaps from numerous research investigations into a single paper.

The research studies [2], [3], [15], [4], [5], [16] revealed widespread issues associated with manual methods and systems used in healthcare for patients' data or information management. The paper-based method of health data handling and processing has limitations such as data sharing, accessibility, poor information quality, misfiling, environmental sustainability, security concerns, errors, delays, and hospital congestion. However, according to studies

[4], [5], [33], the proposed solutions didn't consider the control over data by patients themselves towards safety while accessing it with promised privacy.

Cloud computing offers significant features and benefits for healthcare services, enabling data exchange between disparate systems and revolutionizing traditional IT paradigms. Research studies [18], [24], [28]–[30], [20]–[22], [27] revealed those features and benefits in terms of virtualization, cost reduction, quick scalability, enhanced collaboration, unlimited resources, global access, pay-per-use, interoperability, minimize errors, automation, facilitate data sharing, enhance service quality, multi-tenancy, energy efficiency, reduce paper documents, etc. These features can be used for building smart and green healthcare services. However, based on the reviewed articles, the research gaps identified are security-related issues that need to be critically considered in healthcare data or information management. According to [59], smart healthcare systems are highly susceptible to security violations and several attacks. Security and privacy threats are hampering the exponential growth, adoption, and acceptance of cloud computing in healthcare. The majority of the reviewed articles, i.e., 54% (i.e., 28 papers out of 52 reviewed research articles), were focused on security and privacy concerns, as portrayed in *Fig. 5*. The health data domain is facing fears and threats due to potential vulnerabilities suspected to be exploited on cloud-based systems. Thus, all cloud users should be authenticated before accessing e-healthcare services over the cloud.

The majority of the studies reviewed in this paper did not provide up-to-date security solutions or energy efficiency/greenness in their proposed or designed solutions, as explained in Table 2. Again, studies [2], [3], [5], [31] revealed several issues with health data standardization. Many researchers [18], [40], [62] have disclosed that most medical errors are due to poor access to patient information. Numerous recent research studies [14], [18], [29], [30], [35]–[38], [42], [43], [21], [25], [49]–[51], [53], [55], [56], [58], [59] typically overlooked secure shareability, service collaboration, energy efficiency, and accessibility features in their study contexts. The research studies [36], [37], [40], [45], [47], [51], [63] didn't measure the performance of the proposed models. They also ignored important parameters such as energy consumption, data integration (consolidated health data storage), inter-institution accessibility, and carbon footprints. The studies [21], [22], [24], [27], [55], [62] didn't provide any specific solutions to mitigate the challenges listed in their studies. Cloud computing is widely utilized in the software industry, but its full potential in the healthcare sector has yet to be fully explored.

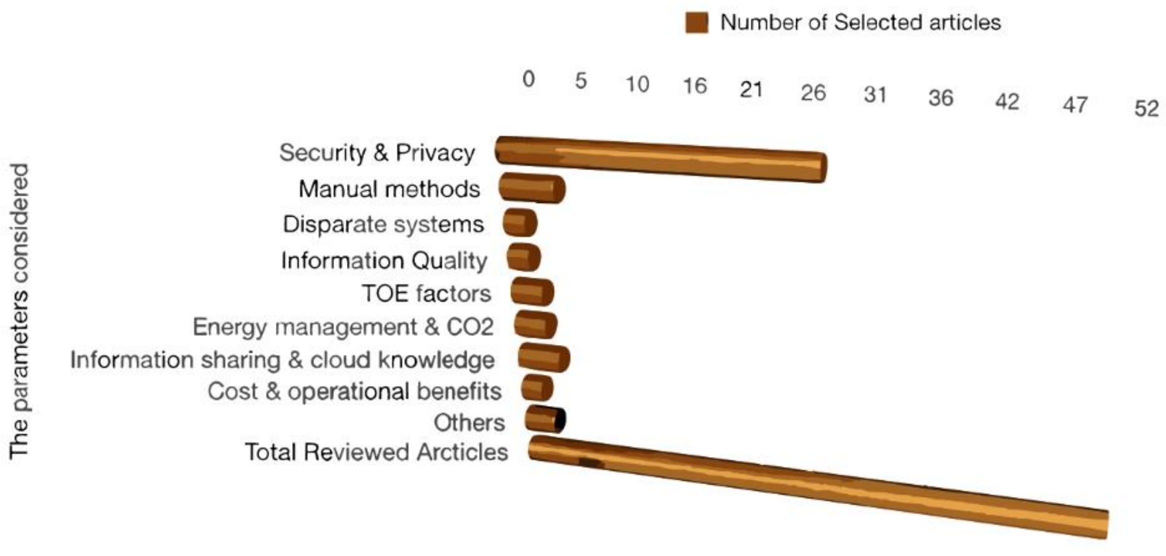

Fig. 5 Categorized parameters considered in the reviewed articles

Upon rigorous review, each reviewed research publication has a different study context and solution model, along with defects and deficiencies as synthesized in Table 2. However, the following statements are made upon further synthesis and integration of similar and related research gaps identified in Table 2 under the last column.

1) Security and privacy concerns

The fears and threats of sensitive data vulnerabilities in the cloud environment. However up-to-date security solutions are not provided in the present solutions. Most of the reviewed articles lack up-to-date security and privacy solutions. But up-to-date security and privacy solutions are provided by studies [14] and [51]. However, the schemes neglected greenness, energy savings, and carbon footprints (reducing greenhouse gases) in their solutions.

2) Health data standardization

Seamless accessibility of health data among health institutions is not well structured, legalized, and facilitated by technology-enabled solutions.

3) Shareability

Health data sharing across multiple health institutions (hospitals) still needs to be identified, structured, and facilitated over technology-based platforms such as the cloud.

4) Collaboration

Collaboration among hospitals, patients, doctors, and allied health professionals is still not fully studied and explored for modernized technology-enabled solutions.

5) Self-health data access control

Patients have the right to control and access their health data anytime, anywhere, over any digital device, but in the current state-of-the-art solutions available in developing countries and hospitals such as Ethiopia, it is almost missing or unavailable.

6) Consolidated health data repository

Different health data formats that are not easily accessible or processable in different hospitals (i.e., interoperability issues) need to be redesigned for enhanced processing and revealing hidden insights as new knowledge for decision-making.

7) Energy efficiency

The issues of energy savings and power consumption are the major issues and concerns overlooked in most of the reviewed studies. Greenness issues in healthcare data solutions need to be critically investigated and analyzed for developing the next generation of energy-efficient and green healthcare data and information systems over modern technologies such as the cloud.

8) Greenness

Reduce greenhouse gas emissions. The IT solutions need to be investigated and analyzed for their greenness and certifications.

9) Carbon footprints

Reduce unnecessary carbon emissions and congestion in hospitals. In current practices, a patient has to visit the hospital(s) to get different reports in person, which can cause carbon emissions from a means of transportation. Such redundancy in data repositories is a critical problem and needs to be studied to minimize redundancies in future solutions.

10) Performance evaluation

The performance of existing systems and proposed models should be evaluated, and their real differences must be identified. The performance of the existing system solutions needs to be investigated in light of modern technologies such as the cloud.

Table 5 provides a detailed extraction and comparison of the findings and insights categorization in the context of the relevant work in the reviewed articles and the excavated gaps.

F. Strong and weak aspects of the paper:

The paper raised research questions that clearly defined the points to be investigated and the intent of the study. The study clearly set out the method, search strategy, and article selection procedures that were used to make sure that all the relevant and contemporary research articles were considered. The PRISMA flow diagram is used to clearly show the articles' selection procedures (i.e., based on the predefined eligibility criteria). The reviewed articles are from well-known databases and include various studies, including reviews, surveys, and original articles, based on inclusion and exclusion criteria. The paper summarized the challenges encountered, proposed cloud-based solutions, and identified research gaps in each of the reviewed articles. These gaps are consolidated into a single paper that can help researchers easily find the gaps and develop innovative and novel solutions. The paper contributed to scientific society by revealing gaps in technical and applied domains, such as cloud knowledge and healthcare.

Potentially less-defined quality evaluation and synthesis may cause partiality due to the limited number of articles (i.e., only 52 articles) included in this study. The paper lacks the inclusion of model or framework figures for reviewed articles due to the number of figures (i.e., lots of figures in each reviewed paper). Also, articles that are oversimplified may risk varying or omitting the essential concepts of the articles' conclusions. These might be considered the weaknesses of the paper. As a limitation, the selection procedure may lead to bias since there are millions of publications indexed in different databases but only a few articles are studied in this review paper, i.e., a selection bias. Also, there is the heterogeneity of challenges/problems encountered in each article reviewed and the proposed solution models or architecture.

TABLE 5
CATEGORIZATION AND COMPARISON OF THE PARAMETERS CONSIDERED IN THE REVIEWED ARTICLES AND THE IDENTIFIED GAPS

Parameters considered in the reviewed articles	References	No. of articles	In %	The identified research gaps compared to the parameters in the reviewed articles
Security and privacy issues	[14][24] [29][18][34][35][37] [38][41][42][43][44][48][49] [51][52][53][21][55][56][25] [58][59][60][61][62][50][63]	28	54%	Security & privacy concerns
Manual methods	[2][3][5][33][15]	5	9.6%	Health data repository standardization, sharing, and ownership access control
Disparate systems	[32][30]	2	3.8%	Interoperability issues, data access control, consolidated, health data repository
Information quality	[28][26]	2	3.8%	Accessibility, availability, energy saving, and green
TOE factors	[46][47][57]	3	5.8%	Service collaboration, security, data share-ability
Energy management & CO2	[20][16][22]	3	5.8%	Energy efficiency, carbon emission
Information sharing and Cloud knowledge	[39][40][41][45]	4	7.7%	service collaborations, Share-ability, IT infrastructure, data security
Cost and operational benefits	[54][27]	2	3.8%	Affordability (cost efficiency), up-to-date security solution, reliability, availability
Cervical cancer screening	[4]	1	1.9%	Own data access control, Energy efficiency, security & privacy issues
Human functionality likely impaired at an older age	[31]	1	1.9%	Health data Integration/ consolidation, and energy efficiency
Storage aspects & efficiency	[65]	1	1.9%	On-demand accessibility, scalability (upscale/downscale), and Big Data Analytics

VI. CONCLUSIONS

Numerous features and benefits trigger the positive intervention of cloud computing in the world's healthcare services. The crucial aspect of healthcare data or information is to migrate or redesign the existing systems with more modern technology-based ones, such as cloud-based systems. The several studies reviewed in this paper revealed various challenges in the cloud environment. However, it is still a promising and robust technology platform that can help transform existing health data or information systems into next-generation green, secured, and interoperable systems with add-on features. In this paper, extensive efforts have been made to rigorously review recent, contemporary, and relevant research articles from reputed sources to excavate research gaps related to smart, green, and interoperable features in cloud-based healthcare data or information management systems. The paper consolidated the parameters, proposed solutions from reviewed articles, and identified research gaps from several research studies into a single study. The paper took significant steps to search, screen out, and rigorously review 52 selected articles related to cloud computing in healthcare. As a result of the review, the research gaps identified are security and privacy, data standardization, data shareability across multiple hospitals, patient-centric data access control, inter-hospital collaboration, energy efficiency/greenness, a consolidated health data repository for interoperability, carbon footprint, and performance evaluation. Thus, these research gaps are compiled in a single paper with comprehensive parametric analysis that can be used to develop unique solutions by researchers to improve healthcare services without searching, reading, and reviewing numerous research studies scattered over the salient sources. In the future, the authors are interested in designing and demonstrating the latest cloud computing solutions for improved healthcare services, incorporating smart and green features.

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