How the integration of Emergency Medical Services with Health Information Systems enhances quality of service

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Abstract

Emergency Medical Services (EMS) are the responses and medical support provided in urgent cases. It is an essential component of the healthcare delivery system and represents part of a country's social security and welfare policy. As an expanded need for seamless healthcare information exchange, integrating EMS with Health Information Systems (HIS) has become a crucial step to support responsive life-saving decision-making. Although the US government has reached a certain level of consensus on EMS data standardisation and integration through NEMSIS, the primary cause that hinders the future development of EMS systems is that the use of the system is not consolidated across regions. Over 60% of states only build "one to three" linkages of EMS and healthcare information systems, whilst 6 states have no data linkage and data sharing at all. Therefore, the US case study demonstrated four challenges in modern EMS agencies: 1. inconsistent and decentralised data; 2. ad-hoc legacy environment; 3. non-standardised EMS process; 4. data security and privacy concerns.

This paper aims to address the following research question: how does Enterprise Architecture support the integration of Emergency Medical Service systems with Health Information Systems to enhance the quality of service? This research has properly addressed these challenges by proposing solutions to the architecture development for EMS, guided by the nine pre-defined principles within TOGAF®[1], and four architectural domains (business, application, data, and technology). The architecture development learns from the WHO Emergency Care System Framework and establishes a standardised business architecture. It displays a holistic view of the EMS system with an integrated health information platform to facilitate data exchange and system application integration, using III-RM as a technical reference model. It also encompasses a design of robust technology infrastructure to ensure system and data security and maintain incident responsiveness.

Keywords: Emergency Medical Service (EMS), Health Information Systems (HIS), Enterprise Architecture (EA), TOGAF® ADM, Information System Integration, Architecture Development, Integrated Information Infrastructure Reference Model (III-RM)

1. Introduction

Emergency medical services (EMS) encompass the initial stage of emergency care regionally and contribute significantly to decreasing disability rate and mortality to time-sensitive illnesses such as stroke and cardiac arrest. Many EMS agencies have integrated health information systems (HIS) to satisfy a broad spectrum of emergency care needs, but little improvement has been proven (Ben-ssuli, Leshno & Shabtai 2012, p. 3795). EMS agencies continue to suffer from the inconsistent data and obsolete software of legacy EMS systems. The absence of a standardised EMS process among EMS delivers an uncertain quality of care. EMS systems also inevitably arouse data security and privacy concerns.

Enterprise architecture (EA) is a technology and management practice used by organisations to support business processes and service operations. To achieve EMS integration, the four architecture domains of the TOGAF®

[1] TOGAF is a registered trademark of The Open Group.

framework is adopted to develop enterprise architectures for the business processes and functions, the application, data and technical layers respectively to address the above-mentioned challenges.

This paper aims to address the following research question: '*How does Enterprise Architecture support the integration of Emergency Medical Service systems with Health Information Systems to enhance quality of service?'* By this research, this paper will demonstrate the reasonableness of applying the proposed architectural solutions with principles to enhance the quality of emergency medical services. The proposed architectural solutions can provide a precise taxonomy of business processes and functions by applying the WHO framework, a data and application model and an infrastructure plan, named III-RM, to enable faster decision-making, effective resource allocation and efficient information exchange within a robust IT infrastructure.

The report structure is as follows: Section 2 states the relevant background of Health Information Systems. Section 3 studies the current status and challenges of EMS integration in the US. Section 4 introduces the adopted EA framework. Section 5 uses the TOGAF® framework to construct specific solutions. Section 6 concludes this report, and then discusses the limitations and further research respectively in Section 7 and Section 8.

2.Background

2.1 State of the Health Information Systems

In recent decades, information technology (IT) has been widely adopted in the medical industry in the US (Conte et al. 2021, p. 1). As a result, electronic medical records (EMR), medical information services, remote consultation, and health management systems become increasingly mature. IT has successfully merged into medical services such as medical guidance, clinical decision support, and electronic supervision services.

Health information systems (HIS) are composed of "all computer-based components, allowing related healthcare professionals or patients themselves to input, process, store and transmit patient-related information in the context of inpatient or outpatient care" (De Keizer & Ammenwerth 2005, p. 45). US Hospitals have initially established information systems such as HIS, PACS, LIS, ICU and EMR. These systems could better support the basic diagnosis and treatment procedures. US hospitals have made the considerable effort on the hospital integration platform in recent years, but the idea of integration has a greater focus on data integration and exchange within a hospital while the linkages between external medical information systems are still fragmented (Martin et al. 2018, p. 880).

To elaborate, Emergency Medical Service (EMS) is defined as "a comprehensive system that provides personnel, facilities and equipment to achieve the effective and coordinated provision of medical services under emergency conditions (Moore 1999, p. 325). The main tasks involve receiving emergency requests, dispatching emergency personnel to the scene to provide first aid (Finnell & Overhage 2010, p. 226) and transporting patients to the hospital emergency room (Aringhieri et al. 2017, p. 350). However, many EMS systems lack prehospital data exchange with other healthcare providers, especially between states. As a result, prehospital providers (e.g. patient, family member or bystander), who are the only available medical information source for medical staff (Martin et al. 2018, p. 884), might not be able to provide precise information about the patient's medical treatment, such as current medication, allergies and past medical history. Accordingly, it can be challenging for the current HIS to support the realisation of medical management goals in the core diagnosis and treatment procedures in the hospital. Even worse, ambiguous health indicators might mismatch the care capability of targeted health institutions while dispatching ambulances, which in turn delays medical treatment.

As the modern pace of development of medical information systems has slowed down, to continually provide personalised diagnosis and treatment in the high risk patient handover stage, the next-generation HIS could be integrated with EMS to achieve medical data synchronisation and sharing with the ultimate goal of enhancing the quality of EMS (Martin et al. 2018, p. 884).

2.2 The Need for Integration

Integrated healthcare information is essential for maintaining EMS quality involving transportation efficiency and medical treatment effectiveness. As current EMS system users usually cannot access complete patient historical e-health information in real-time (Finnell & Overhage 2010, p. 226), the integration of HIS and EMS becomes important in reducing medical errors caused by the high risk of patient handover and achieving high-quality continuous services (Martin et al. 2018, p. 884).

The combination of EMS and HIS could enhance the manageability of healthcare services for medical administrators. First, to improve EMS and other public safety services, it requires more traceable, available, and accurate medical data to support continuous evaluation (NHTSA 2011, p. 57). Then from the perspective of the US government, nationwide integrated data could help accurately manage the benchmark for the statistical comparison between performances (NASEMSO 2020, p. 138) and assess the effectiveness of medical interventions. Finally, from the viewpoint of medical practitioners and stakeholders, integrated systems are vital to facilitate access to EMS and promote further medical investigation (NEMSIS 2020).

3. Current situation and challenges

3.1 Case Study: EMS Integration in the United States

3.1.1 EMS Development History

With the purpose of EMS integration, in the past 50 years, EMS has experienced dramatic growth in the US. Many electronic medical systems were developed by diverse vendors with limited knowledge of efficient systems and processes to solve the spectrum of issues faced by contemporary EMS (NHTSA 1996, p. v). In fact, since 1973, state-level EMS officers found it impossible to compare data from one state to another. Until 1994, a national consensus document proposed by the National Highway Traffic Safety Administration (NHTSA) defined 81 crucial elements to an EMS information system. After a few years of development, the National Emergency Medical Services Information System (NEMSIS) was released in 2001, which was funded by the National Highway Traffic Safety Administration (NHTSA) and its partners. NEMSIS is a collaborative system for collecting EMS data from US states and territories, providing national EMS data standardisation and aggregation (NEMSIS 2020).

3.1.2 EMS Current State

Although the US government has reached a consensus on EMS data standardisation and integration through NEMSIS, the use of the system is not consolidated across regions. There are over 21,000 Licensed Local EMS Agencies in the US (NHTSA 2011, p. 1), but only 10,137 EMS agencies in 49 states and territories have registered in NEMSIS to 2016. These agencies vary from organisational types such as Fire-Department-Based (40%), Private Non-Hospital-Based (25%), Governmental (21%), and Hospital-Based (6%) etc. that is shown in Table 1. Thus, different states may serve in different ways. Even within states, local EMS agencies provide diverse types of services. For example, in Colorado and California, counties provide the traditional emergency service, starting with 911 calls being responded to by ambulance agencies, then transporting patients to hospitals, while in Delaware agencies support "basic life support (BLS) and advanced life support (ALS) 911-responding ambulance services". Most state-level EMS offices regulate public EMS, while Ohio EMS offices exist for private ambulance services (NASEMSO 2020, p. 11).

Table 1. EMS Agency Numbers by Organisational Type (NHTSA 2011, p. 5)

EMS Agency Numbers by Organizational Type, 2011

EMS Agency Organizational Type	States With Org. Type	Mean	Median	Min	Max	Sum
Fire-Department-Based	46	138.9	61.5	1	581	6,388 (40%)
Governmental, Non-Fire-Based	44	74.0	30	1	800	3,255 (21%)
Hospital-Based	43	21.0	14	1	100	901 (6%)
Private Non-Hospital-Based	45	86.9	40	1	823	3,910 (25%)
Tribal	19	4.4	3	1	25	84 (1%)
Emergency Medical Dispatch	11	33.9	27	1	81	339 (2%)
Other EMS Agency	7	139.7	63	1	683	978 (6%)
Total						**15,865**

**CA, IL, VA, and WA data unavailable

Despite the incomplete integration of EMS systems, the linkage between EMS and healthcare-related information systems is not fully established. In the survey of data linkage in 52 states and territories shown in Figure 1, over 60% of states only build "one to three" linkages of EMS and healthcare information systems, and 6 states have no data linkage and data sharing at all (NASEMSO 2020, p. 132). Inconsistent data identity among different system vendors may contribute to this result. For instance, in Fosbøl, E. L. et al. (2013) a project integrating STEMI patients' data from EMS with the hospital databases found that 30% of samples lose data due to the inconsistency of patients' identities among hospitals. Moreover, NEMSIS suggests XML as the standard language for data storage while there is a considerable amount of PDF files in systems that are difficult to transform (FICEMS 2020). Data exchange is an expectation rather than a rule.

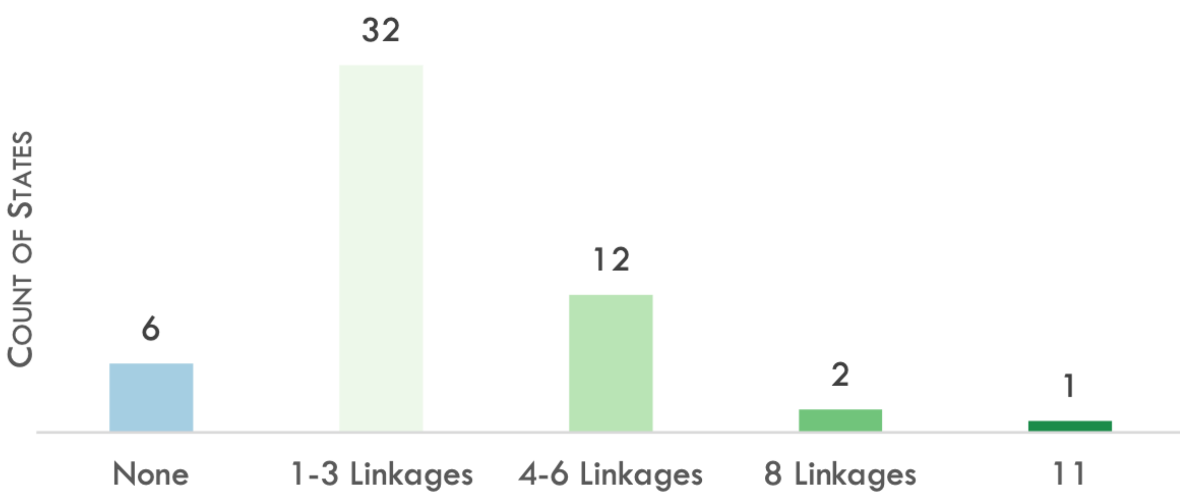

Figure 1. Data linkages between EMS and healthcare information systems (NASEMSO 2020, p. 132)

3.2 Existing Challenges

Inconsistent and Decentralised Data

This challenge can be illustrated by two aspects of data: data input and data storage. On the one hand, inconsistent data input between the HIS and EMS systems can be explained by two causes: first is the inconsistent ID input that exists when the HIS or EMS system only shows the name of a patient, the input definition of a system database can be either full name or only the first name, which may confuse data identification by other systems; second is the multiple medical devices used by EMS agencies in 49 states and territories, and medical personnel are not dedicated at data input, resulting in the same data being kept in different and incompatible formats such as pictures, audio and characters across multiple systems. On the other hand, the patient-related data is often stored in decentralised databases in multiple systems due to a mass of EMS agencies, which compromises information availability and data accessibility that further informs decision-making in non-local emergency treatment (NASEMSO 2020). Moreover, data inconsistency is commonly observed in the legacy environment. Data stored in diverse sources of legacy systems are heterogeneous without centralised and standardised data structures. Hence it is complicated to extract unstructured, old data to be integrated with structured, new data.

Ad-hoc Legacy Environment

Legacy systems refer to previous or outdated systems and applications, and these lead to limited business agility, unmanageable complexity, and information boundaries (Bisbal et al. 1999 p. 103). Nowadays HIS struggles to respond with extending requirements and adopting new technologies. Typically, some legacy HIS run-on obsolete hardware and outdated programs, the maintenance of which requires significant expenditure. On the one hand, it is impossible to migrate all legacy systems with one 'big bang' approach, since the majority have operated for several decades and continuously support the information flow within the organisation. On the other hand, the integration of the legacy system with others is generally hampered by overlapped components. Redundancies must be identified before integrating with other systems but with typically poor documentation from legacy code (Bisbal et al. 1997 p. 5) which involves a manual process. A deeper organisational effort is required to engage system experts to reconstruct the documentation and produce target integrated systems.

Lack of Standard EMS process

This challenge represents a situation where patients may receive disparate emergency care. EMS straddling both public service and medical care usually contains three different processes: efficient on-site management, safe and quick transportation and quality healthcare facilities (Mehmood et al. 2018, p.17). There is a lack of agreed-upon EMS procedure, instead there exists a complicated EMS process involving multiple service providers that may lead to fragmented emergency medical service. For example, nowadays ambulance service providers are classified as public or private hospital-based or non-hospital-based (NASEMSO 2020, p. 11). Randomly dispatched ambulances may add difficulty in tracing responsibility to relevant personnel who could not act cohesively and responsively, resulting in ineffective coordination of human resources and frequent healthcare information loss, which further undermines EMS quality. Thus, the EMS process lacks further elaboration, precise definition and standardisation.

Data Security & Privacy Concern

Security and privacy challenges are frequently mentioned when adopting digital technologies, including the HIS and EMS systems where data reflecting a person's health condition are stored. Although these data are important for possible future treatment and relevant medical research, there are some concerns commonly associated with data loss or information leakage (Hollis 2016, p.421). The sudden loss of critical health information after a system crash with no capability to recover can result in medical staff making inappropriate decisions when relying on incomplete health information. Moreover, if the hospital system is attacked by malicious hackers, the unsolicited disclosure may prove to be harmful (Argaw et al. 2019, p. 2). It is problematic for EMS agencies to have a plain system with few capacities to be responsive against external and internal incidents.

4. Enterprise Architecture Model

4.1 Role of Enterprise Architecture

Enterprise Architecture (EA) is a strategic management tool that integrates a set of special documents or artefacts (Azman 2020, p. 2). It can foster collaboration between business and IT within the organisation and achieve congruence between business and IT (Kurnia et al. 2020, p. 1). The implementation of EA could improve the performance of healthcare functions which can create a positive impact on health services and data processing methods of medical organisations, to some extent (Depalo & Song 2012, p. 1). EMS agencies also need to gain support from resource planning through effective allocation of medical expertise and facilities across the department boundaries, which may shorten the waiting time and maintain the service quality at a certain level (Tamm et al. 2011, p. 147).

4.2 The Open Group Architecture Framework (TOGAF®)

TOGAF® is an architecture framework that provides a comprehensive method for EA design, planning, implementation and management. After analysing 17 existing EA frameworks, Haghighathoseini (2018 p. 95) concluded that TOGAF® is a far superior EA framework to adapt to the healthcare industry compared to other frameworks. It is essential to customise and localise TOGAF® according to specific organisational requirements.

The Architecture Development Method (ADM), a core of part of TOGAF®, describes a lifecycle for developing and managing EA to embrace the business and IT needs of the organisation. The ADM provides detailed processes for transitioning the current architecture to a target state. The phases of the ADM can be divided into four sections: architecture context, architecture development, transition plan and architecture governance (see Figure 2). Regarding the above-mentioned challenges existing in EMS systems, this paper focuses on the architecture context and architecture development to design the enterprise architecture method. The design of target architectures is done in the architecture development section, in accordance with the architecture context set beforehand, such as principles and scope defined at the preliminary phase, as well as enterprise visions and business goals identified at phase A.

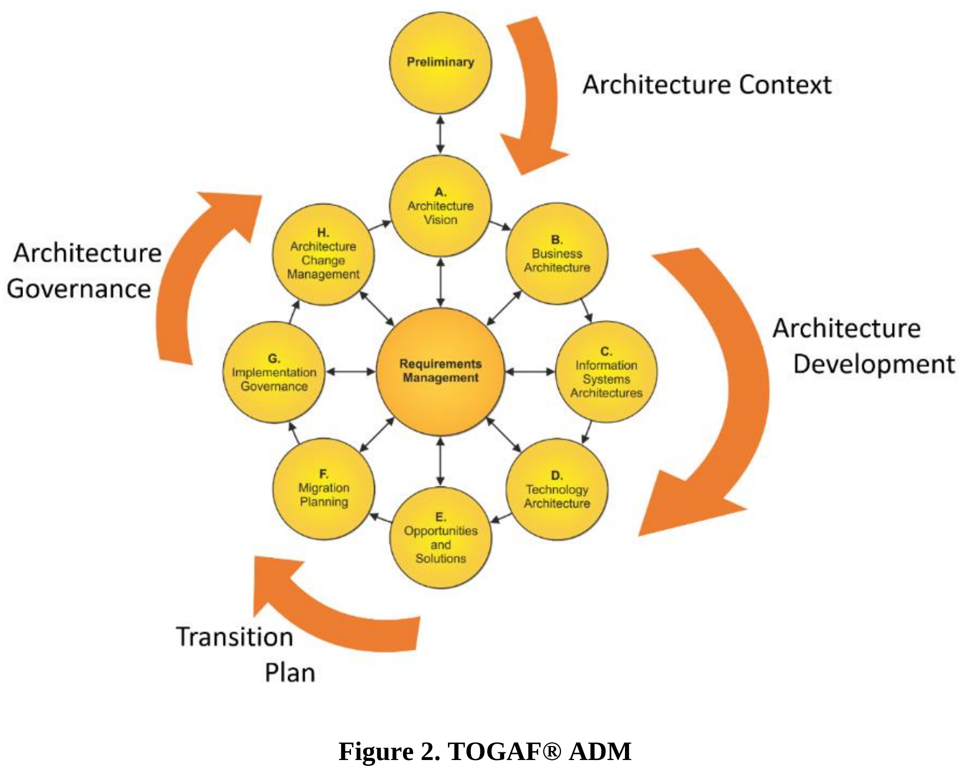

Figure 2. TOGAF® ADM

The TOGAF® framework encompasses the architectural domains to build architecture solutions, which fit in the Architecture Development section of the ADM:

1) Business Architecture defines corporate strategies, key processes and functions (same as phase B of the ADM);

2) Data Architecture defines data storage, management and maintenance methods;

3) Application Architecture defines the deployment and interaction of various application systems and sets the blueprint for core business processes. Data and application architectures together represent phase C of the ADM - information systems architectures.

4) Technology Architecture mainly shows the software, hardware and IT infrastructure that may be involved in the development and deployment of applications (corresponds to phase D of the ADM).

5. Possible Solutions

5.1 Architecture Principles

In high-income countries, most of the EMS fails due to uneven business processes, data inconsistency, ad-hoc legacy environment and information security and privacy concerns. A list of principles is proposed for each of the four TOGAF® architecture domains (see Table 2) to guide the development of integrated EMS with improved efficiency in medical resource allocation, preciseness of emergency medical service, and capability improvement. These would provide a basis for developing a business architecture solution, which then further informs the design of data, application and technology architecture solutions.

Table 2. Architecture Principles

Principles	General Statement	Specification for Healthcare Industry
Business	I. Service Orientation II. Service Integration III. Patient-centred Care	i). Engage all relevant stakeholders in exchanging healthcare data. ii). Connect all related services. iii). Design EMS process in the interest of patients. Coordinate cohesively the EMS care delivery teams across partner networks.
Data	IV. Information Availability V. Data Accessibility	i). Allow integration between databases that health information can be available to interested parties and that healthcare data is accessible from multiple endpoints.
Application	VI. Flexibility VII. Ease of Use	i). Have a comprehensive application arrangement in a modular manner so that it can easily accommodate healthcare needs and update it in case of modification. ii). Foster the communication between all relevant parties using applications without much effort for learning.
Technology	VIII. System & Data security IX. Incident Responsiveness	i). Ensure all medical data records stored internally are subject to effective system maintenance with sound data management and governance. ii). Ensure the system where information and data of related parties is stored are recoverable against cyberattack.

5.2 Architecture Development

5.2.1 Business Architecture

WHO Emergency Care System Service Framework is adopted as a business reference model to map out EMS functions presented as one key component of business architecture. Based on the framework, the EMS process is classified into three sites: scene, transport, and facility (see Figure 3), which indicates a three-step EMS process aiming to guide multiple EMS agencies.

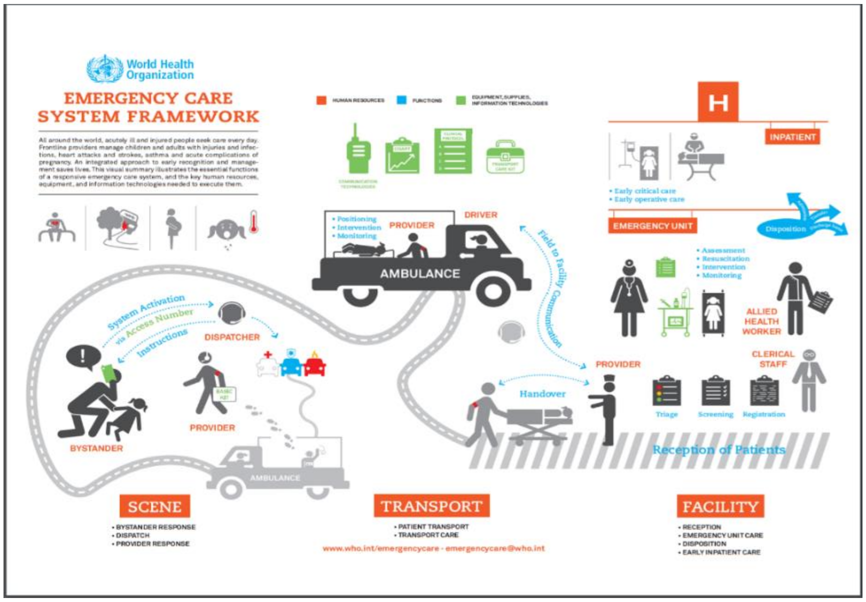

Figure 3. WHO Emergency Care System Framework (World Health Organisation 2020）

The EMS functions are classified into prehospital service, transfer service and hospital service (see Figure 4). These service types horizontally demonstrate the concise three-step business process of EMS. Vertically, a spectrum overview of sub-level functions and activities under each process element is displayed. This service function's taxonomy, at the detailed level, derives a standard for EMS agencies to refine service provision so that they can conduct a precise responsibility assignment on suitable medical personnel and organise a targeted emergency training session for different service functions, which contributes largely to human resource planning and capability increment in the people dimension. The joint effort of the subtle division of responsibility, appropriate medical care infrastructure and eligible personnel accelerates delivery of high-quality care interventions in a responsive manner (Mehmood et al. 2018, p. 17).

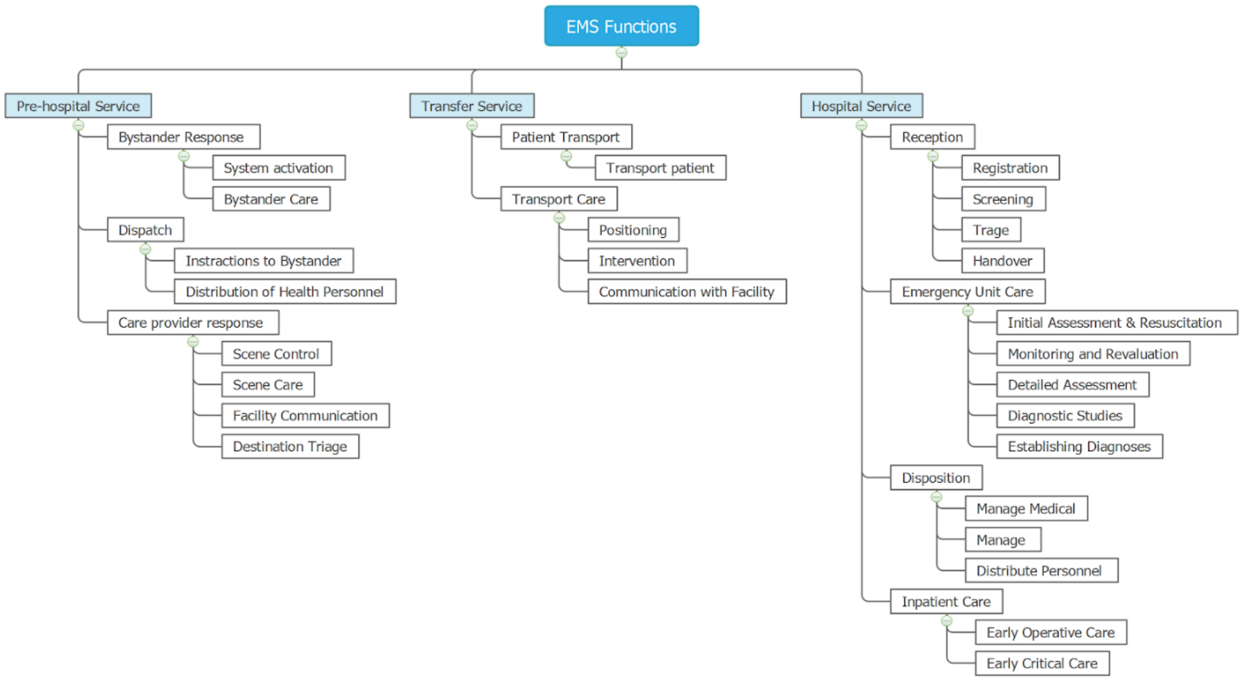

Figure 4. EMS Function Taxonomy

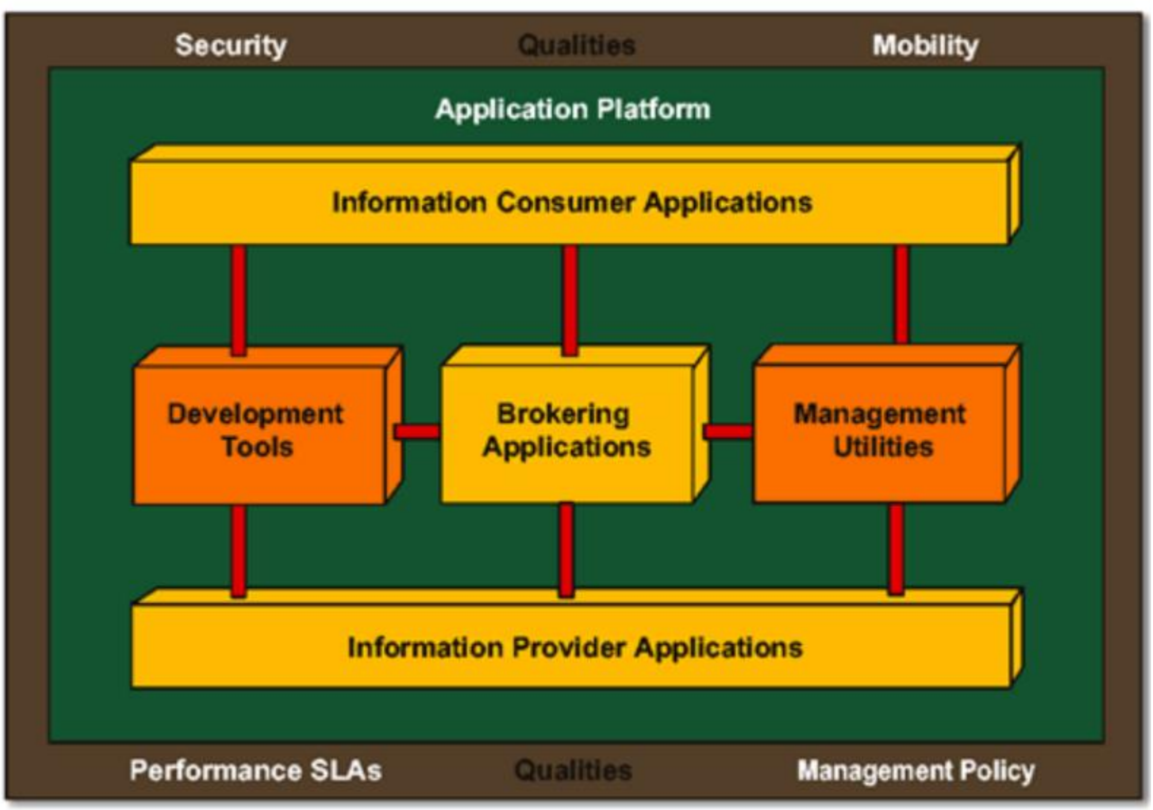

Figure 5. III-RM Model

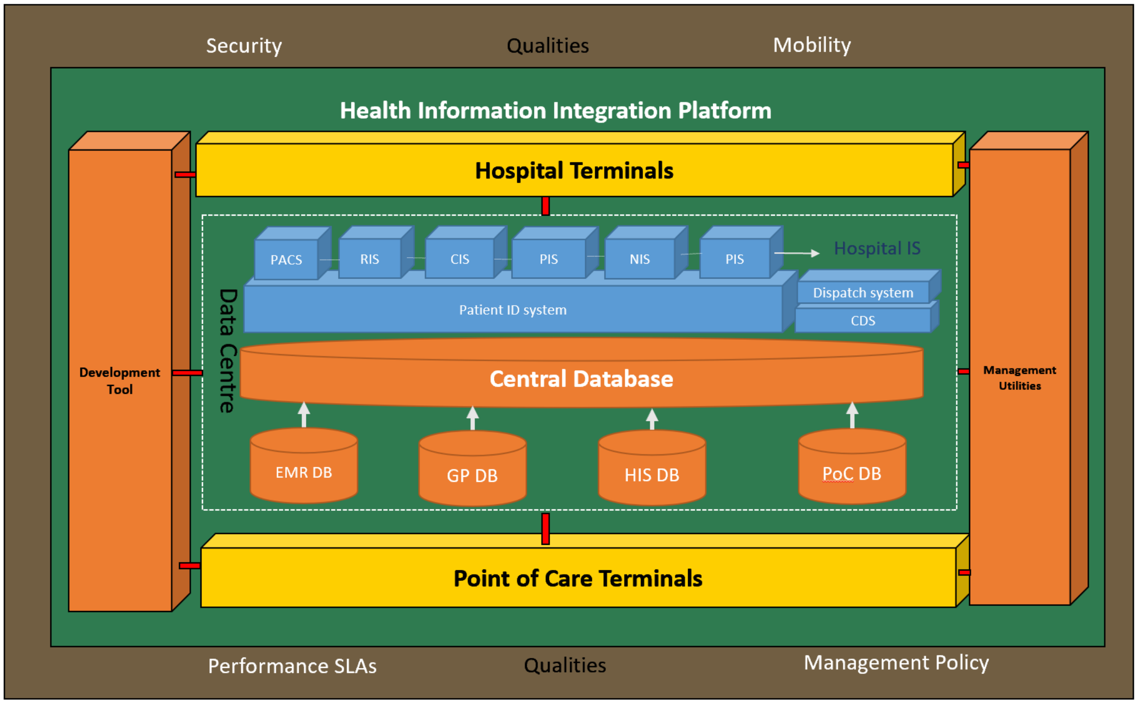

Figure 6. Tailored III-RM Model

5.2.2 IS Architecture (Data & Application)

The Integrated Information Infrastructure Reference Model (III-RM) in TOGAF® is used as the technical reference model to develop information systems architecture for the purpose of integrating EMR into EMS. The III-RM (see figure 5) includes a taxonomy that defines terminology and provides a coherent description of core components of integrated information infrastructure, as well as an associated III-RM graphic, which offers a visual representation and interrelationships of the core components.

The design of data and application architecture (see figure 6) is tailored to the EMS context, using III-RM as a prototype. This solution in the information system layer aims to address information silos, data inconsistencies and ad-hoc legacy environments. A holistic view of the EMS System is presented, the concept of Central Database is highlighted, and the applications are embedded in various terminals and the database.

III-RM Core Components

- Business Applications

Information Provider Applications embedded in Point-of-Care (PoC) Terminals respond to client requests and fundamental access to data managed by a particular server. Paramedics in the ambulance could use the PoC Terminals (e.g. computers or tablets embedded in ambulances) to access a patient's health data from the EMR system. Since PoC technologies are connected to the Clinical Decision Support (CDS) system that has been integrated with HIS, paramedics could provide synchronised information of transport care, such as initial assessment and triage data, back to the central database thus a more comprehensive and timely preparation would be performed by the Emergency Room at the hospital.

Information Consumer Applications embedded in Hospital Terminals deliver content to system users and provide services to request access to information in the system on the user's behalf. This allows front-desk staff to pre-register for patients ready to be directed to the Emergency Room and pre-assign a suitable group of medical personnel based on the triage result. Before the ambulance arrives, the Emergency Unit at the hospital could retrieve and analyse synchronised clinical information from the Data Centre without delay. Therefore, more effective evaluation and personalised in-hospital treatment can be conducted promptly.

Brokering Applications in the healthcare Data Centre manage the requests from clients to and across system service providers. The Data Centre consists of 9 critical systems to support EMS-related data processing and deliver outcomes to endpoints. As the growth of unstructured health data explodes, the Data Centre can group data into master data (rarely changed e.g. patients name) and transaction data (frequently changed e.g. medications), then reference the data by timestamp and patient ID (Handayani et al. 2019, p.7). The Central Database collects enriched information from the EMR system database, personal health database from General Practitioners, PoC database and HIS database. As the PoC goes mobile, the Data Centre can enable information access on various electronic endpoints, particularly the Hospitals and PoC Terminals, which promotes effective communication and delivers a mass of clinical information to multiple EMS agencies. It aims to address data silos by fostering a high-speed data exchange from multiple sources. Additionally, an appropriate geo-location for the Data Centre would optimise the capability of the system environment to reach the entire audience. Gu et al. (2014, p. 315) list several factors to balance data workload and energy consumption: proximity to users increases transmission rates; inland areas are safer and cheaper; sufficient electricity and cheaper fees reduce computation cost.

- Infrastructure Applications

Development Tools provide all necessary modelling, design and construction capabilities to develop and deploy applications that require access to the integrated information infrastructure. Common tools for data modelling include API server, database server and application server. Open-source technologies such as PHP and MySQL can be deployment tools (Handayani et al. 2019, p. 8).

Management Utility provides all necessary utilities to understand, operate and manage the run-time system to embrace evolving business requirements. For example, a Dispatch System uses GPS to dispatch ambulance vehicles supported by the Medical Priority Dispatch System which prioritises the level of severity from least serious to life-threatening situations (Nehme et al. 2016, p. 788).

- Application Platform

Health Information Integration Platform (HIIP) supports the running of the above-mentioned applications and provides users with the ability to locate, access, and move information within the environment. HIIP bridges the HIS and EMS systems through an integrated approach. By converting the legacy environments from ad-hoc to a functional integrated environment, HIIP offers an opportunity for EMS agencies to re-platform business applications from scratch. For example, hospitals can migrate only the critical and reusable components from the Hospital Information System and achieve simplicity in updating outdated systems and applications and removing duplicated processes.

5.2.3 Technology Architecture

Due to the high-level of sensitivity and confidentiality of patients' health information stored in the central database, it is vital for the target technology architecture to adopt an application and network firewall and SSL in the EMS system (Handayani et al. 2019, p. 9). Authentication should also be applied to control the data accessibility based on the user authorisation. Furthermore, a formal IT maintenance process should be developed to sustain the capability of the EMS system to provide a service on a regular basis to adapt the system to evolving needs (Graham, Veenendaal & Evans 2008, p. 50). Moreover, intrusion prevention and detection systems and network monitoring systems should be implemented in the network layer to enhance network security (Handayani et al. 2019, p. 9). It is also necessary to develop a backup/recovery system for the enterprise's information systems as a whole instead of only focusing on certain parts of the system (Qurratuaini 2018, p. 8). This will maintain data availability during system downtime (Mayer 2003).

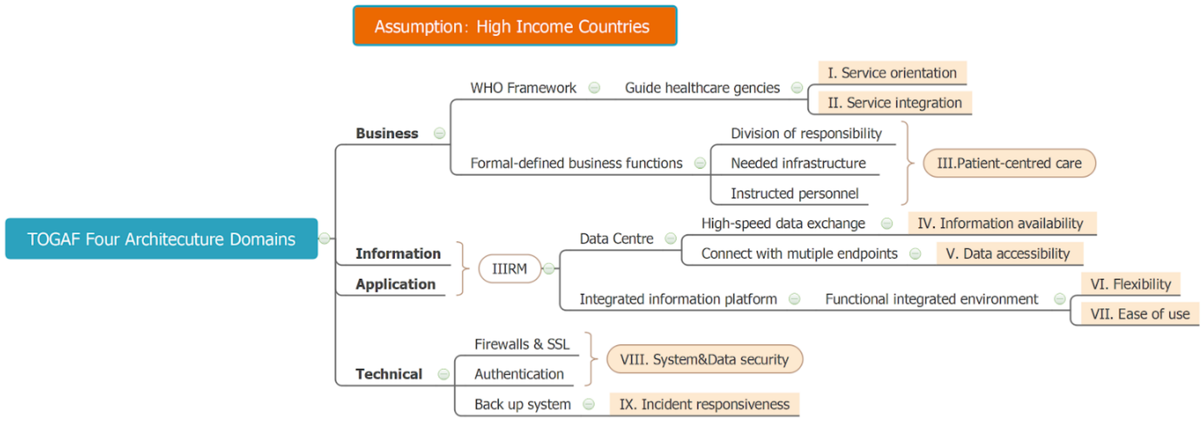

Figure 7. Summary of Solutions in TOGAF® Architectural Domains

6. Conclusion

Although US EMS care has made huge progress in the past five decades and delivers benefit to tens of millions of patients, EMS agencies tend to suffer from unsynchronised data, and a lack of uniformity in processes and functions that undermines the provision of patient care. This paper introduced a US case and showed four challenges, namely inconsistent data, lack of standard EMS process, ad-hoc environment and data security and privacy considerations.

The proposed solutions correspond to the nine principles within TOGAF's® four architectural dimensions to guide the architecture development for EMS (see Figure 7) and enhance the quality of service. The WHO Framework is used to establish needed infrastructure and coordinate precise training for suitable medical personnel on standardised EMS processes and functionality. Furthermore, this paper proposes a holistic view of the EMS system with an integrated health information platform to facilitate data exchange and system application integration.

7. Research Limitation

This research has proposed design solutions for architecture development, instead of the actual implementation for a particular organisation in the healthcare industry. Moreover, III-RM is merely a "Common Systems Architecture" in Enterprise Continuum terms, which only provides a general solution, making it suitable for use in any industry. For it to be applicable in the EMS context, this solution needs to be refined and specified through industrial best practice via collaborative learning in the healthcare domain. EMS operations must also comply with associated healthcare standards and policies that are not sufficiently discussed in this research. Lastly, the provision of EMS varies sharply across various countries, however, this research domain mainly focuses on EMS organisations in high-income countries, characterised by relatively high capacity on EMS care responsiveness to even mild or non-urgent illnesses (Mehmood et al. 2018, p. 13).

8. Future Research

Future studies may move towards an integrated prediction system with the application of data analytics, which enables EMS agencies to predict the severity level of a patient's condition and conduct optimal resource allocation. Additionally, the ambulance's response time varies across geographical locations, thus an IoT-based traffic control system for ambulances regarding urgent medical situations can be considered for future research (Wani, Khan & Alam 2020).

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