How Integrating Healthcare Information Systems and Enterprise Architecture Optimises Patient Flow in Australian Hospitals?

Rod Johnston
University of Melbourne
rod@ens.biz

Bhubet Phunthasu
University of Melbourne
bhubet.p@gmail.com

Yiting Wang
University of Melbourne
wangkristen325@gmail.com

Han Ngoc Nguyen
University of Melbourne
Selenag4.2011@gmail.com

Mao Li
University of Melbourne
Maoli.claire@gmail.com

Rod Dilnutt
University of Melbourne
rpd@unimelb.edu.au

Abstract

Australia's hospital system is under severe strain, including overcrowding in Emergency Departments and extensive ambulance ramping. These issues are symptomatic of broader systemic inefficiencies, especially in managing the flow of patients across different hospital departments. The study critically evaluates the efficacy of the traditional frameworks like TOGAF®[1] and HERA, which despite their comprehensive structure, fail to fully address the unique needs of hospital systems, particularly concerning interoperability and system-wide integration. In response, this study explores the adaptation of ZiRA, a reference architecture successfully implemented within Dutch hospitals and highlights the limitations of conventional approaches intended to resolve patient flow challenges by focusing narrowly on departmental solutions. It emphasises the benefit of a holistic EA strategy that addresses the complete patient care continuum. The findings indicate that ZiRA enables more effective solutions due to its tailored approach to hospital settings, emphasising interoperability between different hospitals and related services. ZiRA is anticipated to significantly improve the patient flow management and reduce Emergency Department congestion in Australian hospitals. This study also indicates future research directions where improved intraoperability and interoperability is desired in healthcare settings across Australia.

1. Introduction

The systemic issue within Australian Emergency Departments overcrowding and ambulance ramping (Boscaini, 2024) indicates severe delays in patient transfer from ambulance to Emergency Departments, and from arrival to discharge (May, 2013). The persistence of this issue highlights an urgent need for a re-evaluation of patient flow management, which currently suffers from fragmentation across different department settings. To address the root causes of the blockages, traditional incremental improvements have proven insufficient and inefficient solutions, as they often overlook the interconnected nature of healthcare services, resulting in information silos that fail to consider the healthcare system as a holistic continuum of care. We therefore develop the primary research question:

RQ: How does integrating Healthcare Information Systems and Enterprise Architecture Optimise Patient Flow in Australian Hospitals?

The scope of this study is confined to Australian hospital settings, focusing primarily on the public sector which is the most impacted by ambulance ramping and patient flow issues. This study analyses the current challenges and inefficiencies in patient flow by assessing the effectiveness of existing EA frameworks such as The Open Group Architecture Framework (TOGAF) and the Healthcare Enterprise Reference Architecture (HERA), and explores the potential of the 'Ziekenhuis Referentie Architectuur' (ZiRA) framework in improving system-wide patient flow and interoperability. The selection of ZiRA, a reference

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

architecture specifically tailored for hospital settings, follows an identification of the limitations inherent in existing EA frameworks. Despite their comprehensive structure, TOGAF and HERA alone fall short in addressing healthcare challenges. This research proposes a new application scenario with the adaptation of ZiRA. This study proposes a sustainable solution to improve patient flow management within the hospital industry.

This report begins by detailing the problem of ambulance ramping and its implications for patient flow in hospitals. It critiques the conventional solutions that often focus narrowly on individual departments or attempt to address symptoms rather than causes by merely investing in resources. Recognising the necessity for a holistic perspective, the study transitions to an analysis of EA frameworks, highlighting the limitations to TOGAF and HERA in the healthcare context. The analysis culminates with an exploration of the ZiRA framework, supported by case studies from the Netherlands, to demonstrate its potential applicability and benefits for Australian hospitals.

2. Background

2.1 Emergency Ramping in the Australian Hospital System

Australia is experiencing unprecedented levels of ambulance ramping, with reports of incidents where people need to be driven to the EDs by family members as there are no available ambulances, and cases where people are dying while waiting for ambulance services (Murphy, 2023). An Australian Medical Association Report Card shows that in Queensland only 56.9 percent of patients were transferred from ambulances to EDs within the target time in 2023, well short of the State’s target of 90 percent (Hope, 2023). It has been shown that EDs across the nation frequently operate at or beyond their capacity, illustrating a severe mismatch between the availability of resources and the ever-increasing demand for care, resulting in delays, staffing gaps, and inefficient hospital ward utilisation (Smithson et al., 2024).

It is clear that States and Territories are not meeting their performance goals, and longitudinal data shows that the duration for transferring patients from ambulances to hospital ED care is growing annually (Boscaini, 2024). This consistently rising transfer time signals increasing strain on Australia's hospital systems (Spencer, 2023). However, the bottlenecks experienced cannot be resolved by merely adding more beds, staff and resources.

2.2 Fragmented Patient Flow Management is a System-wide Challenge

The core of these operational challenges is the fragmented management of patient flow, which refers to the movement of patients through various hospital care settings from arrival until departure (Samadbeik et al., 2024). Poor patient flow can cause overcrowding, especially affecting admitted patients and leading to several adverse outcomes, including decreased quality of care, increased medical errors, and higher costs (Mohiuddin et al., 2017; Samadbeik et al., 2024).

However, addressing the patient flow challenges across hospitals requires more than just incremental improvements, it demands a system-wide lens. In the past two decades, hospitals have been experimenting with a variety of strategies to reduce patient crowding (Smithson et al., 2024; Spencer, 2023). However, evidence specific to the implementation of efforts to improve patient flow and reduce ED crowding is limited (Van Dyke, 2023). This is because these interventions are often confined to individual departments without consideration of the patient journey (Åhlin et al., 2023). Therefore, it highlights the urgent need for a holistic approach that treats the entire healthcare system as a continuum of care when tackling the patient flow issue.

Recognising the limitations of existing methods, this research is aiming for an integrated approach that incorporates both Healthcare Information Systems (HIS) and Enterprise Architecture (EA). HIS offers the essential technological support for efficient data handling and patient tracking, while EA offers a structured framework to align IT strategy with healthcare objectives. Together, these promise a comprehensive solution to improve patient flow across the continuum of care, enabling not only increased throughput of patients but also improving the quality, safety, and satisfaction of healthcare service.

The research has two primary goals: (i) to examine existing studies and identify effective frameworks that facilitate rapid patient movement through hospitals, and (ii) to suggest a systematic framework that guides improvements in patient flow across the entire system. To achieve these, the study will conduct a thorough literature review to understand current strategies from a system-wide perspective, identifying the critical gaps in both the research and practice of patient flow management.

3. Literature review

3.1 The Open Group Architecture Framework (TOGAF)

3.1.1 Introduction of TOGAF

TOGAF provides a comprehensive framework that enables organisations to build EA to address business issues and needs across various industries (The Open Group, 2018b). Da Luz Júnior et al. (2020) have identified TOGAF as one of the most used frameworks for building EAs in the healthcare industry, as it can improve the integration and flexibility of different healthcare systems.

According to The Open Group (2018b), TOGAF has five components:

C1. Architecture Development Method (ADM): Provides a step-by-step process for developing architectures from the initial assessment of business vision to architecture implementation and ongoing maintenance.

C2. ADM Guidelines & Techniques: Supports the development of each phase of ADM by providing guidance and techniques that can be customised to meet an organisation's specific needs, thereby increasing flexibility.

C3. Architecture Content Framework: Specifies the outputs to be produced during each stage of ADM to ensure the clarity of TOGAF and make it understandable to a diverse range of stakeholders.

C4. The Enterprise Continuum & Tools: Stores the outputs of architecture activity by leveraging appropriate taxonomies (Architecture Continuum and Solutions Continuum) to provide a comprehensive view of the organisation.

C5. Architecture Capability Framework: Provides guidance on establishing an internal framework within an organisation to create and sustain a robust architecture environment.

3.1.2 The Benefits of TOGAF

B1. High Flexibility

The TOGAF ADM can offer a flexible modular structure, which allows hospitals to adapt their IT architectures flexibly to be able to accommodate all new health technologies, systems, and innovations (Sardjono & Vijayanto, 2021). Sardjono and Vijayanto (2021) further established that the flexibility of TOGAF ensures that IT architectures can be changed without having to interrupt current operations, and indeed supports the seamless introduction of new services and models of care delivery.

B2. Enhanced Integration

TOGAF helps integrate different systems to ensure they can work cohesively to provide coordinated patient care and facilitate comprehensive health information analysis (Handayani et al, 2019). Handayani et al. (2019) provide an effective example of designing a Health Referral Information System with APIs by following TOGAF guidelines, sharing and integrating data with external health applications in Indonesia.

3.1.3 The Limitations of TOGAF

L1. Complexity of Healthcare Environment:

The healthcare industry has a complicated environment with diverse hospital systems, stakeholders, and facilities (Smith et al., 2008). Applying TOGAF in healthcare can be challenging because architects need to extensively adjust each component to address the specific needs of healthcare operations and services (Da Luz Júnior et al., 2020).

L2. Inefficient Alignment in IT & Business:

In the healthcare industry, EA should focus on supporting healthcare operations and patient care. However, it has been argued that TOGAF tends to focus more on technical aspects instead of business value and outcomes (Capstera, 2023). This may create gaps between the functionalities TOGAF provides and the needs of stakeholders, thus leading to resistance to change.

3.2 The Healthcare Enterprise Reference Architecture (HERA)

3.2.1 Introduction of HERA

HERA is a reference architecture to guide healthcare organisations in developing their own EA. HERA is also crucial for healthcare organisations to navigate the development of the IT architectures, enhancing service delivery and operational efficiency. Therefore, this makes HERA suitable for healthcare enterprises.

HERA comprises three operational cycles (see Figure 1):

C1. The Strategy & Plan: ensuring IT initiatives complement organisational objectives.

C2. The Build & Deliver: developing implementable IT systems that meet strategic plans.

C3. The Operate & Evolve: focusing on system operations and continuous improvement to adapt to evolving healthcare needs.

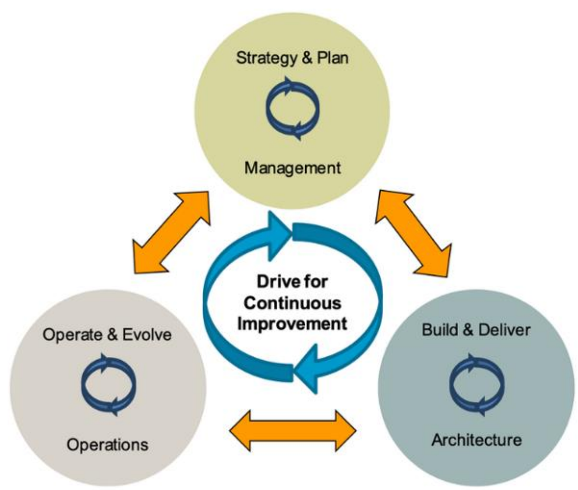

Figure 1 - Three Operational Cycles of HERA (The Open Group, 2018

Additionally, HERA is structured across four levels:

Level 0. Models and Cycles: Laying the foundation to link cycles to their respective management models.

Level 1. Process Domains: Detailing tasks for each cycle.

Level 2. Processes: Outlining specific operations for strategy execution and management.

Level 3. Tools and Practical Application: Connecting theoretical models to practical tools adaptable to healthcare contexts.

3.2.2 The Benefits of HERA

B1. Improved Alignment in IT & Business

HERA aligns IT infrastructure with healthcare-specific objectives. (The Open Group, 2018a). This alignment is crucial for healthcare organisations as it directly impacts patient care and service delivery.

B2. Enhanced Integration

HERA simplifies the inherent complexities of healthcare systems, enabling decision-makers to create practical solutions (The Open Group, 2018a). This simplification helps integrate IT initiatives with the business more effectively, enhancing their ability to focus on patient care.

B3. Improved Interoperability

HERA introduces a structured information model that enhances interoperability. This enhancement occurs because as the information model is made accessible through interfaces, it facilitates interoperability via shared services and minimises the necessity for numerous point-to-point integrations (The Open Group, 2018a).

B4. Continuous Improvement

HERA emphasises the importance of continuous improvement in ensuring high-quality service delivery by utilising KPIs, which are analysed using various analytics tools to enhance and evolve business practices (The Open Group, 2018a).

3.2.3 The Limitations of HERA

L1. Lack of Detailed Guidance

A notable gap of HERA exists between the high-level design and practical implementation, often preventing healthcare organisations from fully utilising the framework (The Open Group, 2023). This is often because HERA does not offer enough detailed guidance on how to implement it effectively.

L2. Insufficient Customisation for Diverse Needs

HERA's broad and generalised approach may not adequately address the unique and diverse challenges faced by different types of healthcare organisations. The framework's overarching scope can sometimes overlook the nuanced operational challenges that vary significantly across healthcare settings (The Open Group, 2023).

3.3 Hypothesis

The literature review indicates that TOGAF and HERA are effective in guiding the development of healthcare EAs. However, these frameworks have deficiencies that can complicate the architectural development process for hospitals.

Table 1 summarises the assessment of TOGAF and HERA in the healthcare industry and reveals that HERA and TOGAF have complementarities. The most obvious deficiency of TOGAF in hospital EAs is a lack of interoperability from the complex nature of healthcare environments and the challenges of aligning IT with hospital objectives.

Table 1 - Assessment of TOGAF & HERA in Healthcare Industry

Criteria	**TOGAF**	**HERA**
Flexibility	FS	NS
Integration	FS	FS
Governance	PS	PS
Specific Guidance	FS	NS
Interoperability in Hospital	NS	FS
Continuous Improvement	FS	FS
	FS = Fully Satisfied, NS = Not Satisfied, PS = Partially Satisfied)	

HERA, a specific framework for healthcare enterprises, can address this issue by serving as the Industry Architecture in TOGAF to fill the gap in hospital EAs (see Figure 2). Therefore, it is hypothesised that combining TOGAF and HERA could enhance the effectiveness of healthcare architectures, particularly by improving the interoperability to hospitals among other key healthcare challenges.

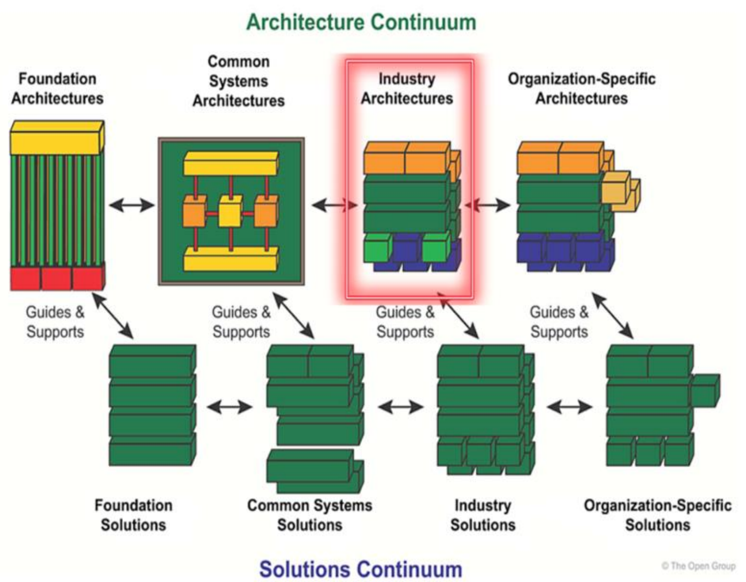

Figure 2 - Architecture Continuum of TOGAF (The Open Group, 2018)

4. Findings

4.1 Introduction of ZiRA

ZiRA was developed by the Nictiz, the competence centre for digital information management in healthcare in the Netherlands, as a hospital reference architecture for Dutch hospitals in 2012 (The Open Group, 2023). ZiRA aims to:

- Develop and maintain a framework and effective tools to support hospitals in their operation with clear information provision on all the functions and key aspects of the hospital.
- Provide a collaboration tool and meaningful knowledge tailored to the specific hospitals and their departments.

ZiRA includes seven key components:

i. Guiding principles: These establish a direction in the architectural design of the organisation, systems and applications, processes and related technologies (The Open Group, 2023).

ii. A Hospital Business Model Canvas: Illustrates all value propositions, in terms of customers, core activities, strategic partners, collaborations, cost and benefits within the hospital (The Open Group, 2023). This supports C-suite management in their decision-making, strategic planning, and value evaluation.

iii. Business Function Model: Displays 48 hospital business functions across five business domains with the main focus on patient care. This model provides structure clarification and logical division of related functions to support strategic discussion on core competency, risk and crisis management, cost and benefits examination (The Open Group, 2023).

iv. Service Model: Describes the services provided by the hospital, divided into the following services – Determine Need for Care; Diagnostic; Additional Diagnostic Testing; Advice; Treatment Plan; Treatment and Transfer (The Open Group, 2023). Thus, the structure for the hospital Service Catalogue goes along with the structure for the related processes.

v. Process Model: Identifies related stakeholders, processes, and activities in the process based upon the service goal (The Open Group, 2023). Subsequently, ZiRA provides insights on dependencies and transfer points, change impact within the process as well as the key ownership of the processes and project charter.

vi. Information Model: Represents the information relationship within the hospital and logical frameworks on its integration and interconnections (The Open Group, 2023). The model intercepts the business activity of the hospital to support the metadata management, ensuring compliance with privacy regulation, robust data governance on execution and responsibility. This function is supported by the Healthcare Information Building Block (or Zorg Informatie Bouwsteen, ZiB), in the Information Domain Model.

vii. Application Model: Consists of subcategories of software functionality that is essential for hospitals based on the existing business process (The Open Group, 2023). The model depicts the critical software capability for each segment of the hospital. Thereby, the hospital can analyse the IT landscape of the organisation, identify the right applications for the existing issue, gain insights on desired application and information for the business process.

All the above reference models follow a three-tiered architecture (see Figure 3) of control, core, and support levels (part A). Part B delves deeper into the Healthcare domain at the core levels and also serves as a common structure to all the reference models.

Besides the guidelines, ZiRA is open source with downloadable template files. These files contain ZiRA models, guidelines of file exchange, principles overview, processes, application and critical aspects and elements for hospitals to implement in their information system.

The implementation of ZiRA in Dutch hospitals ensures cohesiveness in data sharing and exchange, facilitates the best practice of knowledge management, escalates the work efficiency and development process, and ensures standardisation in processes, information, applications, and technology to foster the interoperability across hospital systems.

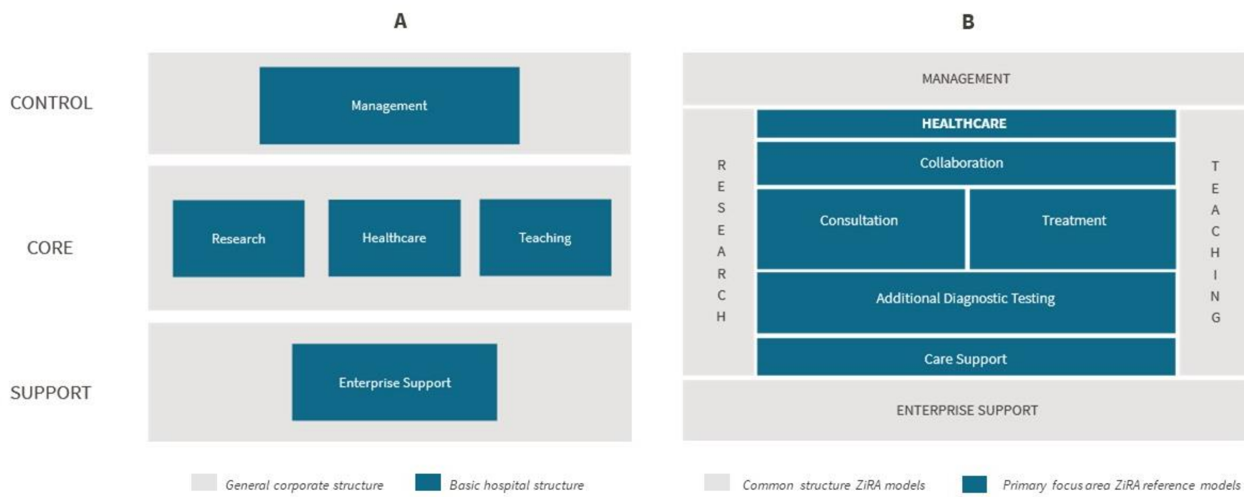

Figure 3 - The structure of the ZiRA Reference Models (The Open Group, 2023

4.2 The Enhancement of ZiRA toward the Existing EA Healthcare Framework

4.2.1 The Governance Practice within TOGAF ADM Framework

ZiRA is constructed upon the Nictiz Interoperability Model with the ZiRA functional model focusing primarily on healthcare operations. The Law and Regulations layer from the Nictiz Interoperability Model covers all ZiRA components (see Figure 4 below). This indicates a robust ZiRA governance structure throughout its framework.

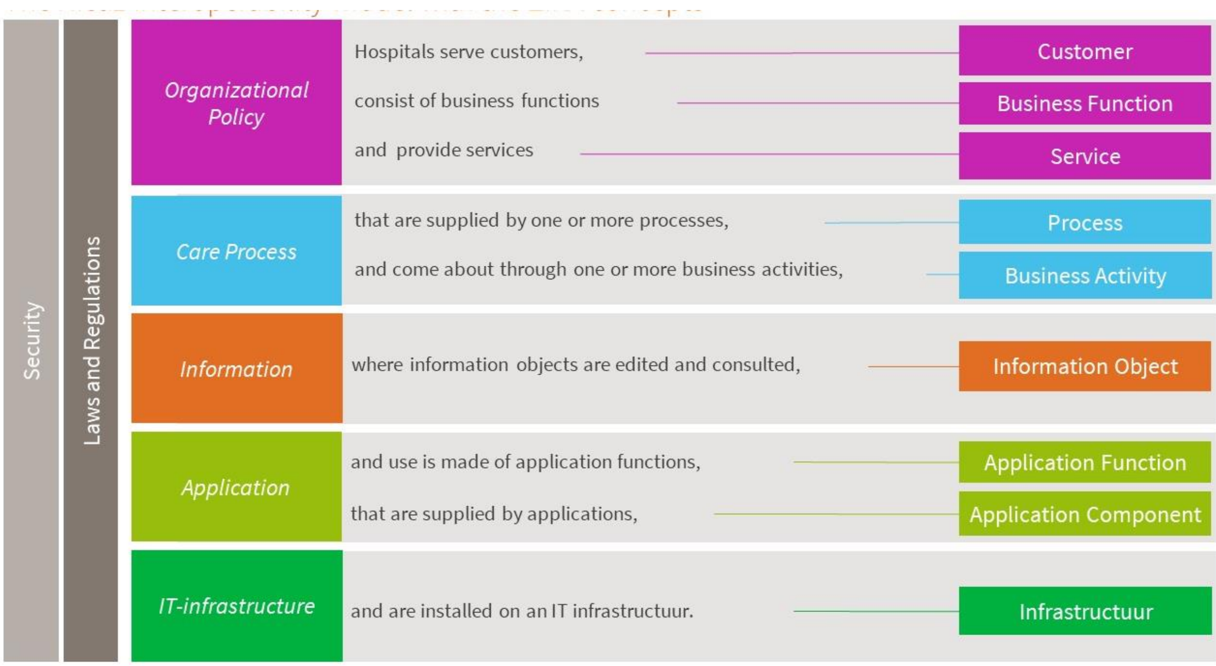

Figure 4 - The relationship of ZiRA towards Nictiz Interoperability Model (The Open Group, 2023)

With this relationship established, the opportunity for Architects to maintain and further develop the ZiRA reference architecture as an enterprise architecture using the complete TOGAF ADM is apparent.

In the TOGAF ADM, the Implementation Governance phase is positioned after the consideration of Business Architecture, Information Systems and Technology Architecture. This structure creates challenges in the governance preparation of these enterprise application phases. Nevertheless, ZiRA prioritises patient care and organisation policies in the early stage, providing a concise provision for hospitals to implement the framework into its operation (see Figure 5).

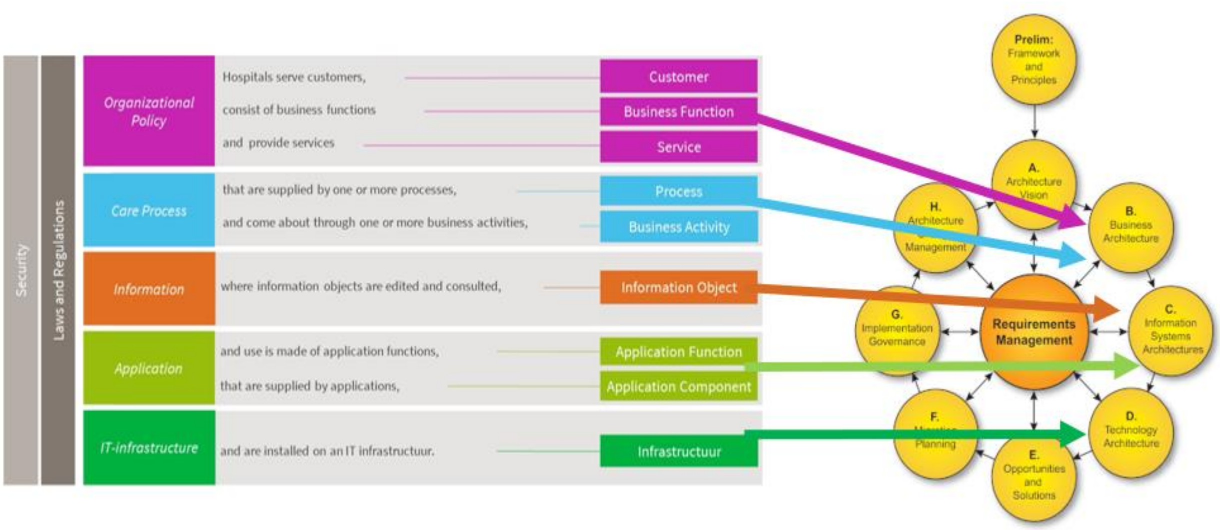

Figure 5 - Nictiz Interoperability Model Relationship to TOGAF ADM (The Open Group, 2023)

4.2.2. The development of practical guidelines for hospitals based on HERA

An advantage of ZiRA is that by addressing implementation detail, it enhances the usefulness of the HERA framework, intended for the Healthcare industry, but with a narrower hospital industry perspective. ZiRA also provides practical downloadable artefacts: ZiRA ArchiMate Exchange File, ZiRA Source File, ZiRA ArchiMate File and ZiRA Excel Spreadsheet (The Open Group, 2023), which collectively address the practical limitations of HERA.

ZiRA may be seen as structurally aligned with HERA's Build and Deliver Cycle, but ZiRA selectively focuses on three HERA sectors: Business, Information and Application. Beyond the NIM, alignment with the HERA Technology sector is not addressed further in ZiRA as ZiRA considers technology to be enterprise specific and not relevant to interoperability, but Technology would be addressed in the architectural model of each enterprise using ZiRA.

The foreword of the ZiRA document (The Open Group, 2023) includes a description of how the Healthcare Forum (HCF) identified ZiRA as a hospital reference architecture that is consistent with HERA and its eight requirements for a hospital reference architecture. However, it does not sufficiently illustrate the relationships between the architectural elements of HERA and those of ZiRA. Figure 6 provides a conceptual representation of how these relationships could be illustrated.

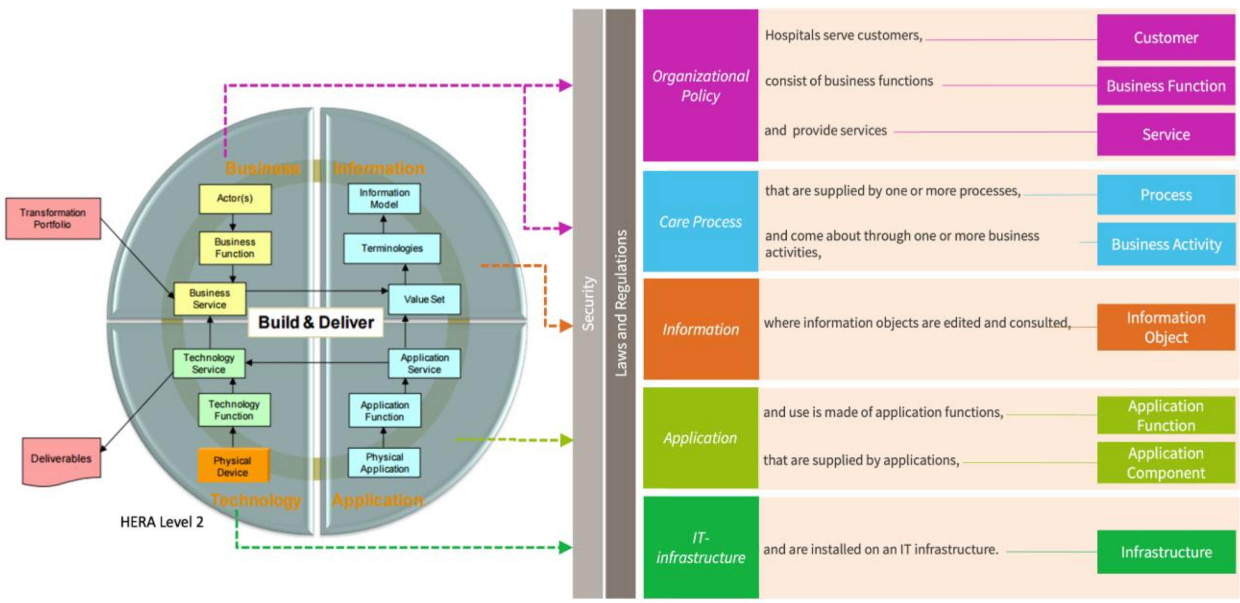

Figure 6 - Conceptual relationships between HERA and the Nictiz Interoperability Model (Author, 2024)

4.3 Addressing Patient Flow issues in Australian hospitals using ZiRA framework

The goal of ZiRA is to address the interoperability challenge in hospital systems. ZiRA provides guiding frameworks and practical tools such as downloadable files for the hospital to integrate directly into existing systems. This provides effective adaptation for hospitals on their operation.

Furthermore, a notable component of the ZiRA's Information Model - ZiB, facilitates interoperability among multiple systems (The Open Group, 2023). This feature is supported by HL7 Fast Healthcare Information Resource (HL7 FHIR®[2]) standard, Systematised Nomenclature of Medicine – Clinical Terms (SNOMED CT®[3]) standard and Logical Observation Identifiers, Names, and Codes (LOINC®[4]) standard (Bender et al., 2013). These standards collectively maintain the standardisation of the coding system, clinical data classification, data and results exchange, and management. Therefore, this fosters a universal structure from the hospitals systems to the data format along with the information exchange methodology across hospitals and their partners without affecting the processing time and the work efficiency of hospital operations.

Additionally, ZiRA itself is an open-source framework (The Open Group, 2023), that is accessible for the public to use and tailor the framework to their purpose and context. This demonstrates the flexibility of ZiRA structure to accommodate the user specific requirements without compromising the scalability of ZiRA or of the hospital's systems.

The implication of ZiRA on the enhancement of Patient Flow is proven by the successful stories in Dutch hospitals. During the COVID19 pandemic, the ZiRA framework evidently showed the critical effect of the hospital reference framework for crisis management (SparxSystems, 2021). For instance, with the support of ZiRA, the Antoni van Leeuwenhoek (AVL) Hospital in Amsterdam launched the integrated Capacity Management program to address their challenge in the patient group management, to have better scope on the patient flow in any given week.

The Healthcare EA is designed to accommodate stakeholder differences rather than cross-country differences (The Open Group, 2018). The Australian Healthcare Interoperability Plan shares similarity with ZiRA in adherence to HL7 FHIR standard, SNOMED CT standard and LOINC® standard (Agency, 2023). This consistency provides a concrete foundation for ZiRA to be implemented in Australian hospitals. It infers that the implementation of ZiRA within Australian hospitals will address the interoperability challenges for patient flow.

5. Conclusion

This study emphasises the importance of integrating HIS and EA frameworks to enhance hospital operations. Due to the broad nature of TOGAF, the research highlights the necessity for more specific frameworks to handle the complexity of healthcare systems. HERA, as a healthcare industry reference architecture, helps addressing the healthcare enterprise challenges, yet is too generalised to fully optimise patient flow in hospitals. The key finding of this research is the efficacy of ZiRA, which is a more refined solution specifically designed for hospital settings to address most gaps identified in TOGAF and HERA, enhancing patient flow management and hospital efficiency. The study on ZiRA's implementation demonstrates its benefits and potential to improve hospital operations. Based on the successful ZiRA implementation cases, it is recommended that Australian hospitals consider implementing ZiRA to improve the information flow in HIS specific operational issues. This is because ZiRA ensures interoperability among HIS, facilitating data exchange and communication. Thus, this research highlights the significance

[2] FHIR® is a registered trademark of HL7 International.
[3] SNOMED CT is a registered trademark of SNOMED International.
[4] LOINC® is a registered United States trademark of Regenstrief Institute, Inc.

of tailored EA frameworks in improving healthcare systems, offering a valuable reference architecture for ongoing improvements in hospital operations and patient management.

6. Limitations

This study is limited to investigating the effectiveness of EA on patient flow and does not consider other external factors such as resource availability, personnel arrangement, and technological trends. Thus, it is recommended that future researchers consider these external factors when building EA for specific hospitals to enhance the usability and adaptability.

Additionally, the reference architectures mentioned in this study, HERA and ZiRA, have not been widely applied so far. As there is a lack of data to support the implementation of ZiRA in Australian hospitals, it is recommended that researchers conduct quantitative research to further examine the effectiveness of ZiRA in Australian hospitals.

7. References

Åhlin, P., Almström, P., & Wänström, C. (2023). Solutions for improved hospital-wide patient flows – a qualitative interview study of leading healthcare providers. *BMC Health Services Research, 23*(1). https://doi.org/10.1186/s12913-022-09015-w

Australian Digital Health Agency. (2023). *National Healthcare Interoperability Plan 2023–2028.* https://www.digitalhealth.gov.au/sites/default/files/documents/national-healthcare-interoperability-plan-2023-2028.pdf

Australian Medical Association. (2023). 2023 Ambulance Ramping Report Card. *AMA.* https://www.ama.com.au/articles/2023-ambulance-ramping-report-card

Bender, D., & Sartipi, K. (2013, June). HL7 FHIR: An Agile and RESTful approach to healthcare information exchange. *IEEE international symposium on computer-based medical systems* (pp. 326-331). https://doi.org/10.1109/CBMS.2013.6627810

Boscaini, J. (2024). SA ambulance ramping hits near-record levels amid 'extreme' pressure on the system. *ABC News*. https://www.abc.net.au/news/2024-04-02/south-australia-ambulance-ramping-march/103656936

Capstera. *Shortcomings, criticisms, and flaws of TOGAF*. (2023, August 10). https://www.capstera.com/flaws-of-togaf/

Da Luz Júnior, S. H., Silva, F. Í. C., Albuquerque, G. S. G., Alencar, D. M. F. P., & Lira, H. B. (2020). Enterprise Architecture in Healthcare Systems: A systematic literature review. *arXiv.org*.https://doi.org/10.17632/44bygxg8w3.1

Handayani, P. W., Pinem, A. A., Munajat, Q., Azzahro, F., Hidayanto, A. N., Ayuningtyas, D., & Sartono, A. (2019). Health referral enterprise architecture design in Indonesia. *Healthcare informatics research, 25*(1), 3. https://doi.org/10.4258/hir.2019.25.1.3

Hope, Z. (2023, November 18). Queensland ambulance ramping 'just getting worse,' says AMA. *Brisbane Times*. https://www.brisbanetimes.com.au/politics/queensland/queensland-ambulance-ramping-just-getting-worse-says-ama-20231118-p5ekz5.htm

May, N. (2023, November 18). Royal Adelaide Hospital operating above official capacity. *ABC News.h*ttps://www.abc.net.au/news/2023-05-24/royal-adelaide-hospital-operating-above-official-capacity/102386350

Mohiuddin, S., Savović, J., Richards, A., Northstone, K., Hollingworth, W., Donovan, J. L., Busby, J., & Vasilakis, C. (2017). Patient flow within UK emergency departments: A systematic review of the use of computer simulation modelling methods. *BMJ Open, 7*(5). https://doi.org/10.1136/bmjopen-2016-015007

Murphy, K. (2023, November 18). How Anne Pedler's last hours were spent ramped in an ambulance. *The Guardian*. https://www.theguardian.com/australia-news/2023/nov/18/how-anne-pedler-last-hours-were-spent-ramped-in-an-ambulance

Samadbeik, M., Staib, A., Boyle, J., Khanna, S., Bosley, E., Bodnar, D., Lind, J., Austin, J. A., Tanner, S., Meshkat, Y., de Courten, B., & Sullivan, C. (2024). Patient flow in emergency departments: a comprehensive umbrella review of solutions and challenges across the health system. *BMC health services research, 24*(1), 274. https://doi.org/10.1186/s12913-024-10725-6

Sardjono, W., & Vijayanto, R. M. (2021). Designing of IT master plan based on TOGAF ADM framework in the regional water utility company. *IOP Conference Series. Earth and Environmental Science*, *729*(1), 012016. https://doi.org/10.1088/1755-1315/729/1/012016

Smith, M. L., Madon, S., Anifalaje, A. A., Lazarro-Malecela, M., & Michael, E. (2008). Integrated Health Information systems in Tanzania: experience and challenges. *The Electronic Journal on Information Systems in Developing Countries*, *33*(1), 1–21. https://doi.org/10.1002/j.1681-4835.2008.tb00227.x

Smithson, R., Doherty, T., & Fisher, A. (2024). Managing patient flow across an acute tertiary care hospital through a centralised coordination hub: Technological and cultural change – A case study 1. *Asia Pacific Journal of Health Management, 19*(1), i417. https://doi.org/10.24083/apjhm.v19i1.417

SparxSystems. (2021b). Nictiz developed a reference architecture for hospitals with Enterprise Architect. Customer Success Story. https://www.sparxsystems.eu/fileadmin/user_upload/pdfs/references/Sparx_Systems_Nictiz_EN.pdf

Spencer, E. (2023, April 20). Ambulance ramping is a signal the health system is floundering - solutions need to extend beyond EDs. *The Conversation*. https://theconversation.com/ambulance-ramping-is-a-signal-the-health-system-is-floundering-solutions-need-to-extend-beyond-eds-187270

The Open Group. (2018a). *Healthcare enterprise reference architecture (HERA).* https://publications.opengroup.org/s182

The Open Group. (2018b). *The TOGAF® Standard, Version 9.2*. https://pubs.opengroup.org/architecture/togaf9-doc/arch/

The Open Group. (2023). Hospital reference architecture guide: The complete and expanded English translation of the Dutch ZiRA (Document No. G23A). https://publications.opengroup.org/g23a

Van Dyke, K. J., McHugh, M., Yonek, J., & Moss, D. (2011). Facilitators and barriers to the implementation of patient flow improvement strategies. *Quality management in health care, 20*(3), 223–233. https://doi.org/10.1097/QMH.0b013e318222a3b0