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Lack of Interoperable Health Information Systems in Developing Countries: An Impact Analysis

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Abstract. Progress of health information system (HIS) in recent years has made significant impact on both developed and developing countries. HIS has played a very important role in the hospital. Construction and employment of HIS can improve the efficiency and quality of healthcare work. But the development of HIS has some problems inherent in them such as non-standard hospital management, poor standardization, and lack of interoperable software development. As a result, HIS run is not able to share medical information and therefore, can't meet the needs of reform in healthcare system delivery. In the future, for the sake of medical information sharing, teleconsulation, hospital efficiency enhancement, all the independent systems will realize interoperability. This paper however, seeks to analyze and address factors militating against interoperability in software systems the healthcare domain and recommends the adoption of service oriented architecture (SOA) within the domain.

Keywords. hospital information system; standardization; digital hospital; information sharing; service oriented architecture

1. Introduction

In developing countries, preventable diseases and premature deaths still inflict a high toll. Inequity of access to basic health services affects distinct regions, communities, and social groups. Under-financing of the health sector in most countries has led to quantitative and qualitative deficiencies in service delivery and to growing gaps in facility and equipment upkeep. Inefficient allocation of scarce resources and lack of coordination among key stakeholders have made duplication of efforts, overlapping responsibilities, and resource wastage common and troublesome problems. Compounding this is the limited knowledge available in deploying applications, thereby leading to a steeper learning curve.

Most countries are at some stage of health sector reform, trying to provide expanded and equitable access to quality services while reducing or at least controlling the rising cost of healthcare. Health reform processes have many facets and there is no single model being adopted by all countries.[21] ICTs have the potential to make a major contribution to improving access and quality of services while containing costs. Improving health involves improving public health and medical programs designed to provide elective, emergency, and long-term clinical care; educating people; improving

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nutrition and hygiene; and providing more sanitary living conditions. These in turn ultimately involve massive social and economic changes, as many health challenges go well beyond the health sector.

If developing countries must strive to provide speedy and efficient healthcare delivery services to her citizens, then computer based health information systems are required to achieve this dream. Unfortunately software systems built for the healthcare domain do not possess the ability to talk to each other or exchange information meaningful with other software products within the domain. A significant barrier, therefore, to the introduction of EHRs is the lack of interoperability; most EHRs do not interact well with other applications.[13]

The result is that for many physicians, even if they have begun using an EHR, the data is fed to an EHR application that is not designed to "speak" to a hospital, laboratory or other external group. The technology in most doctors' offices cannot send or receive clinical information, such as the laboratory and radiology results and medication lists critical to patient care.[2] In a nutshell, nearly all of the EHR systems in use today are little more than database management programs that help generate patient data entry (forms) and produce reports. And none of these applications have the capacity to scale up to fully, multi-functional prototypes or to be commercially viable in terms of complete interoperability in a large-scale distributed environment. Newer socio-technical approaches to design, for example, a distributed systems approach such as a service-oriented architecture (SOA) combined with Web services are needed to produce viable EHRs. Standardized interfaces and use of middleware enable loosely coupled interoperability amongst the various participants and components, thereby eliminating the constraints of disparate vendor-driven systems. Given that SOA is an overarching architecture[22]; it embraces open standards with which vendors of components comply.

In this exploratory research, we discuss applying the SOA approach to developing distributed, interoperable EHR systems. The rest of the paper is organized as follows. First, we identify the design issues in EHRs, focusing primarily on interoperability. Second, we examine the potential of the SOA framework in modeling and implementing interoperable EHRs. Third, we describe a prototype model for a health clinic setting based on the SOA framework. Fourth, we discuss the challenges in implementing SOA-based EHRs. Finally, we offer our conclusions.

1.1. Main Problems in Health Information Systems

There has been a tremendous progress in HIS during the last two decades, especially during the last 10 years, yet there have many problems which limit the further progress. The main problems are as follows:

a. Degree of Hospital Standardization is Poor: Hospital information relate to medical treatment, education, medical research, personnel, money, and substance. Unification of the title, the concept, the classification and the codes are the basic precondition for information interchange. But the most difficulty is that the standards are not unified. For example, the titles and codes of the case reports, drugs, personnel, equipments, inspection and examination differ in different hospitals. The definition, description and practice operation for the same thing are different. Without unified and authoritative hospital

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standardization data dictionaries, it will be difficult for software systems within the healthcare domain to interoperate.

b. Software Systems Developments Lack Unified Layout: HIS developments began to boost up since the early 1990. All level of health administrations, hospitals and some information development companies invested huge personnel and money into HIS development. In developed regions, the HIS achieved success and have larger scale, yet without standards to comply with and without surveillance by some related administrations thereby leading to a non-normative HIS development process. Furthermore, HIS development companies were in different levels, and many of them didn't specialize in HIS development, they were not familiar with the style of hospital management and workflows, or they only knew some specific hospitals. Again, some companies have the idea of eager for quick success and instant benefit, and only considered the current benefits without long term investment. Some companies even thought that HIS market had potential, so they made some simple system packages together, and took some measures to deceive the users. All above brought severe bad influence to HIS development.[33]
c. Models of Hospitals Management are Non-normative: It seems that models of hospitals management have nothing to do with the HIS. In fact, they have many influences on HIS construction. HIS implementation requires technical, structural and behavioral sense, and development of HIS should be carried out within the context of the development itself.[1] Application with HIS without studying and absorbing has become one bottleneck for HIS development. To meet the need of the hospitals management, the developers have to act according to actual circumstance. Good HIS should optimum hospital processes and decision making.

1.2. Interoperability in Healthcare

It is critical to recognize the complexity of the processes that surround healthcare when aiming towards interoperability of healthcare information, in which various categories of players are directly or indirectly involved as enumerated below:

a. Healthcare Companies: This includes vendors of clinical systems, administrative IT systems, and medical devices e.g. imaging, ultrasound, laboratory, etc. This category usually involves large multinational companies with global objectives, to companies of small and medium size, focusing on a market in a small geographic area, or narrow scope.
b. Healthcare Providers: This category includes health professionals, belonging to a variety of professions e.g. physicians, nurses, technicians, etc. Unfortunately, very few have all the necessary and appropriate skills in computer science and technology; or the necessary time to dedicate resources to tackle interoperability problems or participate actively in standardization of health informatics and standards.
c. IT and Administrative Staff: They both play key roles in large healthcare providing institutions, but are often absent in small healthcare facilities. In addition, very few are active in standards, development, organizations or technology integration.

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d. Health Authorities and Governments: This is the related bodies that supervise or manage the health system at the national level. With evolving technologies and standards, usually, governments and authorities enforce interoperability through national standards, and in most cases this has proven to be effective.[10]

Figure 1 depicts the major actors and functionalities that must be taken into cognizance when designing interoperable software systems in the healthcare domain. This is because an SOA-based approach in healthcare domain must support different interoperability needs, several degrees of integration, various messaging patterns, and different phases of the systems lifecycle; since the central challenges for health information systems (HIS) include redundant data and functionality, heterogeneous technologies and the lack of reuse.

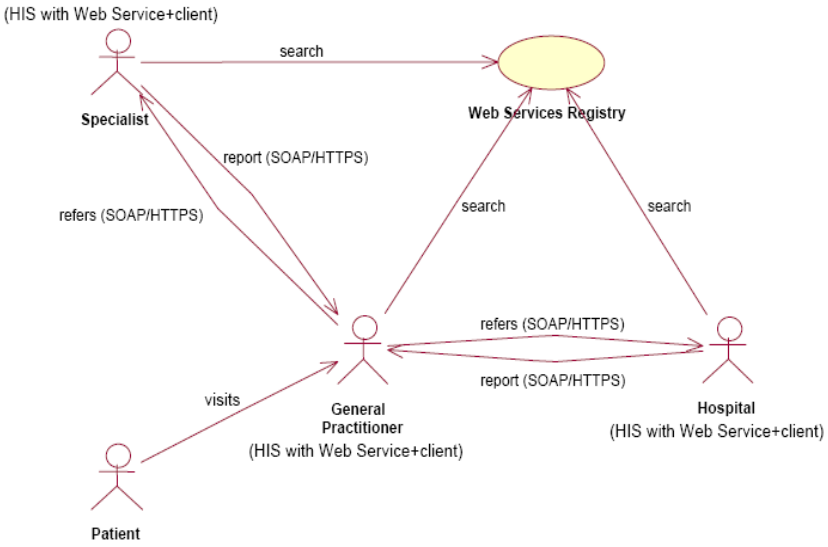

Figure 1. Functionalities for the Interoperability

2. Design Issues in Interoperable EHRS

The EHR, as defined by the Medical Records Institute, is electronically maintained information about an individual's lifetime health condition and health care. The EHR is expected to replace paper medical record(s) as the primary source of information for health care, and still comply with all clinical, legal and administrative requirements (http://www.medrecinst.com).

The Healthcare Information and Management Systems Society (HIMSS) define the EHR more comprehensively as a "longitudinal electronic record of patient health information generated by one or more encounters in any care delivery setting. Included in this information are patient demographics, progress notes, problems, medications, vital signs, past medical history, immunizations, laboratory data and radiology reports. The EHR automates and streamlines the clinician's workflow. The EHR has the ability

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to generate a complete record of a clinical patient encounter, as well as supporting other care-related activities directly or indirectly via interface - including evidence-based decision support, quality management, and outcomes reporting" (http://www.himss.org/ASP/topics_ehr.asp). This definition reflects the interoperable and scalable nature of the EHR. It is not merely limited to the internal organizational use but expands out to include data and processes of all the participants in the health care delivery process.

However, to date, EHR application design appears to have been technology/vendor driven.[13] It also does not adhere to generalized standards for portability. This limitation implies several things: One, as we've mentioned, systems are mostly internal with the primary purpose of tracking patients. Two, there is no multi-function capability, such as inclusion of clinical decision support.[7] Three, the current generation of EHRs lacks compliance with open standards.[13,26] Therefore, the next generation of EHRs must include properties of federation, flexibility, interoperability and openness[11,13,3019] as health care delivery participants (e.g. physician clinics, HMOs, hospitals, diagnostic laboratories and pharmacies) strive to share health information within the context of ethics, privacy and security.

The essential but missing piece is an overarching architectural framework that pulls all the elements together. In this regard, other industries, such as banking and financial services, have begun conceptualizing and developing the SOA framework for their organizational information processing. Considering that characteristics of the health care delivery process, such as multiple providers and systems, are similar to those of these other industries, the SOA has great potential to address some of the design challenges. A comprehensive EHR at the point of care could be created by aggregating and sharing data among all sites at which patient receives care, as well as with data supplied by the patient. To share and use data from multiple institutions, data must be built upon common words (data elements and terminology), structures, and organizations. In the health information technology (HIT) environment, this requirement is called interoperability. Functional interoperability means that the participating groups support common functions and procedures, much as the parts of an automobile must fit and work together. Semantic interoperability means that the language of communication must be understandable by the computer at the receiving end of any communication.[12]

The newer SOA and Web services models hold considerable promise for assimilating the variety of inputs in a decentralized fashion. The need for the SOA-based interoperable EHR has emerged in health organizations because of increased organizational complexity and environmental uncertainty (e.g. the multi-payer system). The SOA, then, provides the conceptual framework for the implementation of distributed interoperable HIT applications such as EHRs on this network.[27] Figure 2 represents framework for basic SOA architecture.

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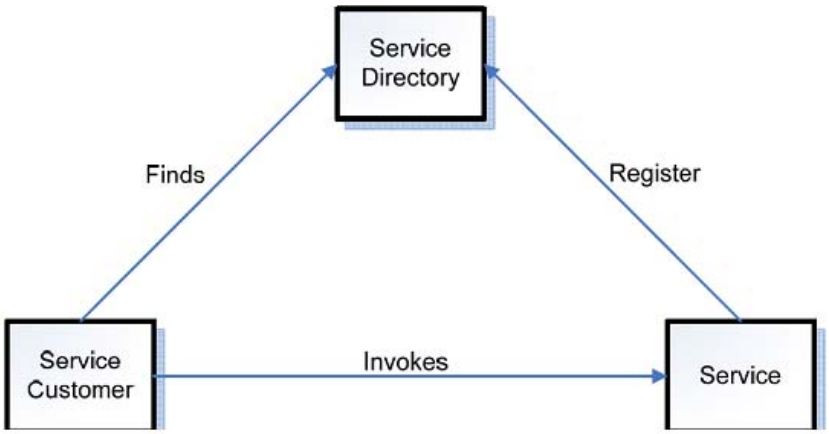

Figure 2. Framework for basic SOA architecture
Source: [27]

3. SOA Framework for a Health Clinic Setting

Because SOA is a new paradigm based on the evolution of distributed computing, a health care application's processing logic or individual functions may be modularized and presented as services for provider-consumer applications as depicted in Figure 3. The key is the services are loosely coupled in nature, that is, the service interface is independent of the implementation. Application developers or system integrators can build applications by composing one or more services without knowledge of the services' underlying implementations. For example, a service can be implemented either in .Net or J2EE, and the application using the service can exist on a different platform or be written in a different language. The SOA then models the reality, that in health care delivery organizations the EHR infrastructure is heterogeneous across operating systems, applications and system software. For example, in South Africa, a National Health Care Management Information System (NHC/MIS) was designed to cover medical records, patient registration, billing and scheduling modules in select hospitals in all nine provinces. Most provinces have minimum patient records. The National Health Information System Committee of South Africa (NHISSA) has prioritized the standardization of the Electronic Health Record. The South African Department of Health (DoH) is working with the Home Affairs National ID System (HANIS) Project to incorporate its data elements onto a smart card being developed by the project. The information will include: a minimum patient record, which includes ID verification; blood group; allergies; donor status; last ten diagnoses, treatment, prescriptions; and medical aid.[17] Therefore for meaningful success to be attained, interoperability of the systems deployed across the nine provinces must be taken into consideration.

Considering the varied diffusion rate, from some organizations having implemented a range of EHR to others still using paper-based records, the SOA with its

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loosely coupled nature allows health organizations to plug in new services or upgrade existing services in a granular fashion to address the varied nuances of health care information processing. Existing applications are not abandoned but instead become part of the services.

An additional dimension of SOA recommends encapsulation based on health care services. Services are independent units of functionality that reveal message-based interfaces accessed across a network. Therefore, SOAs enable very flexible deployment strategies: rather than all data and logic residing on a single computer, the service model allows applications to be networked computational resources. Services are also independent in the sense that they are versioned and managed as discreet units.

In this section we describe a prototype SOA framework for the EHR in a health clinic setting. The following are the identified systems within the healthcare domain and each of these systems must be incorporated in the SOA for the health sector.

1. Inpatient Care (IC)
2. Outpatient Care (OC)
3. Emergency Care Unit (ECU)
4. Surgery Unit (SU)
5. Medical Records (MR)
6. Pharmacy (PH)
7. Laboratory (LAB)
8. Radiology (RD)
9. Finance/Accounting (F/A)
10. Staff Administration

Aggregates of attributes and methods may reside at multiple locations (the participants in the health care delivery process) and in multiple applications (EHRs, databases, transaction processing systems, legacy applications, etc.). One possible service is an aggregation of some of the methods. Typically, within a health care delivery environment, a service can be a simple health care process capability (such as GET PATIENT ADDRESS or CHECK INSURANCE STATUS), a more complex transaction (such as CONFIRM DIAGNOSIS CODE or GET TREATMENT PROTOCOL) or a routine system service (VERIFY USER or RECORD USER LOGIN). The health care related functions are, from an application's perspective, non-system functions that are basic. Health care transactions may appear to be simple functions to the invoking application, but they may be implemented as composite functions covered by their individual transactional context. They may involve multiple, lower-level functions that are transparent to the caller. System functions are generalized functions that can be abstracted out to the particular platform, for example, Windows or Linux.[6] The decomposition of health care applications into services is not just an abstract process. It has very practical implications: services may be low-level or complex high-level (fine-grained or course-grained) functions, and there are very real tradeoffs in performance, flexibility, maintainability and reuse, based on their definitions. The level of granularity is a statement of a service's functional richness. For example, the more course grained a service is, the richer the function offered by the service. Services are typically course-grained health care functions such as ADMITNEWPATIENT because this operation may result in the execution of multiple, finer-grained operations, such as VERIFYPATIENTIDENTITY, CREATEPATIENTRECORD and so on. This process of defining services is normally

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accomplished within a larger scope, that of the application framework. This is the actually work that must be done; that is, the development of a component based application framework, wherein the services are defined as a set of reusable components that can be used to build new applications or integrate existing applications (e.g. legacy systems).

In the health clinic setting all functions of the EHR are defined as independent services with well-defined, invocable interfaces which can be called upon in defined sequences to form health care processes: (a). All functions are defined as services: these include purely health functions, such as CONFIRM PATIENT APPOINTMENT/VISIT; business transactions composed of lower level functions such as VERIFY INSURANCE; and system service functions such as VALIDATE ID or OBTAIN USER PROFILE; (b). All services are independent: they operate as black boxes; external components and/or users neither know nor care how they perform their function, merely that they return the expected result; (c). In the most general sense, the interfaces are invocable. That is, at an architectural level, it is irrelevant whether they are local (within the system) or remote (external to the immediate system). It does not matter what interconnect scheme or protocol is used to effect the invocation or what infrastructure components are required to make the connection. The service may be within the same system or in a different address space in the distributed space, on a completely different system within the organizational intranet or within an application in another participant's system in a B2B type configuration.[6]

Summarily, SOA approach can be used to improve performance and utilization of HIS, especially in handling changes. SOA Service candidate can be constructed first by identifying systems and functions in existing applications. Redundancy in system-function relation will help organization to determine the right services for their SOA-based application.

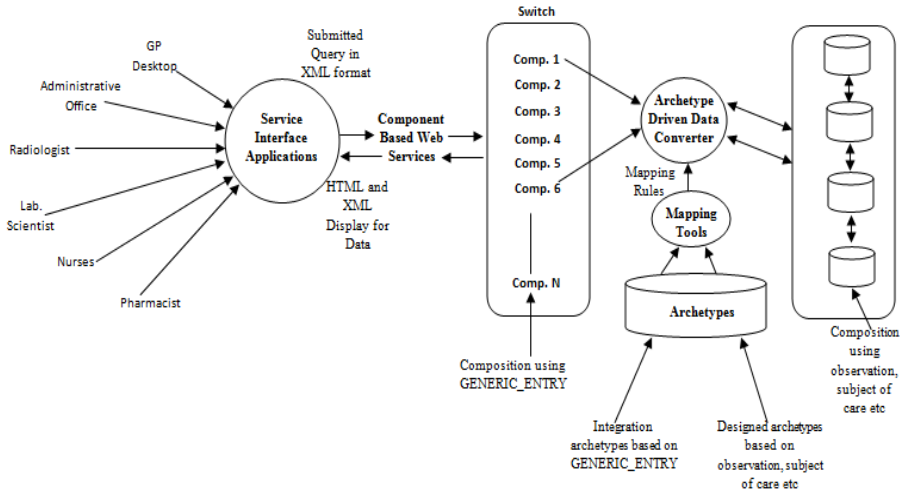

Figure 3. An SOA-based integrated health care delivery framework

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4. Challenges in SOA Implementation

There are enormous challenges in implementing SOA for a health care. This ranges from organizational to technical challenges. Analogous to the paradigm shift to enterprise systems (e.g. ERP), the notion of a "service" forces health care delivery organizations to redesign their health care processes. This shift entails organizational, cultural, political and technical changes that a new architecture brings with it.[18] The health care industry particularly faces the challenges of incomplete standards (e.g. of medical terminology) and lack of robust development and modeling tools. Additionally, security issues are compounded by the inherent complexity in health care delivery wherein multiple providers must work together to deliver quality care. Furthermore, SOA governance has been addressed only recently. Measurement of cost and effectiveness of SOA in the health care industry is critical for rightful allocation of resources. Yet another challenge lies in finding "SOA architects" with experience in implementing complex distributed health care applications.[18]

On the technical side, several issues need to be resolved. Arriving at the right level of service granularity is important. Too much granularity leads to compartmentalization while too little granularity limits reuse.

At the vendor level, vendors must offer service-oriented health process and workflow, as well as service orchestrations, tools and services. Modeling tools must be available that can adequately reflect health care services in an agile, platform-independent way. Technologies must have the tools to generate code from models and to update these models when the code changes (MDA tools, for example). Finally, vendors must offer SOA-enablement software that allows service-oriented architects to build and maintain the level of abstraction between services and underlying technology in a reliable and scalable way. Testing an SOA environment is a challenge. Typically, the testing environment is simulated because the SOA applications are built across multiple health care provider organizations. But simulated data may not reflect the real health care services' processing. Performance limitations due to the distributed nature of the SOA constrain the use of the SOA to logically separate applications. Additionally, loose coupling comes at a price. While tightly coupled interfaces (fine-grained services) have the potential to reduce flexibility and reuse, loose coupling (course-grained services) may limit efficiency. An important challenge is the development of a health care "service ontology." While progress has been made in the area of medical terminology ontology, the application of SOA in health care is relatively new, and there is much more to be done with regard to commonly agreed upon services in health care delivery. For example, hospitals may assign different meanings to the services, "pre-certification" and "pre-authorization" of procedures. Various researchers and standards organizations are addressing these and other challenges.

5. Conclusion

We have discussed the problems and challenges of interoperability in software systems as well as the potentials of the SOA in the design of interoperable EHRs and the development of an SOA framework in a health clinic setting. The framework may be implemented in multiple platforms. Vendors are rapidly accepting SOA and developing platform suites to support SOA in the health care area. Gradually, we are also seeing

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among developers coalescence towards open standards. While new services can be constructed across the health care delivery spectrum leading to reusability, existing systems (including legacy applications such as the ones in hospitals) are not abandoned but rather integrated via middleware. Web services within the SOA provide a platform-neutral approach by uniform access to the health care services and better interoperability as more vendors and health care delivery organizations buy into it. The representation of each health care application, process or resource as a service with a standardized interface allows one to rapidly combine new and existing systems to address changing health care delivery needs and improve the operational effectiveness. Individual organizational systems, such as the EHR in the health clinic setting, can be scaled up to participate in integrated health systems. The SOA framework can enable this by the inclusion of additional components, services, and interfaces and by allowing the participating organizations to join the service bus. Note the larger trend among regional health care providers to use integrated and single-patient-view technology to create unified pictures of service availability and patient care across their geographic areas. Information coordination between and across regional organizations, therefore, is essential for ensuring that care providers work together effectively to support integrated care initiatives, such as multidisciplinary care pathways.

Another paradigm of potential to the interoperable EHR is grid computing which enables one to divide resources into multiple execution environments by applying one or more concepts, such as hardware or software partitioning or time-sharing, machine simulation, emulation and quality of service. The interoperable EHR and related systems would reside on this grid. This virtualization, or on-demand deployment of all the distributed computing resources, lets one use them wherever and however they are needed within the grid. Virtualization is simply a form of resource management for devices, storage, applications, services or data objects. Hence, applying SOA allows one to maximize resource utilization in a grid environment. The user can deploy and migrate services in the health care ecosystem onto appropriate nodes in a grid environment to respond to changes in the internal and external environment. Another potential is on-demand computing, that is, health services on demand where application level services can be discovered, reconfigured, assembled and delivered on demand, with just-in-time integration capabilities. In time, we will also see the augmentation of open source architectures and tools to support the SOA-based interoperable EHR. In this regard, the goals of the Open Healthcare Framework (OHF) “to extend the Eclipse Platform to develop an open-source framework for implementing interoperable, extensible health care systems” are significant (http://www.eclipse.org). Open source addresses the key issues of interoperability, minimal vendor lock-in, flexibility, and universal standards. The Eclipse Platform provides for mapping of the open-source and SOA features onto the interoperable EHRs by enabling the use of the various toolkits. The open source approach has the potential to alleviate some of the costs of implementation. Globally, open-source proves cost-effective to developing countries with limited resources just as it minimizes the learning curve associated with legacy systems. Future research can focus on the operational and validation issues in the implementation of SOA in health care as well as developing solutions to meet the challenges of SOA.

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