An Enterprise Architecture approach to address health interoperability challenges in the United States during COVID-19

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Abstract

With the recent global outbreak and spread of the COVID-19 virus, the intercommunication of medical data has become a pertinent matter that cannot be overlooked. Thus, poor interoperability of the healthcare system in the United States has become an increasing concern. The root cause of this can be attributed to a lack of effective information governance and the overall decentralisation of the healthcare system. This has led to varying degrees of impact on the identification of COVID-19 patients, as well as coordination of care, patient information sharing, drug research, managing medical risks and updating screening and treatment standards. The purpose of this study is to analyse how Enterprise Architecture (EA) can be used to improve healthcare interoperability issues in the United States. The following research is based on two case studies that are used to showcase how EA can be utilised to optimise data sharing in various situations. As a result of our analysis, we identify that the application of EA to healthcare systems is one potential approach to mitigate the above concerns and improve overall interoperability. Moreover, each EA focuses on different levels of interoperability, along with its own advantages and disadvantages for solving integration issues.

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1.0 Introduction

Amid the COVID-19 outbreak, the need for longitudinal health data and interoperability has never been greater. Providers need access to the full picture of every patient they treat, and epidemiologists need to consolidate data from multiple sources to track the spread of the disease and determine where more aggressive containment strategies need to be employed (Van de Riet 2020).

The US now has the world's highest number of deaths from COVID-19 (Hollander & Carr 2020, pp.1679-1681). The fragmentation of the American health system leads to an infrastructure bottleneck, resulting in degraded data quality, gaps in care coordination, medical errors and burdensome workflows (Cebul et al. 2008, pp.93-113). Lack of cohesive medical data undermines a provider's ability to know how many people have the virus, the geographical location of confirmed cases, and the effectiveness of treatment. These challenges highlight the need for a shift to highly interoperable healthcare systems.

This research focusses on enterprise architecture (EA) for improving interoperability. The study will progress by first discussing various enterprise architectures. Furthermore, it will discuss the current situation of the US healthcare systems and proceed to analyse two case studies. The case analysis and discussion will examine how the healthcare industry can benefit from EA concerning the interoperability issues in the United States. Some recommendations will be proposed at the end.

2.0 Enterprise Interoperability

Enterprise Interoperability (EI) is the ability for two systems to understand each other and to use the functionality of each other (Adenuga, Kekwaletswe & Coleman 2015, pp.2-6; Bahill, Botta & Daniels 2006, pp.50-68). From an IT perspective, EI can be demonstrated as the functionality required for two relatively independent computer systems to effectively and accurately transfer information or documents between each other (Chen & Daclin 2006, pp.77-88). Regarding enterprise networks, EI might be interpreted as the capability of different organisations to timely and smoothly exchange services and information (Jardim-Gonçalves et al. 2013, pp.7-32). Many organisations are still struggling with the interoperability, tackling more involved steps only to bring even more confusion.

3.0 Enterprise Architecture

EA is a comprehensive description of all of the key elements and relationships that make up an organisation which is defined as the organising logic for an firm’s IT infrastructure and business process capabilities to address a firm’s need for IT and business process integration and standardisation (Venkatesh, Bala & Bates 2007, pp.79-90). EA is a popular approach for dealing with EI issues in many public agencies which must adapt to support business needs for the changing demands of the economy (Schekkerman 2004). Apart from that, many companies across industries have embraced the need to develop an effective enterprise architecture. However, research suggests that the health care sector still lags in this regard (Chapman 2002, pp.197-199).

3.1 Zachman Framework™

The Zachman Framework™ is considered as an essential structure of EA, which aims more at proposing a methodology of viewing and analyzing an organization (Zachman 2008). The model is a normalised six by six classification schema for organising descriptive representations of an enterprise. The primary strength of this model is that it provides a way of viewing a system from many different perspectives and showing how they are all related. The disadvantages come from the fact that there is no procedure in the application of the architectural model (Kotusev 2018, pp.1-3).

The Zachman Framework™ does a poor job of supporting interoperability since it does not allow any modification after the infrastructure is in place (Zachman 2008). Even though middleware can be deployed to improve interoperability between heterogeneous systems, some critical information may be distorted (DePalo & Song 2012, pp.1-6). Any single error in the EHRs may put patients in great danger.

3.2 TOGAF™

The Open Group Architecture Framework (TOGAF™) is a widely used architecture framework (Chang, Abu-Amara & Sanford 2010). It helps design, produce, accept, use, and maintain the architecture. TOGAF™ is based on an iterative process supported by best practices and reusable architectural assets. It provides a high-level and holistic approach to design EA, which is typically modeled at four architectures: Business, Data, Application, and Technology (Josey et al. 2011).

Interoperability requirements are found throughout the entire TOGAF™, which is one of TOGAF's architecture principles. It is used as an input for multiple phases of the Architecture Development Method (ADM), which is the core of the TOGAF™ framework. All eight phases of the ADM can contribute to interoperability (The Open Group n.d.). Since TOGAF™ emphasises the potential for asset reusability, there might be no interoperability conflicts (DePalo & Song 2012, pp.1-6).

3.3 FEAF

Federal Enterprise Architecture Framework (FEAF) provides a common methodology for IT acquisition, use, and disposal in the Federal government. It mainly aims at facilitating the US government to establish a well-structured and complex architecture (Urbaczewski & Mrdalj 2006, pp.18-23). This architecture has six sub-architectural domains which interrelate six ‘reference models’: Strategy, Business, Data, Applications, Infrastructure, and Security. By applying these six reference models, the organisation can build a vision from the strategic goals at the highest organisational level to the system infrastructure needed to achieve those goals (The Whitehouse 2013). It also focuses on the responsibilities of the EA core team members and functional roles.

According to FEAF, the architecture components are considered as relatively independent, causing interaction among different systems under this framework ‘difficult and daunting’ (DePalo & Song 2012, pp.1-6). Consequently, this framework only has a limited ability to improve interoperability.

4.0 SOA

Service-oriented Architecture (SOA) is initially an IT architecture where data and logic functionality are encapsulated with only their input and output exposed for others to use (MacKenzie et al. 2006, pp.4-5). Then, driven by the interest within the IT community to move to the creation of services that more directly map business needs, SOA alters the way IT integrates with business units within and across organizations. This transformation makes SOA work in tune with the business units and partners, not only on service definition and development, but also on the associated business process redesign (Hirschheim, Welke & Schwarz 2010, p.47).

With open standards, SOA enhances interoperability between services. The functionality of SOA can be achieved by the exposure of services through a given program. The services can become interconnected with each other, which in turn improves the potential of the architecture (Avila et al. 2017, p.1703). For healthcare, SOA and healthcare standards enable interoperability by encoding healthcare information using one or more common representations (Kart, Moser & Smith 2008, pp.24-30).

5.0 Challenges of COVID-19 for the healthcare industry in the US

Over the past decade, federal officials have spent $36 billion switching from paper to EHRs, expecting to harness volumes of medical data to improve the healthcare process or clinical outcomes (Keesara, Jonas & Schulman 2020, pp.1-3). However, the COVID-19 pandemic is bringing into stark relief just how far the nation is from achieving the promised benefits. To cope with the pandemic, US hospitals are racing to boost their telehealth offerings as an increasing number of patients seek care from home (Hollander & Carr 2020, pp.1679-1681; Wosik et al. 2020, pp.957-961). In Washington state, telehealth vendor Amwell has seen a 700% uptick in patient volume since the start of the pandemic (Garrity 2020). To ensure valuable care delivery, these third-party telehealth vendors will want to ensure their virtual doctors have up-to-date patient records before diving into a consultation (Hjort-Madsen 2006, p.71; Holmgren, Patel & Adler-Milstein 2017, pp.1820-1827).

Figure 1: The level of interoperability of American hospitals (Hollander and Carr 2020, pp.1679-1681)

However, only 8% of hospital leaders think they're extremely successful at sharing data with other health systems (Figure 1). What's worse, COVID case reports and other forms exchanged between hospitals and laboratories often resulted in the loss of critical information, which led to delays in contacting patients and identifying people they had close contact with. Poor interoperability hinders quick and informed decision making, cutting out repeated work and improving patient safety with fewer errors (Benson & Grieve 2016). The following points are five ways that interoperability can impact the pandemic:

- **Research:** Researchers rely highly on the interoperable health data, which can be obtained from diagnostic tests, patient address, the denominator of total tests administered, treatment results and evolving case definitions, to produce research for insight about the behavior and potential treatment of the virus (Menachemi & Collum 2011, p.47).
- **Coordination of Care:** Coordination among first responders, public health officials, labs, acute, and post-acute facilities will be critical to efficiently deal with the explosion of cases (Ding et al. 2020). Accessing information about hospitalisations and test results among healthcare participants will be vital for enhanced continuity of care.
- **Patient Identification:** Bringing disparate medical records together into a cohesive story enables health professionals to have insight into an individual's pre-existing medical conditions, medications, and allergies to make the most informed decisions and acute response (Belden, Grayson & Barnes 2009; Unni et al. 2017, pp.2026-2035).
- **Big data:** Using big data for analytics and developing platforms to inform where infected people have been (Wang, Ng & Brook 2020, pp.1341-1342). This can in turn be used to protect high-risk populations.
- **Quick adoption:** Ever-evolving guidelines for screening potential COVID-19 and emerging evidence require hospitals to quickly update standards of screening and care. Interoperability is of key importance as it affords the ability to update once and push that out across many different systems and institutions in real-time as guidance and local epidemiologic data comes in.

6.0 Enterprise Architecture for Healthcare systems

The challenges facing the US healthcare system to maximize the benefits of e-health are highlighted below:

1) A large number of distributed electronic healthcare systems. Unlike the nationalised health systems of many countries, the U.S. healthcare system is made up of private, independent hospitals, ambulatory care and long term care facilities, and private individual and group provider practices (Cebul et al. 2008, pp.93-113), which does not inherently generate practical mechanisms for sharing information. The actors who compose the healthcare system are presented in Figure 2.

2**)** Lack of strong information governance to ensure compliance with standards and legalisation for appropriate use of health data. HIPAA is the broadest piece of legislation regulating the confidentiality and security of patient care data among the numerous federal laws addressing the use of health information (Dunlop 2006). A patient's right to maintain the confidentiality and security of health information hinders the way to interoperability.

Figure 2: Defferent actors of the healthcare system(Cebul et al. 2008, pp.93-113)

The adoption of appropriate EA and the principle of management of information systems can rise to the eHealth interoperability challenge (Adenuga, Kekwaletswe & Coleman 2015, pp.2-6; Natalia et al. 2013, pp.1-4; Ahsan, Shah & Kingston 2009). This has been made possible because of EA's robustness in developing holistic, coherent and responsive solutions along with a governance model that guides the use of IS (Chen, Doumeingts & Vernadat 2008, pp.647-659; Hjort-Madsen 2006, p.71). An enterprise architecture approach to the development of healthcare information systems allows identifying essential interrelationships between components that need to be aligned (Sajid & Ahsan 2016, pp. 181-192; Ahsan, Shah & Kingston 2009). It is in accord with the nature of healthcare which is a special complexity of information, processes, and technologies involving multiple organisations with different technical architectures.

7.0 Research method

The research question is ‘How can the healthcare industry benefit from EA with regard to the interoperability issues in the US?’ Through the critical analysis of case studies and related work, this research will adopt a comparative approach to demonstrate how TOGAF™ and SOA have improved medical information interoperability in the healthcare industry. Then, in connection with the EA framework mentioned before and the current medical challenges in the US, how the healthcare industry benefits from EA will be discussed from different aspects.

8.0 Case analysis

8.1 Building the healthcare system based on the SOA

In 2008, a project was proposed to build an SOA-based distributed electronic medical system. As mentioned before, in the US, the highly diverse and decentralised nature of healthcare made it difficult to electrically create standardised data and establish timely sharing among healthcare professionals (Kart, Moser & Smith 2008, pp.24-30). Typically, computer systems were not interoperable.

In this project, SOA combined with web services, Atom and RSS feed was used, as well as leveraging open standards such as XML and SOAP in order to provide interoperability between services running on different platforms. One of the important approaches that this project adopted is web services, which was designed to support interoperable machine-to-machine interaction via the World Wide Web (Kart, Moser & Smith 2008, pp.24-30) as well as manage security. This project provided a way to incorporate security capabilities in the headers of SOAP messages to ensure the privacy of interoperable information. A variety of encryption techniques, trust domains, and security token formats were also supported.

As shown in figure 3, the prototype distributed electronic medical system was designed based on SOA to implement basic software architecture principles and was divided into three modules to provide practical services (Kart, Moser & Smith 2008, pp.24-30).

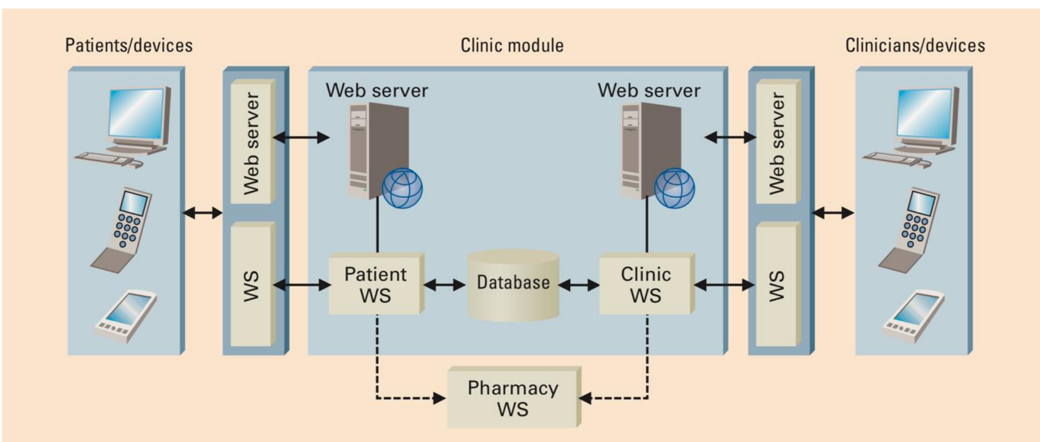


Figure 3 Prototype distributed electronic medical system (Kart, Moser & Smith 2008, pp.27)

The three modules are the patient module, clinic module, and pharmacy module. As shown in Table 1, they supported different activities and were effectively interconnected:

Table 1 Three modules of the distributed electronic medical system

Patient module	Clinic module	Pharmacy module
Support patients' routine activities. • The patients can make appointments, check their prescription status and prescription history. • The medical monitoring devices are supported over wired or wireless networks to report periodically or to send alerts in an emergency.	**Support physicians and nurses' routine activities at the clinic.** • During the appointment, doctors could access the clinic module, retrieve and obtain the patient's healthcare data using a PDA. • Prescriptions can be sent from the physician to the pharmacy over the internet. • To ensure accuracy, doctors identify prescription drugs and their dosages upon entry and integrate with pharmaceutical applications to warn drug interactions.	**Serve the pharmacy and the pharmacy's equipment.** • Pharmacists in different regions can search patients' prescription records for reference and update the prescription status in real-time.

This SOA-based distributed electronic system established an association with specific patients through the clinic's web services and made it possible to monitor patient recovery progress remotely. At the same time, patient information could be viewed and updated by relevant doctors and pharmacists of different organisations. In addition, this system can be easily extended to other medical industries and interfaced with other programs. The exchange of medical information provided higher efficiency and interoperability, and better communication among healthcare personnel reduced the risk of prescription errors.

Based on the cases, it is obvious that SOA pays more attention to the technological aspects of the business. In the early stages of SOA, the framework is IT-driven and may not achieve value-stream 'service thinking'. This will make it difficult for theorganisation to meet the hoped-for business values in the big picture and therefore SOA cannot be viewed as an adaptive architecture (Hirschheim, Welke & Schwarz 2010, p.47). However, SOA offers many benefits. It is able to provide real-world solutions using services and technology implementations (Seppänen 2008). It can be observed from the distributed e-healthcare system case that it provided detailed technical information to enhance data sharing. It describes how the three modules of the system are designed for different types of users and interconnect to enhance interoperability. The underlying information technology is also offered, including the language used to build the system and the combination with web Services, Atom and RSS. In addition, because a large number of interest groups and stakeholders are involved, protocols and service interfaces become critical, leading to governance as the central theme for service representation and implementation.

8.2 Addressing England healthcare gaps based on TOGAF™

With the Five Year Forward View, the National Health Service (NHS) England recognised the need to mitigate some gaps within the healthcare industry and address the challenge of poor health information integration in England， which requires that all patient care records be interoperable and real-time. Therefore, in 2015, NHS England and other related groups proposed several strategies and roadmaps based on TOGAF™ to guide the interoperability journey of the healthcare industry in England.

According to The Open Group® (2010, p.68), one common method to implement TOGAF™ is following the top-down approach to design the architecture. This means that the order for designing should begin with the Business Architecture (Phase B) and end by designing the Technology Architecture (Phase D). Therefore, the first step to achieving interoperability in England's healthcare is to include interoperability requirements in their vision and tie them to business goals. The second step is to design data processing methods and application requirements. Finally, identify the need for technology (The NHS England 2015, pp.5-42).

To be more specific, the NHS England defined their own standards for key building blocks which will be included in their architecture for the improvement of interoperability (The NHS England 2015, pp.10-11). Two examples are shown in Table 2:

Table 2: Building Block examples

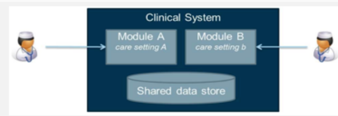
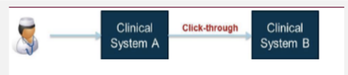
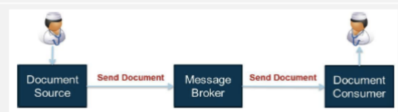
Building block #1	**Building block #2**
• Setting up regional interoperability communities to provide and integrate their digital care record solutions which can be the main approach to support care-coordination among different local care settings and organizations. • Examples: Leeds Care Record, Bristol Connecting Care, and Hampshire Health Record.	• Creating a national patient record locator service to support regional and local indexing, which allows users to use Open APIs to locate and retrieve a patient's health records. • Examples: the Summary Care Record.

Moreover, the NHS England proposed several architecture patterns to support interoperability. These 'patterns' correspond to the definition of 'pattern' in TOGAF™, which is a formal method for documenting general, reusable solutions to common problems -- in this case, sharing clinical and care information among various healthcare systems. Three types of patterns: application sharing, document exchange and data sharing which are describing the output of the Information System Architecture were highlighted as follows in Table 3 (The NHS England 2015, pp.21-33).

This case shows that applying TOGAF™ to improve interoperability addresses both business and IT needs. This is due to its implementation approach and comprehensive nature, which covers business, application, technology, information system and other aspects (The Art of Service 2020). TOGAF™ not only helps enhance interoperability at the technical level, but also focuses on the strategic level (Seppänen 2008). The clear roadmap connects the different perspectives of the company and provides a consistent model for handling the various areas and integrity tests. Therefore, applying TOGAF™ to improve interoperability ensures the alignment between business vision and technology.

However, TOGAF™ deals primarily with the strategic and functional issues of the organisation and identifies areas where it can be implemented. It considers 'Requirements Management' as a central theme and manages high-level strategies and deliverables to support business planning and analysis. This is only a starting point for building an enterprise architecture, rather than solution models (Seppänen 2008). Based on this case, NHS England just regarded TOGAF™ as a guideline to build its own technical section, which includes building blocks and patterns specialized for healthcare interoperability. For example, how to design the operating system for GP to improve interoperability.

Table 3: Architecture pattern examples

Application sharing pattern		
It is a simple way to achieve interoperability. Mainly solve technical interoperability problems.		
#1 **Single shared application**	It has specialized modules for each care setting and process but allow the sharing of data via the common data store.	
#2 **Click-through**	It provides users the ability to access information from other systems through a new tab of their own systems.	
Document exchange pattern		
Compared to sharing applications, this is a more complex and flexible way to integrate digital care records which can introduce greater semantic interoperability.		
#1 **Document repository**	• It receives and stores every new or changed documents and send out notifications to inform other parties that the new documents are available. • It allows all document customers to share the documents available in the repository.	
#2 **Message broker**	• It simplifies the process of developing the connection among various systems.	
Data sharing pattern		
It can both improve the technical interoperability and the semantic interoperability. But the complexity of understanding individual data elements for each system's meaning and use exists.		
#1 **Point-to-point portal**	• It extracts information from multiple systems and provides a summary of the information that can be viewed via the portal. • This pattern reduces the complexity of understanding individual data element for each system's meaning and use since it uses the portal instead of directly sharing data to other systems.	

9.0 Discussion

There is limited coordination between the different levels and functions of the health system and sector. The case analysis clearly illustrated that EA has the potential of simplifying the complexity of healthcare systems and enabling organisations to develop a more interoperable healthcare system. The strength of EA in improved interoperability among the healthcare industry can be concluded:

9.1 Integrity

Each organisational unit at different times provides an information system based on its needs, which has led to a collection of different health information systems by different providers. These information systems are inherently heterogeneous, even within the same hospital multiple systems can coexist. It indicated a weak relationship between hospital information systems. Our case study showed that EA can improve both internal integration and horizontal interoperability and establishes a high level of integrity in the way that IS in the health organisations are organised. Further, system assets that are currently isolated can be enabled to share by implementing EA. For instance, the SOA-based prototype discussed in the previous case analysis provided interoperability between different computer platforms, which allowed communication between the clinic, pharmacy, and a network of sensors that capture patient data.

9.2 Capturing multiple perspectives

Multiple care providers and settings suggested that the architecture and any specific digital investments must focus not just on individual needs, but also on the collaboration between providers and organisations. EA is a collaboration which includes representatives from all key stakeholders and value network members into an EA program: national health department, senior management, partnered health organisations and patients. These extended relationships typically have their own technology components and standards that must merge with each other to promote seamless service delivery and effective decision-making.

Meanwhile, it's beneficial for obtaining "buy-in," ongoing support and collaboration. A high initial cost and uncertain return on investment hinder the implementation of eHealth technology. There are many examples of organisational leaders initially buying into a strategic vision for enterprise architecture only to withdraw that support when they see no immediate return on investment. The commitment from the top to bottom can be made by understanding that the architecture would need to evolve, and its full benefits would not materialise for several years.

9.3 Consider the health system as an ecosystem

The US healthcare systems are better understood as an ecosystem of silos, fragmented processes and interconnected stakeholders. Traditionally, data is more of a competitive advantage than a basis for coordinated care. This is the reason why both providers and vendors have been accused of "information blocking" or intentionally interfering with the flow of information between different EHR systems.

To improve the health of populations, all nations will need to go beyond improvements in the performance of their healthcare delivery systems to embrace the broader determinants of health. From the above case studies, EA has shown its robustness in developing holistic solutions that make it unparalleled in improving the production and interoperability of services. Most EA efforts are beyond inward-focused, instead, they associate the extended enterprise with business structure, business activities, infrastructure, information flows, standards and policies. This holistic method supports the cross-organisation initiatives critical to national interoperable healthcare systems.

Regarding business-IT alignment, EA is a good tool for analysing and defining the healthcare organisation on a high level of abstraction which promotes alignment of their current functions and future needs. The two cases above involved aligning the infrastructure, applications, business models and strategies with the IT organization. On the other hand, EA frameworks can vary widely. Some emphasise high-level strategic viewpoints, others may focus on providing ways of structuring business data, technology and infrastructure designs. They differ in content and target audience which may inevitably compromise on supporting interoperability in different respects. Take TOGAF™ and SOA for example. If the US healthcare system were built solely based on the TOGAF™ framework, it would likely gain only guidelines to improve interoperability, rather than detailed and practical solutions. Also, it is not perfect to simply apply SOA to all the problems of its healthcare systems. Although SOA provides a detailed solution to resolve the disconnect between IT and business, it focuses more on the IT segment rather than the entire organisation.

This variation suggests that different EA models cannot be viewed as substitutes for each other. Meanwhile, EA models are not mutually exclusive, which implies it's possible to build on the strengths of different architecture frameworks.

10.0 Recommendation

Based on the case analysis and discussion above, EA is proven to improve interoperability in the healthcare industry. But different EA frameworks have different pertinence and advantages, and one architecture alone may not have the ability to eliminate all problems. Therefore, based on the current situation of the US healthcare industry, it is recommended to adopt the combination of EA frameworks to meet the challenges.

The US is recommended to apply EA to promote its healthcare system interoperability:

- EA can establish a high level of integrity in the way information systems are organised.
- EA can collaborate with major stakeholders and value network members to jointly promote and support the enhancement of healthcare interoperability.
- EA can ensure the US healthcare system is integrated with the standards and policies, infrastructure, business activities, business structures, and information flows.

A single architecture may not be sufficient to address all the interoperability issues of the US healthcare system, which requires a comprehensive approach that combines multiple EAs. Based on the above analysis, it seems that each architecture has its own strengths and cannot be replaced by another. One of the possibilities for combining multiple frameworks is the combination of SOA and TOGAF™. Due to the large overlap between them, this combination is not abrupt and can better leverage the advantages of both frameworks (Kistasamy, Van Der Merwe & De La Harpe 2010, pp. 129-137). SOA can be combined with each phase of the TOGAF™ ADM to ensure US healthcare's governance compliance and requirements management, while obtaining a direct, detailed, and practical technical model to build their own technology strategies.

11.0 Conclusion and Further Research

The interoperability problems in the US healthcare industry have been amplified by the COVID-19 outbreak. The interactivity of EHR becomes valued by the medical community. Because of the decentralised nature of healthcare information systems and the lack of strong information governance, the collection, analysis, use and sharing of health data in the United States is challenging. To address the root cause of this interoperability problem, the health community could adopt EA to improve its healthcare systems in order to improve the structure and delivery of routine care and obtain health data in real-time for situational awareness and response. EA's strengths in improving interoperability are primarily in three areas: improving the high degree of integrity of the healthcare system, considering the representation of all key stakeholders and value network members, and treating the health system as an ecosystem to achieve cross-organisational initiatives. Due to the various focuses and advantages of different EAs, it is recommended to build health information systems based on combined architecture frameworks to achieve a more complete solution. An example presented in this research is the combination of TOGAF™ and SOA.

In addition, there are several opportunities for future research: 1) researchers can analyze the focus and advantage of each architecture, 2) according to the situation of the healthcare industry, what architectures will be combined to build a more perfect framework, 3) how to build the matched framework to solve the medical challenges in the United States.

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