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An In-Depth Analysis of Cloud Computing in Health Information Systems: Evaluating Opportunities, Risks, And Strategic Frameworks

[1]- Khaled Mohammed Ibrahim Thubab,[2]- Rami Mohammad Alkhleitit,[3]- Ashwag Owaib Alenezi ,[4]-Bashayr Fahad Baaljahr,[5]-Abdulsamad Hamdan Turi ,[6]-Muneerah Ali Saeid Al-Thobiti,[7]- Salhah Yahya Alneami,[8]-Adel Mohammed Hakami,[9]- Annah Ahmed Abdo Awaji,[10]- Rawan Ahmed Nasser Adawi,[11]- Mohammad Hamad Alawad,[12]-Saleh Rasheed Alwatban,[13]- Yazeed Mohammad Alanazi ,[14]-Abtsam Mohammed Alnema,[15]-Mobarak Fahad Mobarak Aldossari

[1] Ksa, Ministry Of Health, Abu Arish General Hospital
[2] Ksa, Ministry Of Health, King Fahad Medical City
[3] Ksa, Ministry Of Health, Khalidiya Health Center
[4] Ksa, Ministry Of Health, Jeddah Second Health Custer
[5] Ksa, Ministry Of Health, Muhayil General Hospital
[6] Ksa, Ministry Of Health, King Khalid Hospital In Majmaah
[7] Ksa, Ministry Of Health, King Saud Medical City
[8] Jazan University Hospital , Jazan University
[9] Ksa, Ministry Of Health, Western Sector Health Centers Management
[10] Ksa, Ministry Of Health, Western Sector Health Centers Management
[11] Ksa, Ministry Of Health, King Faisal General Hospital Al-Ahsa Health Cluster
[12] Ksa, Ministry Of Health, Privatization Affairs Office
[13] King Abdullah University Hospital
[14] Ksa, Ministry Of Health, Madinah Health Cluster
[15] Ksa, Ministry Of Health, Wadi Aldawaser General Hospital

Abstract

Background: The integration of cloud computing into Health Information Systems (HIS) represents a transformative shift in healthcare technology, offering both significant opportunities and inherent risks. As healthcare organizations increasingly seek efficient, scalable solutions to manage vast amounts of patient data, the potential benefits of cloud computing, such as cost reduction and enhanced operational agility, become paramount.

Methods: This study employs a mixed-methods approach, combining a systematic literature review with qualitative interviews from healthcare informatics experts, to identify key factors influencing the adoption of cloud-based HIS.

Results: Our findings reveal three primary dimensions critical to the successful implementation of cloud computing in healthcare: financial performance and cost considerations, operational excellence through IT and DevOps practices, and security, governance, and compliance challenges. Each dimension presents unique motivators and obstacles that healthcare leaders must navigate to leverage cloud technologies effectively. The results indicate that while cloud computing can facilitate real-time data processing and improve decision-making, security concerns and regulatory compliance remain significant barriers to widespread adoption. The study proposes a strategic framework that healthcare executives can utilize to assess their organization's readiness for cloud adoption and to devise actionable strategies for overcoming identified hurdles.

Conclusion: In conclusion, this research underscores the necessity for healthcare organizations to adopt a proactive approach in addressing the complexities associated with cloud computing in HIS. By fostering collaboration between IT and clinical stakeholders, organizations can enhance operational efficiency and patient care outcomes, ultimately driving the future of health information management.

Keywords: Cloud computing, Health Information Systems, operational excellence, security compliance, healthcare technology.

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1. Introduction

Information systems (IS) represent the intersection of information technology and business. An information system is described as a collection of linked components that gather, process, store, and disseminate information [1]. A Health Information System (HIS) is an information system designed for the healthcare industry. Such systems use Health Information Technologies (HIT) and its components to generate Electronic Health Records (EHR) as the principal information product. HIS is an essential business system for every healthcare firm, complementing other information systems that provide financial and operational features. An HIS may substantially improve the operations and performance of healthcare organizations by decreasing costs and enhancing results [2]. Health Information Systems (HIS) are deemed essential to healthcare companies worldwide due to their many advantages.

The data included in the HIS is used to facilitate decision-making and improve organizational controls. Business intelligence (BI) and Clinical Decision Support Systems (Clinical DSS) use information held in Health Information Systems (HIS) to enhance both business and medical decision-making, hence improving organizational operations and performance [3]. Patient data in healthcare exemplifies the three qualities of big data: volume, diversity, and velocity. Artificial intelligence (AI) and machine learning (ML) models may be used on this patient data to improve decision-making and facilitate expedited diagnoses and pattern recognition. The insights derived from this study may substantially improve the quality of healthcare [4-7].

Due to the essential function of Information Systems (IS), several techniques and paradigms have been proposed to enhance its agility, efficiency, and availability. Cloud computing is one of the prevalent concepts. Agility in the present environment is essential for information systems to adapt to the ever-evolving business demands. Technological and environmental shifts (e.g., legal frameworks, pandemics) need rapid adaptations in information systems, since the majority of essential corporate processes depend on them. His face encounters same issues with IS agility as well [8]. Cloud computing enhances information systems agility while also offering cost reduction and access to on-demand, cutting-edge, high-performance, and highly accessible infrastructure, platforms, and applications. Cloud computing offers tools and functionalities to enable Continuous Integration (CI) and Continuous Delivery (CD), hence supporting the introduction of DevOps in a company. DevOps is an established approach that improves the agility of Health Information Systems (HIS) and Information Systems (IS) by enabling the rapid and incremental deployment of new and upgraded functionality. These technologies and ideas may facilitate the maintenance and upgrading of HIS. These also provide HIS with a competitive edge by enabling a swifter market introduction of new features and functionalities. HIS must be enhanced to provide greater scalability, high availability, and fault tolerance. All these advantages may once again be derived from the use of cloud computing. Nonetheless, cloud computing has its own issues. These include expenses, operations, security, and a multifaceted and rather novel business strategy, among others [9].

This research examines both scholarly and notable practitioner publications in the domain of cloud computing and Health Information Systems (HIS). It also leverages the knowledge of an author with over six years of experience in technology and consulting in this domain, together with interviews with specialists in healthcare informatics and cloud computing. Three key variables influencing the adoption of Health Information Systems in the cloud have been identified based on the review, author expertise, and interviews.

The identification of variables influencing the adoption of cloud computing technologies in the development of Health Information Systems has been inadequately addressed in academic literature, resulting in a scarcity of research characterized by systematic analysis and rigor [10]. This study seeks to address such shortcomings via its suggested research approach. It offers a framework for examining the principal drivers and obstacles in the specified dimensions and introduces a model. The suggested model has face validity, content validity, and nomological validity, and may be validated by empirical study. The model and subsequent research may enhance comprehension of the issues and potential solutions regarding the use of cloud computing within the healthcare industry, particularly concerning Health Information Systems (HIS).

This study's findings are directed at the executive management of health organizations, particularly senior clinical roles such as CTOs, CIOs, and IT managers, enabling them to make educated decisions on cloud computing adoption. The research elucidates how the functionality of HIS may be augmented using cloud computing. The study also examines enhancements in operational excellence and financial performance of healthcare organizations via cloud computing technologies that address the constraints of existing legacy information systems. This study will assist future researchers and adopters by providing a comprehensive analysis of the factors and obstacles relevant to the adoption of cloud computing technologies for Health Information Systems, hence facilitating managerial decision-making.

2. Comprehensive Examination of Health Information Systems

Yusof et al. [11] describe a Health Information System (HIS) as an information system used in healthcare environments, including interrelated and interdependent components. The primary tasks of a Health Information System (HIS) are to collect, process, store, and disseminate information pertaining to healthcare providers and their stakeholders, thereby enhancing the efficiency and efficacy of healthcare delivery. HIS comprises people, processes, technology, and their interrelations [12,13]. HIS may alternatively be characterized as a socio-technical subsystem inside hospitals, including information processing systems and personnel or technical staff responsible for processing, hence facilitating hospital operations [14].

The 1960s saw the emergence of computerized systems aimed toward healthcare [15]. The objective of these systems was to automate some operational and administrative duties and oversee staff and patient finances. The advancement in medical and Medicaid sciences, together with the implementation of evidence-based care, resulted in heightened emphasis on medical records [15,16]. The technological advancements in information technology and systems throughout the 1970s resulted in the inception of electronic health records (EHR). Nguyen et al. [17] describe the Electronic Health Record (EHR) as the comprehensive digital documentation of all health-related occurrences of a person throughout their lifetime, including, but not limited to, medication history, allergies, hospital admissions, and outpatient clinic visits. The International Organization for Standardization (ISO) defines an Electronic Health Record (EHR) as a store of information about the health condition of a patient, formatted for computer processing [18]. Consequently, decision support functionalities were included into the Health Information System to enhance diagnosis and treatment. HIS has also profited from the broader use of information technology and advancements in communication and computer networks. The proliferation of internet access via various data networks has resulted in the emergence of several centralized and decentralized systems that enable information exchange and dissemination across diverse entities. These systems are referred to as Health Information Exchange (HIE) [19].

A Health Information Exchange (HIE) is an organization, either regional or nationwide, that enables the electronic exchange of healthcare data among clinicians, facilities, health information organizations, government entities, and patients [20-22]. Health Information Exchanges (HIE) enable healthcare institutions to access and securely communicate a patient's medical information electronically before, during, and after a healthcare incident. HIS plays a crucial role in the dissemination of EHR via HIE [23]. Nonetheless, several interoperability issues persist in the exchange of EHR, necessitating resolution via standardization across multiple levels of technology, data, human factors, and institutions [24]. Despite the absence of interoperability issues, Health Information Exchanges (HIEs) indicate that Electronic Health System (EHS) manufacturers and healthcare institutions participate in information blocking. Cloud-based Health Information Systems may mitigate some technological issues associated with exchanging Electronic Health Record data via Health Information Exchanges; nonetheless, the concept of consolidating personal health information into a singular repository raises significant security and privacy apprehensions among patients, as well as worries over control and ultimate use from clinicians [25,26]. Presently, the proliferation of cloud services and providers has led to the emergence of ideas such as e-health and Personal Electronic Health Records (pEHR) to enhance patient empowerment [16,20,27,28].

Owing to advancements in information technology and medical sciences, contemporary health information systems have evolved to be more intricate and proficient and are anticipated to execute the following functions: clinical information management pertains to patient data, including electronic health records (EHR), information derived from internal submodules, and interaction with external third-party systems. These sources may originate from labs, radiology, inpatient settings, outpatient facilities, emergency departments, or pharmacies. Clinical decision support, knowledge bases, and order communication systems are also included in this area. Operational management encompasses all non-clinical responsibilities, including financial operations such as invoicing and payroll, as well as human resources tasks, which include roster and shift management. Operational management include procurement, supply chain management, maintenance, and engineering. Strategic decision support that aids senior management in strategic planning and enhances organizational control. This may include enhanced marketing data, market trends, and rival conduct.

Electronic networking encompasses all interfaces that facilitate the transmission of health information across networks. Examples include web-based telemedicine, e-health, and personal electronic health records (pEHR), which enable people to exert more control and authority over their health profiles electronically, independent of the physical locations of healthcare institutions. Furthermore, network integration with external systems and their stakeholders may be classified under this category.

Gaardboe et al. [5] assert that healthcare firms with information systems have superior profit margins compared to those without, attributable to enhanced operational performance. Kros et al. [29] and Kwon et al. [30] emphasized the significance of information systems in healthcare supply chain management. Kwon et al. [30] discovered that information system-enabled supply chain management positively impacts efficiency by decreasing per-patient costs. The research contends that supply chain management systems in healthcare improve patient care by emphasizing supplier relationship management, logistical operational tools, and process enhancement.

3. Cloud Computing

Emerging technologies such as virtualization, grid computing, and software-defined data centers, including storage and networking, have attained mainstream status and precipitated a paradigm change in the IT sector. Virtualization allows computer hardware to run several operating systems and applications concurrently by abstracting the underlying hardware from the applications and mimicking the required hardware. Grid computing is the allocation of processing tasks across numerous computer systems to attain sufficient computational capacity for task execution [28]. These technologies, among others, have given rise to the notion of cloud computing [1,15,31,32]. Cloud computing is a service model that offers on-demand access to resources supplied by a distant vendor, often over the Internet; however, some businesses may lease a link to the closest provider facility for performance optimization. Cloud service providers often provide shared pools or virtualized resources. These materials may be classified into three categories, according on their characteristics. Infrastructure as a Service (IaaS) offers infrastructure resources; Software as a Service (SaaS) delivers software as the resource; and Platform as a Service (PaaS) encompasses a complete platform as the hosted resource [28,33].

Cloud computing may significantly enhance healthcare services and influence other areas innovatively. Marston et al. [8] propose that cloud computing emerges from two key developments in information technology. Primarily, cloud computing offers enhanced efficiency [34]. Cloud companies often deliver highly available and scalable solutions. Healthcare firms might use these capabilities to diminish the capital expenditure linked to an on-premises datacenter deployment [35]. Data centers for healthcare businesses are costly due to the critical nature of their services and the need for the data center to facilitate this goal. To do this, ensuring high availability and zero downtime of services is essential. Ensuring high availability and zero downtime presents intricate technological challenges that need substantial resources, making it a costly endeavor.

In a non-cloud environment, firms often implement numerous tiers of redundancy, along with high availability and disaster recovery measures. This may include several data centers or co-located equipment in third-party data centers to ensure service availability and adherence to regulatory legislation and national or international standards [34,36,37]. This necessitates significant financial investment. Recently founded companies may capitalize on cost advantages by transitioning to the cloud, therefore reallocating those savings towards investments in essential medical operations, such as medical staff. Established enterprises may transition to the cloud incrementally when their existing equipment reaches full depreciation. The hybrid cloud architecture enables the integration of existing datacenters with the cloud for purposes of growth and disaster recovery [38]. The use of cloud computing reduces operating expenses by removing expenditures associated with data center operations, such as energy and cooling. It also decreases the expenses associated with technical and IT workers required to administer and run the infrastructure [8]. The on-demand characteristic of cloud computing services exemplifies the efficiency it offers in information technology. Cloud services enable enterprises to get infrastructure and services as required—on demand. As demand for the system escalates, supplementary infrastructure resources are automatically provisioned and deployed, then terminating as demand diminishes. This adaptive resource allocation lowers the operating and fixed expenses of the IT infrastructure for healthcare institutions.

Secondly, cloud computing, as previously said, also offers information systems and business agility. Execution agility is the defining characteristic of cloud services. Cloud services provide enterprises capabilities and functionalities to enhance company operations. The high availability and disaster recovery capabilities of cloud services are essential for healthcare and facilitate rapid recovery. Service providers may also provide prebuilt, production-ready technologies and platforms that enhance the organization's application development pace. These may be integrated with current systems via a well-documented Application Programming Interface (API) and provider assistance. For instance, products such as Tableau provide a cloud-based Business Intelligence (BI) platform. If an enterprise requires substantial processing power for AI, ML, and Business Intelligence (BI) that surpasses its infrastructure capability, cloud services provide parallel computing and big data solutions.

Numerous instances of cloud computing applications exist within the healthcare sector, outside Health Information Systems (HIS). Healthcare firms may use Microsoft Office 365 and Google GSuite [39]. Microsoft and Google provide several PaaS and SaaS solutions to their clients. Amazon Web Services, Microsoft, and others provide Infrastructure as a Service (IaaS) for software-defined data centers. Koutsouris et al. [2] examined the use of cloud computing for personal Electronic Health Records (pEHR). The mobile cloud computing-based stroke healthcare system exemplifies a cloud computing system used for the identification of stroke patients with cardioembolic and cryptogenic subtypes using mobile applications [40]. Numerous instances of cloud-based healthcare system installation exist throughout several nations in the Americas, Europe, and Asia [16,28,35].

4. Conclusions and Prospective Research

The study indicates that the healthcare sector has enhanced the local integration of its Health Information Systems (HIS). Nonetheless, several HIS concerns have to be resolved. The IT infrastructure and the Health Information System exist, although the effective application of the system for enhanced patient care management is questionable. Dissatisfaction exists with the present patient records systems, particularly concerning the interface, data entry duration, and other factors. Cloud-based Health Information Systems may mitigate some of the previously identified challenges. Additional advantages may include restructured financial performance and cost protocols to provide enhanced real-time processing.

Users, managers, and workers may be uninformed and more doubtful about the value-added potential of the cloud-based Health Information System owing to privacy and security apprehensions, as well as worries connected to diminished control. Effective communication is essential, requiring a coordinated effort between DevOps and senior management to inform and educate end-users about the value-added potential of the cloud-based Health Information System (HIS). DevOps may exemplify improved IT operational excellence by facilitating the frequent introduction of new functionalities. In conjunction with this communication, it is critical to provide supplementary training to managers, physicians, and staff on the cloud based HIS to leverage its novel features and advantages.

The proposed model is founded on thorough research and has face validity, content validity, and nomological validity. The model serves as a resource for managers and decision-makers to inform their cloud-computing adoption choices for Health Information Systems (HIS). Each parameter presented may be rigorously assessed prior to the adoption decision. Each problem and driver may be formulated into a multi-item scale to provide a more thorough assessment. The HIS domain presents distinct issues because to the sensitive nature of the information contained and its mission-critical significance. The crucial nature of this task is a significant factor, since it may result in loss of life in some instances. The cloud computing concept is well shown by service providers such as Netflix, which use it extensively to supply its services. The current surge in cloud computing use across several businesses is propelled by the economical, operational, and security advantages these services provide. The healthcare industry should also benefit, but necessary legislation and facilitations must be established to modernize the adoption of Health Information Systems in a trustworthy and secure manner. It is imperative that HIS adopts a cloud computing paradigm, which may be facilitated by more research on the subjects delineated in this study.

Additional trends and advancements may facilitate the expedited adoption of cloud computing for Health Information Systems (HIS). Security, as previously said, is a critical factor for the EHR repository. Blockchain technology and smart contracts may provide a resolution. Blockchain technology solutions have been used to resolve several challenges, including security, data privacy, authentication, interoperability, inaccessibility, and the management of stored patient or provider data across multiple sectors of healthcare applications [40]. Numerous problems in the use of blockchain continue to endure. These include block sizes and block propagation, scalability, query latency, and performance, among others. Numerous designs and frameworks for blockchain-based electronic health records (EHR) have been presented; nonetheless, their implementations in mainstream health information systems (HIS) used by healthcare organizations have been very constrained [41-43]. A variety of solutions have been suggested to address the issues presented by blockchain technology [44-46]. Moreover, the solutions and frameworks include the use of blockchain inside Health Information Systems (HIS), which will be enhanced by cloud computing, since blockchain, being a distributed computing technology, is more effectively deployed utilizing cloud technologies.

A further trend anticipated to propel the usage of cloud computing for Health Information Systems (HIS) is the utilization of wearables and Internet of Things (IoT) sensors and devices. IoT sensors, gadgets, and wearables provide remote patient monitoring, which may be integrated with video and/or in-person care for diverse interventions and care outcomes [47]. The wearables and IoT sensors provide data at consistent intervals, necessitating real-time storage and analysis to identify abnormalities that may demand prompt intervention. The aggregated data from all patients exhibits all the characteristics of big data as previously mentioned. The storage, processing, and analysis of big data need resources that may be effectively supplied by cloud computing. The incorporation of wearables, IoT devices, and sensors into Health Information Systems (HIS) will be enhanced by the use of cloud computing for HIS. Several frameworks for integrating wearables and IoT devices have been suggested; however, as previously noted, legislative frameworks addressing security, privacy, and proper use must be established prior to such integration.

The model introduced in this study is intended for evaluation in Palestine by one of the authors, and subsequent to this assessment, the model may be enhanced and examined in the United States and India. Results are anticipated to be comparable in the US and Palestine; however, this may not apply to India, which has a robust supply of IT professionals and is a major provider of infrastructure management expertise. It is anticipated that other scholars would use this model in other nations and may enhance and adapt it depending on their own observations. Models evaluated in various nations may be compared and contrasted. Due to varying economic and political conditions among nations, the outcomes may fluctuate significantly and provide additional valuable information.

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تحليل معمق للحوسبة السحابية في أنظمة المعلومات الصحية: تقييم الفرص، المخاطر، والأطر الاستراتيجية

الملخص

الخلفية :يمثل دمج الحوسبة السحابية في أنظمة المعلومات الصحية تحولًا جذريًا في تكنولوجيا الرعاية الصحية، حيث يوفر فرصًا كبيرة إلى جانب مخاطر كامنة. مع سعي المؤسسات الصحية بشكل متزايد إلى حلول فعالة وقابلة للتطوير لإدارة الكميات الهائلة من بيانات المرضى، تبرز الفوائد المحتملة للحوسبة السحابية، مثل تقليل التكاليف وتعزيز المرونة التشغيلية.

الطرق :استخدمت هذه الدراسة نهجًا مختلطًا يجمع بين مراجعة منهجية للأدبيات ومقابلات نوعية مع خبراء في معلوماتية الرعاية الصحية لتحديد العوامل الرئيسية التي تؤثر على تبني أنظمة المعلومات الصحية القائمة على السحابة.

النتائج :كشفت النتائج عن ثلاثة أبعاد رئيسية حاسمة لتنفيذ الحوسبة السحابية بنجاح في مجال الرعاية الصحية: الأداء المالي واعتبارات التكلفة، التميز التشغيلي من خلال ممارسات تكنولوجيا المعلومات وDevOps، والتحديات المتعلقة بالأمان والحوكمة والامتثال. يقدم كل بُعد محفزات ومعوقات فريدة يجب على قادة الرعاية الصحية التعامل معها بفعالية للاستفادة من تقنيات السحابة. تشير النتائج إلى أنه على الرغم من أن الحوسبة السحابية يمكن أن تسهل معالجة البيانات في الوقت الفعلي وتحسن اتخاذ القرار، إلا أن مخاوف الأمان والامتثال التنظيمي لا تزال تشكل عوائق كبيرة أمام اعتمادها على نطاق واسع. تقترح الدراسة إطارًا استراتيجيًا يمكن لقادة الرعاية الصحية استخدامه لتقييم جاهزية مؤسساتهم لتبني السحابة ووضع استراتيجيات قابلة للتنفيذ للتغلب على العقبات المحددة.

الخلاصة :تشدد هذه الدراسة على ضرورة اتباع المؤسسات الصحية نهجًا استباقيًا لمعالجة التعقيدات المرتبطة بالحوسبة السحابية في أنظمة المعلومات الصحية. من خلال تعزيز التعاون بين تكنولوجيا المعلومات وأصحاب المصلحة في المجال الطبي، يمكن للمؤسسات تحسين الكفاءة التشغيلية ونتائج رعاية المرضى، مما يدفع مستقبل إدارة المعلومات الصحية نحو الأفضل.

الكلمات المفتاحية :الحوسبة السحابية، أنظمة المعلومات الصحية، التميز التشغيلي، الامتثال الأمني، تكنولوجيا الرعاية الصحية.