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Information Technology Graduate Program

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# AN INFORMATION SYSTEMS ARCHITECTURE FOR UNIVERSITY HOSPITALS: A CASE STUDY AT HOSPITAL DAS CLÍNICAS OF UFPE

MASTER'S DISSERTATION

JOÃO PESSOA

2021

**Silvano Herculano da Luz Júnior**

# An Information Systems Architecture for University Hospitals: A Case Study at Hospital das Clínicas of UFPE

Dissertation presented as a partial requirement for obtaining the title of Master in Information Technology, by the Post-Graduate Program in Information Technology of the Federal Institute of Paraíba – IFPB.

Advisor: Prof. Dr. Francisco Petrônio Alencar de Medeiros

Co-advisor: Prof. Dr. Heremita Brasileiro Lira

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# ABSTRACT

Enterprise Architecture (EA) has been present in the literature since the 1980s and has been widely applied in several fields, bringing notable benefits in supporting the management and governance of organizations. However, this concept is still little explored when we refer to the application of EA in health systems. The objective of this research in the area of Business Architecture applied to health is to investigate and propose an Information Systems Architecture Model for University Hospitals through a case study carried out at the Hospital das Clínicas of the Federal University of Pernambuco (HC-UFPE). The methodological path covered two main stages, with a Systematic Literature Review (SLR) followed by a case study at HC-UFPE. The SRL was developed from a protocol, using the methodology addressed by Kitchenham (2007) and Dybå & Dingsøyr (2008). Nine specific research questions were selected to explore quantitative and qualitative aspects of state of art in applying EA in health. The Cohen's Kappa method was also used to assess the level of disagreement between the two teams of researchers involved in this SLR. The case study considered two primary data collection methodologies, semi-structured interviews, and second participant observation. The data analysis was based on a data triangulation of collected data through open coding, including technical and normative documents from the HC-UFPE. Lastly, the development of an initial Information Systems Architecture modeling the hospital IT sector's current and future business processes. With the SLR, it was possible to identify, from specific research questions, which environments of EA application; what are the positive impacts that EA has brought to the organization; what are the problems and challenges encountered during the application of the EA; and what are the critical success factors for the application of EA. The main publication channels and authors who publish on the topic were also identified. In the case study, the Information Systems Architecture of HC-UFPE was built, using the TOGAF 9.2 framework and the Archi software as a construction tool, aligned with the Archimate language. The data presented here can help IT, and health professionals search for methods to support management hospitals. Regarding the case study, it was possible to present tools that can help in the governance of the HC-UFPE and open doors for new studies to be started for future implementation of EA in the network of university hospitals in Brazil.

**Keywords:** Enterprise Architecture; hospital; TOGAF; Systematic Literature Review.

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# LIST OF ABBREVIATIONS AND ACRONYMS

| | |
|---|---|
| EA | Enterprise Architecture |
| EBSERH | Empresa Brasileira de Serviços Hospitalares |
| HC-UFPE | Hospital das Clínicas da Universidade Federal de Pernambuco |
| ICTSP | Information and Communications Technology Strategic Plan |
| IT | Information Technology |
| TOGAF | The Open Group Architectural Framework |
| UH | University Hospital |
| UHS | Health Unic System |

# SUMMARY

# 1. INTRODUCTION

University Hospitals (UHs) are centers for training human resources and developing technology for the health area. They are hospitals dedicated to teaching, research, and extension. Its adequate provision of services to the population enables constant care and technical protocols for the various pathologies, ensuring better efficiency standards available to the Unified Health System (UHS) network. Its continuing education programs offer technical updating opportunities to professionals throughout the health system (EDUCAÇÃO, 2018).

Each university hospital has its particularities, and they are highly heterogeneous in terms of their installed capacity, technological incorporation, and comprehensive service. Everyone plays a prominent role in the community where they operate (EDUCAÇÃO, 2018). Of the fifty Brazilian University Hospitals, Brazilian Hospital Services Company (EBSERH - Empresa Brasileira de Serviços Hospitalares in portuguese) manages forty-one. Since 2011, when the Brazilian government established EBSERH, it has taken on the significant challenges of managing these hospitals' resources and policies. UHS public policies and internal regulations govern university Hospitals managed by EBSERH, like all other public health services in Brazil.

The role of Information Technology (IT) is fundamental in these hospitals since it is easy to observe the increasing immersion of technology in health, leveraged by automated means that facilitate medical procedures and optimize administrative management and governance processes, adding value to the hospital business. However, as they are public institutions whose main area is, in fact, health, it is still common to find some resistance concerning investments in technology, in addition to the lack of strategic alignment of IT with other hospital areas. This problem has been reflected in providing services to the patient and in the acquisition and management of technological resources that streamline and improve the hospital's business processes. Therefore, there is a great need to understand these bottlenecks to improve business processes and efficiently carry out strategic issues.

For this, having a holistic view of these hospitals' key processes, through models that guide implementations of Enterprise Architecture (EA), can assist management in decision-making. According to Varveris and Harrison (2004), EA represents all behavior in an organization, the data processed, who does what, where things are, and why things are done. EA's goal is to align the company's strategy and the configuration of its IT assets (WEIL, 2007).

## 1.1. Motivation and Justification

With technological advances, IT is more and more immersion in the provision of healthcare services, with complex systems distributed to speed up the delivery of value to the hospital business. That process increasingly faster responses that assist health professionals in making decisions that directly or indirectly impact patients. *Enterprise Architecture* is a management and technology practice devoted to improving enterprises' performance. EA Enables organizations to see themselves in terms of a holistic and integrated view of their strategic direction, business practices, information flows, and technology resources (BERNARD, 2012). As governance becomes a critical success factor for Organizational management, its inclusion in EA aligns the framework with the best business practices, ensuring visibility, guidance, and control, which will support architectural stakeholders' requirements and obligations (ZACHMAN, 2016).

With the systematic literature review carried out in this work, it was possible to identify relevant benefits with the application of EA in healthcare, such as:

- Describe and categorize the architecture and operation of business processes;
- Promote improvements in the management of changes and processes;
- Systematize elements for decision making;
- Contribute to the maturity of management and governance, among other positive impacts that can assist hospital management.

However, implementing EA in an organization is not a simple task and is usually accompanied by several challenges. The main challenges raised in the review were the organizational complexity of healthcare environments, the difficulty in integrating or accessing data of various types, the stakeholders' conflicts of interest, the communication problems, and others. Therefore, there is a necessary effort to implement EA in a hospital environment regarding stakeholders' issues, necessities, and expertise.

The Hospital das Clínicas of UFPE (HC-UFPE) is a large UH, with an area of 64 thousand m2, 2823 employees, 418 beds, and an average of 5600 consultations and 748 hospitalizations per month. It currently has 185 departments, among the largest and most complex university hospitals in Brazil. Furthermore, as it is a public institution whose main area is, in fact, health, it is still common to find resistance regarding investments in technology, in addition to the lack of strategic alignment of IT with other hospital areas. This problem has been reflected in the provision of patient services and in the acquisition and management of technological resources that streamline and improve the hospital's business processes. Therefore, there is a great need to understand these bottlenecks to improve business processes and efficiently carry out the strategic issues of HC-UFPE.

In several recent surveys, Enterprise Architecture (EA) is efficient in supporting corporate governance processes worldwide, including in hospitals. Therefore, in order to identify how EA can support the hospital governance of Brazilian UHs, this work aims to propose an information systems architecture for HC-UFPE, seeking to understand, in a first methodological step, how enterprise architecture is being applied in healthcare systems worldwide through a broad and deep systematic literature review. In the second step, a case study was carried out at HC-UFPE. Data were collected through interviews with key stakeholders of strategic areas of the hospital, access to institutional documents, and participant observation within the IT sector. The analyzed data served as the basis for constructing the current and future architecture of information systems at HC-UFPE.

This research also hopes to assist the managers of these institutions in making decisions so that projects and investments are directed and executed increasingly efficiently and aligned with institutional strategic planning, including to serve as a basis for future research and actions that can improve the application of EA in university hospitals managed by EBSERH. For Gasevic, Djuric, and Devedzic (2006), a model must show the constructs and rules necessary to build a specific model in the domain of interest. It must provide a basic model with the minimum feature set and then support optional extensions during the Enterprise Architecture development.

## 1.2. Delimitation of research

The boundaries of this research can be classified into two parts. The first refers to the systematic review, which sought complete articles between the years 2015 to 2019, in four scientific bases, answering nine specific research questions related to the application of Enterprise Architecture in Hospitals and Healthcare Systems. Moreover, the second, related to the case study, is limited to the proposal of an information systems architecture model for the HC-UFPE, more specifically to the Information Technology Process Management Sector (ITPMS). The main processes of the sector and its relationships with other hospital areas through interviews, participant observations, and documentation using theoretical references, methodologies, and tools selected from information extracted from the systematic review carried out. The built architecture resulted from multi-mode research, intending to investigate problems and needs of UHs.

## 1.3. Objectives

### 1.3.1. General Objective

The research objective is to investigate and propose an Information Systems Architecture Model to University Hospitals through a case study at Clinics Hospital of the Federal University of Pernambuco, from methodological factors found in the Systematic Review of Literature.

### 1.3.2. Specific objectives

i. Systematize the benefits brought by Enterprise Architecture according to each health environment's specific characteristics, such as whether they are public or private hospitals, health information systems (HIS), digital health (e-health), based on systematic literature review.
ii. Systematize the methods and frameworks used to implement the Enterprise Architecture in reference hospitals based on the systematic literature review.
iii. Categorize the HC-UFPE business's macro processes, identifying problems, challenges, limitations, and critical success factors in hospital management practice using information technology
iv. Develop an Information Systems Architecture model for application at HC-UFPE and possibly in other University hospitals in Brazil.

## 1.4. Methodology

The methodology used in this work comprises two main steps:

### 1.4.1. Systematic literature review (SLR):

The systematic literature review (SLR) was a method chosen to start this research. Its results can assist the realization of the case study at Clinics Hospital of the Federal University of Pernambuco. The SLR allowed us to understand relevant and current factors on the state of the art of applying Business Architecture in Health and collect information on how it was applied, its application, the success factors, and the difficulties encountered. Five researchers conducted the RSL, in which they composed two teams. The researchers were two undergraduate students, two advisors, and this graduate student, managing all the processes.

#### *1.4.1.1. Elaboration of research questions for SLR*

The researchers defined the main research question and the eight specific questions that provided a theoretical scientific basis for the case study. The main question is "RQ1 - What is the state of the art of applying Enterprise Architecture in healthcare systems?". The specific questions aimed to analyze the primary and empirical studies about EA's practical application in healthcare systems, such as methodologies and tools most used and the criteria for their choice. RSL also identified the main positive impacts, challenges, and critical success factors described by the articles' authors and listed the main publication channels and authors who have published the most on the topic.

#### *1.4.1.2. Elaboration of a protocol for SLR*

The SLR protocol followed the methodology used by Kitchenham (2007) and Dybå & Dingsøyr (2008). The protocol defined four phases: phase one and two - selection of studies, phase three - Data extraction, and phase 4 - data synthesis. The publications were collected from a search string used in four scientific databases. They were Hubmed, Scopus, IEEE, and Science Direct.

#### *1.4.1.3. Conducting SLR*

RSL tasks were selecting, reading, extracting, and synthesizing data. Cohen's Kappa method was used to assess the researchers' level of disagreement, based on a table of values that guide the teams on the differences and offer greater transparency to the research. Disagreements were dealt with through meetings, in which researchers re-read and discussed disagreed topics until there was a consensus on the decisions.

### *1.4.2. Case study*

According to Yin (2005), a case study is an empiric scientific method of research that investigates data within an authentic context through in-depth analysis of one or more objects of analysis, which suits the context investigated in this work. A case study was chosen to investigate, model, and build the information systems architecture model of the Clinics Hospital of the Federal University of Pernambuco (HC-UFPE).

The factors raised in the systematic literature review, such as frameworks, methods, and tools used in the construction of Enterprise Architecture in Hospitals, carried out in the previous stage of this work, provided a basis for carrying out the case study. Based on the information acquired and analyzed, an Information Systems architecture model for HC-UFPE was built using the TOGAF conceptual methodology in conjunction with the open-source tool Archi, based on the modeling language of Archimate - TOGAF (Pankowska, 2018). Nugraha et al. (2017) concluded that TOGAF ADM is suitable for healthcare systems because it can encompass several phases facilitating business architecture construction. The method is detailed, flexible, and adjustable to changes and engineering demands. The case study followed the steps:

1. Registration and approval of the research in the ethics committees of HC-UFPE and the Federal Institute of Paraíba;
2. Documents analysis, semi-structured interviews with managers and key employees of strategic sectors of the hospital; use of the participant observation methodology to collect data on the work routine of employees of the institution's technology sector associated to professional experience of the author, given that he is an employee of the technology sector at HC-UFPE;
3. Analysis based on a data triangulation of collected data through an open coding;

4. Development of an initial Information Systems Architecture model, based on the TOGAF 9.2 framework, and Archimate 3.1 specifications, using the open-source tool Archi version 4.7.1, for application at HC-UFPE, which makes up the modeling of the main current and future business processes of the hospital IT sector.

This case study followed an exploratory approach, which, according to Robson (2002), aims to discover what is happening, seek new insights, and generate ideas and hypotheses for new research. It will use a combination of quantitative and qualitative data, which, according to Seaman (1999), provides a better understanding of the studied phenomenon. The quantitative data will come from information on the current infrastructure of HC-UFPE, such as the number of sectors, number of employees, and other documentation that provides data of this nature. On the other hand, the qualitative basis will be captured from interviews, observations, diagramming, and process modeling to help the construction of the Information Systems Architecture model for the hospital.

The case study methodology was chosen instead of action research because this work aims not to commit to changing or implementing a new management model for the hospital in question. Instead, this research proposes an EA high-level model based on findings from a systematic literature review, documents, data from macro-processes of the Information Systems of HC-UFPE, semi-structured interviews, and observations.

## 1.5. Contributions

The Systematic Literature Review gathers studies that provide relevant information on the EA's state of the art in healthcare systems, promoting a discussion about essential aspects of empirical research related to the implementation of EA in healthcare systems. The case study carried out in this research, on the other hand, seeks to contribute to hospital management, providing a proposal for an information systems architecture model in which relevant information was collected to assist in the strategic alignment of IT with other areas of the hospital. It can also sensitize the senior management of HC-UFPE so that the business architecture is extended to all sectors, providing a holistic view of the hospital's processes and assisting in decision-making that may bring benefits in quality service to the public.

Considering the network of university hospitals that make up the EBSERH - Brazilian Company of Hospital Services, to which the HC-UFPE is a part, the results of this research can serve as an instrument for reflection by managers of these hospitals and as a reference architecture for information systems to be considered in future changes.

## 1.6. Work Organization

Subsequent chapters are organized as follows. The Enterprise Architecture concept is presented in Chapter 2, including a description of TOGAF and implementation steps. Chapter 3 presents the methodology and main steps for conducting the systematic review of the literature. Chapter 4 describes the case study carried out at HC-UFPE. In chapter 5 is found the conclusion of this research, including suggestions for future work.

# 2. THEORETICAL BACKGROUND

## 2.1. Enterprise Architecture

Enterprise architecture is a management and technology practice dedicated to improving companies' performance, allowing them to see themselves in terms of a holistic and integrated view of their strategic direction, business practices, information flows, and technological resources (BERNARD, 2012). EA includes details about an organization's processes, resources, data, application systems, and IT infrastructure using various standardized representation techniques (KAISLER et al., 2005; LANKHORST, 2013). An enterprise-wide architecture should serve as an authorized reference, a source of standards for processes/resources, and a supplier of projects for future operational states. Moreover, as the methods of implementing and maintaining many of the best practices require a lot of resources and the scope is not comprehensive, the organization faces the challenge of deciding which to adopt, how to do it, and what overlaps, contradictions, and gaps produced from the resulting collection (BERNARD, 2012).

EA research focuses on the "strategic" implications of EA's efforts in the mission, vision, strategy, objectives, actions, and operations of the analyzed business systems (AIER, 2014; BOH AND YELLIN, 2007; ROSS et al. 2006). According to Bernard (2012), when EA is the architecture of an organization in all dimensions, it becomes the highest-level discipline and the authorized reference for standards and practices. Therefore, it makes the "best practice battle" dilemma disappear. Organizations use EA to decide what best practices should be adopted, what they will cover, and how they can relate to each other. There are several benefits achieved with the implementation of EA, among which can be mentioned:

- Increased transparency of accountability and informed the delegation of authority;
- Controlled risk management;
- Protection of the existing asset base by maximizing the reuse of existing architecture components;
- Proactive control, monitoring, and management mechanisms;
- Process, concept, and reuse of components in all organizational business units;

- Value creation through monitoring, measurement, evaluation, and feedback;
- Greater visibility that supports internal processes and external party requirements;
- Greater shareholder value; given studies that have demonstrated a correlation between increased shareholder value and well-governed companies.

When dealing with healthcare environments, as technology advances, there is increasing IT participation in providing healthcare services, with systems that assist professionals in making decisions that directly or indirectly affect patients. EA seeks to reflect the complexity of modern IT systems, which comprise hundreds of components, organized in different layers, with many relationships between them (SAMBUMURTHY; ZMUD, 2000; YOO et al., 2010).

The Adaptive Integrated Digital Architecture Framework (AIDAF) is an Enterprise Architecture framework that integrates an adaptive EA cycle for different business units. This integration involves the Architecture Council conducting architectural analysis and aligning the IT architecture strategy and each solution architecture in Information Systems or IT projects, including digital IT solutions (MASUDA et al., 2017).

Currently, several EA frameworks can help organizations with their management and governance processes. Furthermore, each of them has characteristics that can meet certain types of organizations and their specific needs. For example, in a comparative study between several EA frameworks conducted by Haghighathoseini et al. (2018), The Open Group Architecture Framework (TOGAF) was chosen as the most appropriate for hospitals.

## 2.2. TOGAF 9.2

TOGAF 9.2 considers the company as a system and strives to balance promoting the concepts and terminologies of ISO / IEC 42010: 2007 - ensuring that the use of terms defined by it is consistent with the standard, thus maintaining commonly accepted terminology that is familiar to most TOGAF readers. This framework deals with four types of architectural domains that are commonly accepted as subsets of a general corporate architecture (EA), all of which TOGAF was designed to support (GROUP, 2020):

1. The Business Architecture: defines the business strategy, governance, organization, and the central business processes - key business.
2. The Data Architecture: describes the physical and logical structure of the organization's data assets and the management capabilities of that data.
3. The Application Architecture: provides a model for the individual applications to be deployed, their interactions, and their relationships with the organization's primary business processes.
4. The Technology Architecture describes the logical software and hardware resources needed to support business services, data, and applications. Resources include IT infrastructure, networks, communications, processing, and standards.

The Architecture Development Method (ADM), a TOGAF method, provides a tested and repeatable process for building architectures, including a framework, content development, transition, and architecture implementation management. These activities are carried out within an iterative cycle of defining and implementing continuous architecture, allowing organizations to transform their companies in a controlled manner in response to business objectives and opportunities. The phases within the ADM are as follows (GROUP, 2020):

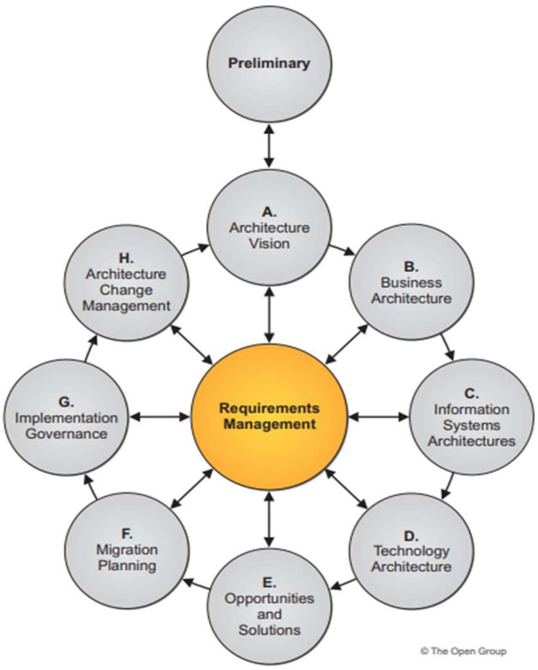
- Preliminary phase - describes the preparation and initiation activities necessary to develop an Architecture Capability, including customizing the TOGAF and defining Architecture Principles.
- Phase A: Architecture Vision includes information about defining the scope, identifying the stakeholders, creating the Architecture Vision, and obtaining approvals.
- Phase B: Business Architecture describes a Business Architecture development to support the agreed Architecture Vision.
- Phase C: Information Systems Architectures describes the Information Systems Architectures for an architecture project, including the development of Data and Application Architectures.
- Phase D: Technology Architecture describes the development of a Technology Architecture for an architecture project.
- Phase E: Opportunities and Solutions - describes the process of identifying

delivery vehicles (projects, programs, or portfolios) that effectively deliver the Target Architecture identified in previous phases.

- Phase F: Migration Planning - addresses how to move from the baseline to the target Architectures, finalizing a detailed Implementation and Migration Plan.
- Phase G: Implementation of Governance - provides architectural oversight of the implementation.
- Phase H: Architecture Change Management - establishes procedures for managing the change to the new architecture.

The ADM Architecture Requirements Management is a chapter looking at managing architecture requirements throughout the ADM. This phase ensures that the Requirements Management process is sustained and operates for all relevant ADM phases. Figure 1 represents all the mentioned phases.

Figure 1 - Phases of the TOGAF ADM processes




Source: (GROUP, 2020)

The construction of EA through ADM will produce process flows, architectural requirements, project plans, project compliance assessments, etc. The TOGAF Architecture Content Framework provides a structural model for architectural content that allows significant work products to be consistently defined, structured, and presented. It defines three categories to describe the type of architectural work product:

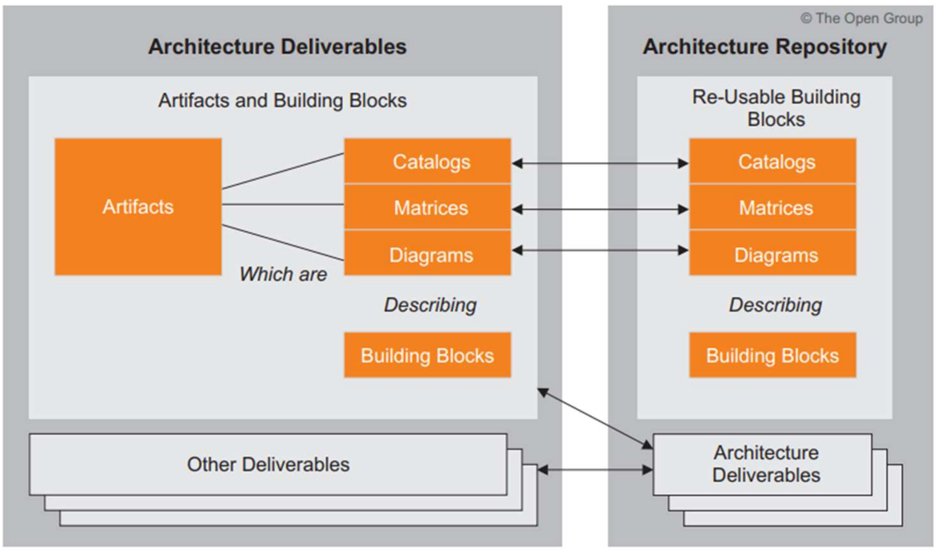
a) *A deliverable* is a work product formally reviewed, agreed, and signed off by the stakeholders. Deliverables represent the output of projects. Those deliverables in documentation form will typically be archived as results of a project or transitioned into an Architecture Repository as a reference model, standard, or snapshot of the Architecture Landscape at a point in time.

b) *An artifact* is an architectural work product that describes architecture artifacts generally classified as catalogs, matrices, and diagrams. An architectural deliverable may contain many artifacts that will form the content of the Architecture Repository.

c) *A building block* represents a (potentially re-usable) component of enterprise capability combined with other building blocks to deliver architectures and solutions. Building blocks can be defined at various levels of detail, depending on what stage of architecture development has been reached. Building blocks can report to "architectures" or "solutions."

Figure 2 presents a graphical representation of the interaction between Delivery, Artifacts, and Building Blocks present in the Architecture Deliveries and Architecture Repository.

Figure 2 - Relationships between Deliverables, Artifacts, and Building Blocks (GROUP, 2020)




Source: (GROUP, 2020)

The Information Systems architecture, represents Phase C and is divided into two main sections. The first has the objective of developing the Data Architecture and has the following steps:

a) Select reference models, viewpoints, and tools
b) Develop the description of the current data architecture
c) Develop a description of target data architecture
d) Perform gap analysis
e) Define the components of the candidate route
f) Resolve impacts across the architectural landscape
g) Conduct a formal stakeholder review
h) Finalize the data architecture
i) Create the architecture definition document

The second section aims to build the application architecture, and its steps are:

a) Select reference models, viewpoints, and tools
b) Develop the description of the current application architecture
c) Develop the description of the target application architecture
d) Perform gap analysis
e) Define the components of the candidate route
f) Resolve impacts across the architectural landscape
g) Conduct a formal stakeholder review
h) Finalize the application architecture
i) Create the architecture definition document

Although the focus of this work was the implementation of Phase C of TOGAF (Information Systems Architecture), this research also permeates parts of other phases of TOGAF, such as the Preliminary Phase (with the description and preparation of architectural activities), the Phase A (Architecture Vision), Phase B (Business Architecture), Phase D (Technology Architecture) and Phase E (Opportunities and Solutions), but within the context of the Information Technology Sector at HC-UFPE and its relations with others strategic areas of the hospital.

## 2.3. Archimate 3.1 Specification

Archimate is a visual language with a set of default iconography for describing, analyzing, and communicating many concerns of Enterprise Architectures as they change over time. The standard provides a set of entities and relationships with their corresponding iconography to represent Architecture Descriptions. It offers an integrated architectural approach that describes and visualizes different architecture domains and their underlying relations and dependencies. Its language framework provides a structuring mechanism for architecture domains, layers, and aspects. It distinguishes between the model elements and their notation to allow for varied, stakeholder-oriented depictions of architecture information. The language uses service orientation to distinguish and relate the Business, Application, and Technology Layers of Enterprise Architectures and uses realization relationships to relate concrete elements to more abstract elements across these layers (GROUP, 2020).

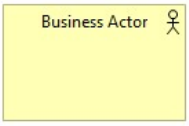
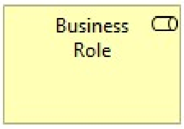
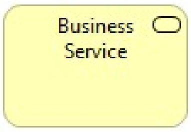
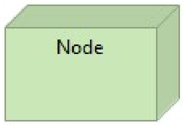
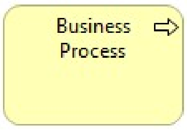
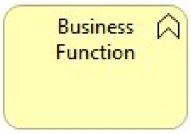
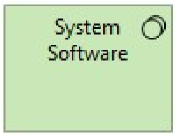
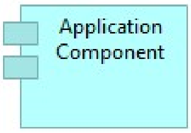
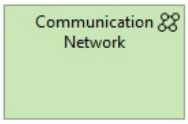
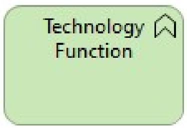
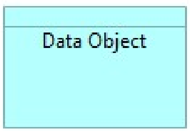
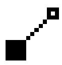
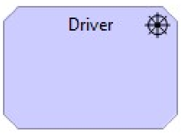
The ArchiMate language can be implemented in software used for Enterprise Architecture modeling. However, compliance requirements for Archimate implementations must be followed, including defined standards for terminology.

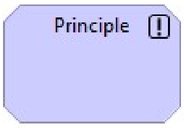
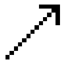
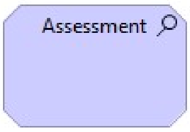
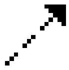
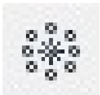
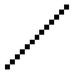
## 2.4. Archi® Software

Archi® is a free, open-source, cross-platform tool to create ArchiMate models and supports the latest version of the ArchiMate® 3.1 language. The download is available for free from https://www.archimatetool.com. Archi can be installed on Windows, Mac, and Linux (Beauvior & Sarrodie, 2021). A user guide is available on the website, which contains all the details, from installation to the specifications of the software's functionalities. The Archi tool has been quite complete for this research and offered a wide range of graphical representations that allowed the modeling of the information systems architecture at HC-UFPE according to the objective of this research.

It was not the focus of this work to present details of this tool. All documentation necessary to understand the symbologies used in the modeling of diagrams carried out in this work is found in the user guide available free of charge on the tool's website. However, the most used symbols and their graphical representations have been shown in Table 1.

Table 1 - Relationship between symbology and meaning used in Archi software

| Symbol | Meaning | Symbol | Meaning |
|---|---|---|---|
|  | Business Actor |  | Location |
|  | Business Role |  | Grouping |
|  | Business Service |  | Node |
|  | Business Process |  | Device |
|  | Business Function |  | System Software |
|  | Application Component |  | Communication Network |
|  | Application Function |  | Technology Service |
|  | Application Service |  | Technology Function |
|  | Data Object |  | Equipment |
|  | Stakeholder |  | Composition Relation |
|  | Driver |  | Access Relation |

| | | | |
|---|---|---|---|
|  | Goal |  | Realization Relation |
|  | Principle |  | Serving Relation |
|  | Assessment |  | Flow Relation |
|  | Visualiser |  | Association Relation |

Source: Extracted and adapted from Archi software

With the symbologies presented in Table 1, it will be possible to understand the modeling carried out for the information systems architecture at HC-UFPE, using Archi software in version 4.8.1, in line with Archimate 3.1 specifications.

## 2.5. Related Works

The related works that will be presented below were identified from the systematic literature review (SLR), which will be presented in chapter 3. The SLR is a methodological step of this master's work.

Haghighathoseini et al. (2018) presented an Enterprise Architecture structure located for the Iranian university hospital and made a comparative study between 17 frameworks, in which it extracted 44 general characteristics. The authors developed a survey to distinguish the necessity of those characteristics using the expert's opinions and the Delphi method. The result showed eight essential criteria. In the next step, using the AHP method, TOGAF was chosen to have appropriate characteristics and the ability to be implemented among reference formats. The last step was to create an Enterprise Architecture conceptual model using TOGAF framework. A survey with 145 questions was written based on literature review and expert's opinions for determining architecture framework parts. The results showed that 111 of 145 parts were chosen and certified to be used in the hospital. In conclusion, the results showed that TOGAF could be suitable for use in the hospital.

Vinci et al. (2016) described the research methods used as the basis for a proposal of an evaluation model of municipal and regional management of a Mental Health Care Network that comprises computerized information systems and specific indicators. The authors conducted a review of Brazilian legislation on management in mental health care networks formulation of semi-structured interviews with stakeholders to obtain the knowledge required from people who have extensive work experience in the field. Zachman's framework was used to support acquiring information on the reality of the network under study.

Mayakul & Kiattisin (2018) used the Delphi-technique to open the expert in-depth session to evaluate the conceptual framework with the assumption. Were selected experts who specialized in the medical, health informatics, health management, enterprise architecture, engineering, and IT management sectors from academics and management. Before the discussion, the researchers provide some EA briefings to ensure the experts understand the same EA concept. The question related to e-health goals, successful implementation factors, the public health role of e-health and technology, and unique or critical concern. In the second step, the framework was developed by breaking down the components from the interview. The authors developed a set of agreement questionnaires and used a Likert scale for measurement.

Purnawan & Surendro (2016) conducted a case study at Permata Group Hospital, in Indonesia, in which defined a suitable approach to build Enterprise Architecture for hospital information systems. The authors defined the architectural needs, analyzing the existing frameworks to fit the requirements, and tailoring the architecture as the proposed solution. This research made a comparative analysis between Zachman, TOGAF, FEA, and Gartner, based on criteria that were defined to establish scores on the characteristics of each analyzed framework. So, the researchers choose TOGAF to build a business architecture model for the hospital group. The research also used the methodology called Business Transformation Enablement Program (BTEP), a methodology that is a preferred methodology by TOGAF to assess business transformation readiness.

The related works used different methodologies and specification tools for applying EA in Healthcare systems that are quite relevant to our research's objectives. The choice of the most appropriate framework or tool for each specific health environment, based on comparative tables, is a methodology that helps the researchers cover their perception of these tools' strengths and weaknesses. However, there are relevant differentials in this qualification proposal compared to related works, and SLR analyzed studies in general. This research is applied to HC-UFPE, a large Federal University Hospital governed by Brazilian public policies. Federal Universities Hospitals are an essential player responsible for teaching, research, and high complexity healthcare. They are associated with the big, broad, and complex healthcare system UHS. The Systematic Literature Review did not find any work applying EA in university hospitals in Brazil. We feel motivated to start this research to contribute to the hospital management of HC-UFPE and for new studies to be carried out in the other university hospitals in Brazil, seeking to improve the provision of services to patients increasingly.

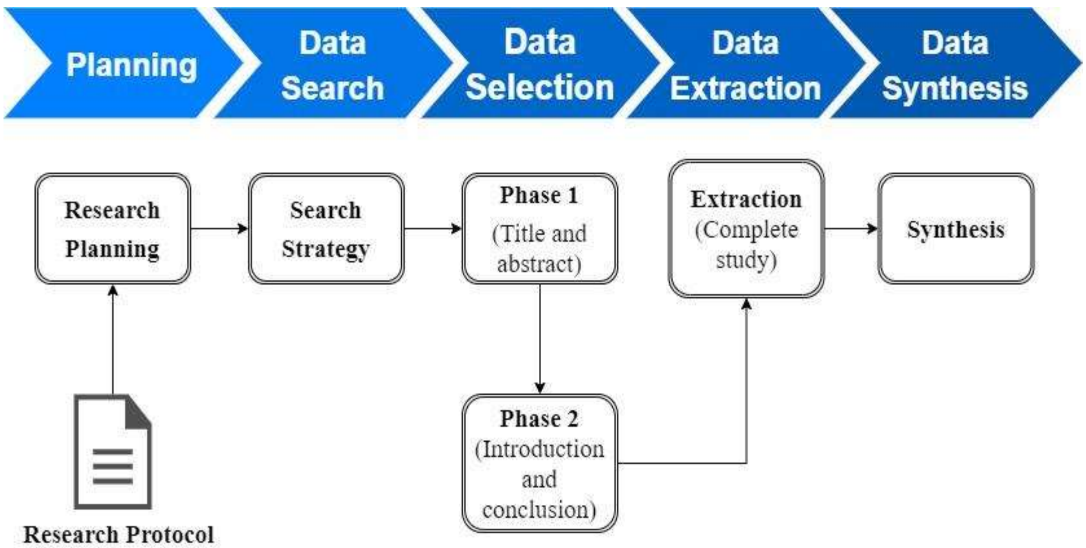
# 3. ENTERPRISE ARCHITECTURE IN HEALTHCARE SYSTEMS:A SYSTEMATIC LITERATURE REVIEW

The systematic literature review (SLR) carried out in this work will be presented below. This step was carried out by two groups of researchers, and a protocol was drawn up to define the methodologies and phases of the review.

## 3.1. Systematic Literature Review Protocol

The protocol in this research complies with the guidelines and procedures of Kitchenham (2007) for conducting Systematic Literature Reviews (SLR) in Software Engineering. It is complemented by the approach of Dybå & Dingsøyr (2008) in the sense of mapping the methodological evidence that concerns the state of the art of Enterprise Architecture application in healthcare environments. The result can help researchers understand the current leading practices, motivations that led to the choice of frameworks, methods, models, methodologies, and tools for applying EA in healthcare systems. Figure 3 shows the systematic review flow chart.

Figure 3 - Systematic review flow chart




Source: Own authorship

The main research question that motivates this study is: RQ1 - What is the state of the art of the Enterprise Architecture's application in Healthcare Systems? In other words: How has the domain of Enterprise Architecture influenced healthcare management and/or governance? Given the broad scope of RQ1, the following research questions help to map evidence that will identify specific aspects of EA's phenomenon applied in healthcare systems:

- RQ2 - What are the most used methodologies, frameworks and best practices guide for the application of Enterprise Architecture in Healthcare systems?
- RQ3 - What are the most used tools and models for the development of the Enterprise Architecture in Healthcare systems?
- RQ4 - What are the criteria for choosing the methodology, framework, and tool used for application of the EA in Healthcare systems?
- RQ5 - What problems or challenges the application of EA in Healthcare systems face?
- RQ6 - What are the main positive impacts achieved with the application of Enterprise Architecture in Healthcare?
- RQ7 - What is the context of the application of Enterprise Architecture in healthcare systems?
- RQ8 - What are the main publication channels, and who are the most influential authors on the topic of EA in healthcare systems?
- RQ9 - What are the main critical success factors mentioned for the application of Enterprise Architecture in Healthcare systems?

From the research questions above, the authors extracted the constructs to identify and codify the main characteristics found during this study. For RQ2, the constructs were methodology, framework and good practice guide; for RQ3, models and tools; and for RQ4, criteria for choosing the framework or tool; RQ5, problems and challenges; RQ6, positive impacts; RQ7, context/environment of the application; RQ8, publication channels and authors; RQ9, critical success factors. The following parameters were used as exclusion criteria: Studies not published in English; (2) studies that did not report empirical findings or literature that was only available in the form of extended abstracts, abstracts or presentations; (3) articles published before 2015; (4) secondary or tertiary studies; (5) studies that do not present the application of Enterprise Architecture in healthcare systems; (6) inaccessible study. The inclusion criteria are studies that answer at least one specific research question. The strategy of this survey used the following scientific web databases: (1) Hubmed, (2) IEEE, (3) ScienceDirect and (4) Scopus.

According to Kitchenham (2007), depending on the specific needs of each database search engine, SLR protocols build strings from the research question structures, and sometimes adaptations are necessary. At this point, this research string considered studies with the following terms: (1) Enterprise Architecture; (2) Health; (3) Hospital. Terms were found anywhere in the searched documents. They were combined in boolean expressions AND and OR, adapted for each search engine, but obeying the following expression: *S1 = ((1) AND (2)) OR ((1) AND (3))*.

The studies collected by the strings in the search engines went through a filtering process set in two phases. In Phase 1, the protocol analyzed the studies title, summary, and keywords, excluding the articles that could not answer any of the research. The articles selected in this first phase went to Phase 2, in which researchers read the studies introduction and conclusion. The selection of studies was carried out by all researchers, reducing the chances of discard relevant studies (Edwards et al., 2002). During the selection process, based on the method used by Tallon et al. (2019), the researchers worked through entire search results to ascertain if the publications found were relevant to a discussion of the application of EA in healthcare systems.

The researchers were split into two teams, and each performed the reading and selection of all studies, according to the definitions of each phase. To assess the level of agreement between the teams, Cohen's Kappa was applied, an association measure used to describe and test the degree of agreement (reliability and precision) in the classification (KOTZ et al., 2006). Landis & Koch (1977) characterized different ranges for Cohen's Kappa values, regarding the degree of agreement that these values suggest, according to the following description: For value < 0,00 – Poor; between 0,00 and 0,20, slight; between 0,21 and 0,40, fair; between 0,41 and 0,60, moderate, between 0,61 and 0,80, substantial; between 0,81 and 1,00, almost perfect. The Cohen's Kappa is calculated by:

$$Kappa = \frac{P(0) - P(E)}{1 - P(E)}$$

- P(0): observed proportion of agreements (sum of the answers agreed divided by the total);

- P(E): expected proportion of agreements (sum of the expected values of the answers agreed divided by the total).

Cohen's Kappa is an interobserver agreement measure that allows for assessing if the agreement is beyond what is expected by chance, and the degree of this agreement. This measure has its maximum value as the unit value, which represents total agreement. Values close to and even below zero indicate no agreement or strong disagreements between the judges.

## 3.2. Data extraction Strategy

After the Studies Selection phase (Phase 1 and 2), the researchers on the extraction phase read the included studies entirely (with the possibility of exclusion if there is no clear pertinence of the study to the context addressed in this survey). Data Extraction Phase seeks to answer the research questions. At this stage, all researchers independently performed the analysis and compared the results. Conflicts were resolved by consensus through a disagreement meeting.

The tool used for data extraction and synthesis was MaxQDA, a qualitative analysis software. In this phase, the information to be extracted from the studies were those that were related to, or that answered some specific research question. Whenever necessary, researchers took essential notes that helped in the process of synthesizing. The researchers worked separately at MaxQDA performing article extraction, following the process of joining (merge) all of the extractions using the MaxQDA itself.

## 3.3. Data Synthesis

The adoption of this synthesis method assumes the homogeneity of the studies included in the analysis. To assist in the analysis process, we also used the MaxQDA tool in this phase to generate reports, in which it was possible to identify the correlation between the studies and the research questions, as well as to quantify these correlations with graphs and tables.

The synthesis carried out for each RQ followed specific methods adapted to each question's proposal. For RQ2, RQ3, RQ7, RQ8, and RQ9, researchers used a deductive approach, focused on the actual body of the text, in which the elements analyzed have clear and precise definitions to answer the research questions, and were classified following the explicit mention of the authors. For RQ4, RQ5, and RQ6, researchers used the method of document analysis performed by Tavakoli et al. (2017). The classifications of the coded excerpts were based on analyzes of the contextual content, using a mainly inductive approach.

Due to the volume of information extracted from the questions RQ5 and RQ6, researchers create groupings of terms with semantic congruence, following the methodology of the thematic analysis coding (EZZY, 2002) to prepare groupings of definitions and concepts found in the analysis of the extraction. The documentary analysis allows the transition from a primary or original document to a secondary material that is an analytical and synthetic representation of the first, made through approximations that use theoretical frameworks of analysis (BOWLING, 2009; LIAMPUTTONG & EZZY, 2009). The process used tables to assist the analysis by creating semantic groups to cover the totality of the extractions of RQ5 and RQ6, being reviewed by all researchers. The divergences and additions were treated by consensus in the meetings.

## 3.4. Results and discussion

The search strategy found 302 studies, of which 16 were in IEEE, 55 in SCOPUS, 184 in Science Direct and 47 in Hubmed. The search string needed to adapt to the specificities of each repository. The protocol filtered the selections by the last five years from the beginning of the research (2015-2019). To ensure the reliability of the selections, each team performed the same procedures and compared the results of the quantitative studies selected.

In Phase 1, after the processes of eliminating duplicate studies and applying the exclusion criteria defined in the protocol, researchers analyzed the introduction, the abstract, and the keywords of the remaining 280 studies. If a study led to a divergence between the teams on the inclusion/exclusion criteria, researchers included it for Phase 2. It resulted in a total of 68 studies, as shown in Table 2. Cohen's Kappa for Phase 1 resulted from the analyses of the two teams, which was 0.79, which represents a substantial agreement, as illustrated in Table 2.

Table 2 - Cohen's Kappa from Phase 1

| Calculated Cohen's Kappa | | | |
|---|---|---|---|
| ***Kappa Value*** | **0,79** | ***Team 1*** | |
| | | *Included* | *Excluded* |
| ***Team 2*** | *Included* | 49 | 8 |
| | *Excluded* | 11 | 212 |
| ***Total of studies selected*** | | | **68** |

Source: Own authorship

In Phase 2, the studies were gathered in PDF format, but it was not possible to access three of them integrally due to their availability; therefore, researchers excluded these studies considering exclusion criteria EC06 "inaccessible studies." These studies are: (MOCKER & ROSS, 2018), (DARVISHZADEH et al., 2019) and (AFWANI et al., 2018). Therefore, the introductions and conclusions of the 65 studies were analyzed simultaneously with eleven exclusions. Cohen's Kappa was also used in this phase and was scored 0.59 (moderate agreement level), according to Table 3.

Table 3 - Cohen's Kappa from Phase 2

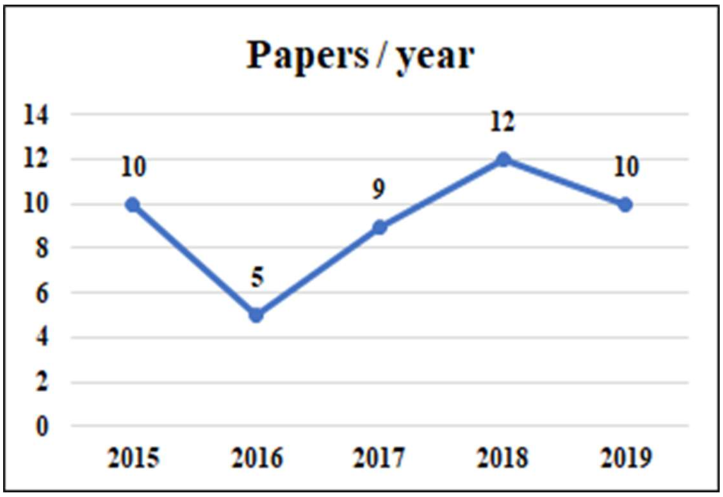
| Calculated Cohen's Kappa | | | |
|---|---|---|---|
| ***Kappa Value*** | **0,59** | ***Team 1*** | |
| | | *Included* | *Excluded* |
| ***Team 2*** | *Included* | 44 | 1 |
| | *Excluded* | 9 | 11 |
| ***Total of studies selected (after meeting)*** | | | **49** |

Source: Own authorship

Following the methodology proposed in the protocol, the two teams resolved the disagreements resulting from Phase 2 through a "disagreement meeting." They reconsidered the disagreements by re-reading the introduction and conclusion of the ten studies in question. By consensus, they decided to include 5 of them for Phase 3, resulting in a total of 49 studies. In phase 3, each team read the 49 studies in full, in which there was a consensus to exclude three more articles that did not answer any of the research questions in this systematic review, totaling 46 studies. The researchers used MaxQDA to conduct the entire extraction process, a qualitative analysis tool used to categorize relevant information through the use of codes, colors, symbols, or even emoticons. They perform statistical analysis of these data, allowing a holistic view of all work done on the software. The segment encodings and annotations made in the studies using MaxQDA were exported, through the software itself, in a spreadsheet in .xls format, and used for team analysis in the data synthesis phase.

In phase 4, the researchers conducted the data synthesis process on a thorough analysis of the spreadsheets and graphs resulting from the extraction process carried out by the two teams of researchers using the MaxQDA tool and Excel. The two teams analyzed the coded excerpt and annotations in the 46 studies to see if there was any inconsistency in the relationship between the extracted segments and the research questions. Figure 4 shows the graph with the distribution of these studies in the years 2015 to 2019, which represents an average of 9 studies published per year.

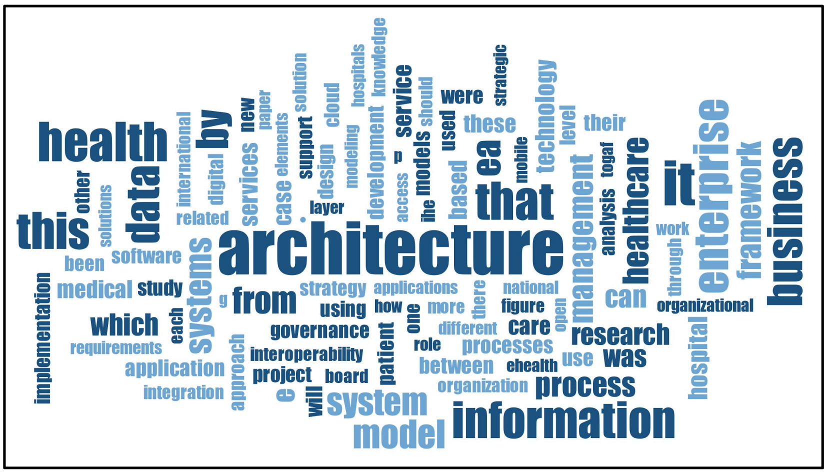
Figure 4 - Number of studies per year




Source: Own authorship

Figure 5 illustrates the word cloud, generated from the 46 studies, in which approximately 15500 words are present. The most common terms, excluding connectors like “the”, “of”, “in”, which do not add value to the formation of the cloud were “architecture”, “health”, “information”, “enterprise”, “business”, “data” and “healthcare”.

Figure 5 - Word cloud of the 46 selected studies




Source: Own authorship

To simplify the arrangement of data in the tables that respond to the RQ's, we created equivalence codes for each of the 46 references of the selected studies, as shown in Table 4. Sections 4.4.1. to 4.4.9. presents the research questions, and the results found by the teams in the data extraction process.

Table 4 - Equivalence code for references

| Autor | Cód. | Autor | Cód. |
|---|---|---|---|
| (NUGRAHA et al., 2017) | A1 | (OLSEN, 2017) | A24 |
| (YAMAMOTO; TRAORÉ, 2017) | A2 | (ELDEIN et al., 2017) | A25 |
| (MEMON et al., 2019) | A3 | (ATEETANAN et al., 2017) | A26 |
| (WAUTELET, 2019) | A4 | (BYGSTAD; HANSETH, 2016) | A27 |
| (ZWIENEN et al., 2019) | A5 | (HANDAYANI et al., 2019) | A28 |
| (MAYAKUL et al., 2018) | A6 | (TRAORÉ; YAMAMOTO, 2018) | A29 |
| (MASUDA et al., 2019) | A7 | (HAGHIGHATHOSEINI et al., 2018) | A30 |
| (FELTUS et al., 2015) | A8 | (BAKAR; SELAMAT 2016) | A31 |
| (MAYAKUL; KIATTISIN, 2018) | A9 | (JAVED et al., 2015) | A32 |
| (MOTOC, 2017) | A10 | (FOSSLAND; KROGSTIE, 2015) | A33 |
| (TARENSKEEN et al., 2015) | A11 | (STÄUBERT et al., 2015) | A34 |
| (YAMAMOTO; ZHI, 2019) | A12 | (PANKOWSKA, 2015) | A35 |
| (LESSARD et al., 2017) | A13 | (VINCI et al., 2016) | A36 |
| (MASUDA et al., 2018) | A14 | (TARENSKEEN et al., 2018) | A37 |

| | | | |
|---|---|---|---|
| (PURNAWAN; SURENDRO, 2016) | A15 | (PANKOWSKA, 2018) | A38 |
| (MASUDA et al., 2019) | A16 | (MASUDA et al., 2017) | A39 |
| (GEBRE-MARIAM; FRUIJTIER, 2018) | A17 | (WINTER et al., 2018) | A40 |
| (AHMAD et al., 2018) | A18 | (BEŠTEK; STANIMIROVIĆ, 2017) | A41 |
| (MOUSAVI et al., 2018) | A19 | (KAUSHIK; RAMAN, 2015) | A42 |
| (RIJO et al., 2015) | A20 | (GEBRE-MARIAM; BYGSTAD, 2016) | A43 |
| (ADENUGA et al., 2015) | A21 | (HERDIANA, 2018) | A44 |
| (YAMAMOTO et al., 2019) | A22 | (NORAN, 2015) | A45 |
| (AJERA et al., 2019) | A23 | (TOMA et al., 2019) | A46 |

Source: Own authorship

### 3.4.1. RQ2 – What are the most used methodologies, frameworks and best practices guide for the application of Enterprise Architecture in Healthcare systems?

To answer the RQ2, the researchers considered data extracted from the studies referring to which methodologies cover the development of EA in healthcare systems. Table 4 shows that the TOGAF framework was applied in 11 studies, representing 22% of the applications, followed by AIDAF, with 5 (11%), Weil, and Ross with 3 (6%) and Zachman's framework, applied in 2 studies (4%). These four frameworks were the most used in Health EA applications, representing a total of 43%. Many of these 46 selected studies performed combinations between frameworks, methods, methodologies, or proper practice guides to achieve a broader scope of work. In A30, the authors apply TOGAF alongside Kendall's W method (OKOLI & PAWLOWSKI, 2004), a non-parametric statistical method used to assess agreement between evaluators. They used AHP (VARGAS, 2010), a method to support decision-making, and ANOVA (STATISTICS, 2018), a one-way variance analysis method used to determine whether there are statistically significant differences between the means of three or more independent (unrelated) groups. In Table 5, it is also possible to verify the countries where these frameworks were applied, the total number of studies and their references.

Table 5 - Most used methodologies/frameworks/best practices

| Methodology /Framework / Best practices guide | Country | Nº Papers | Identified studies |
|---|---|---|---|
| TOGAF (The Open Group Architecture Framework) | Indonesia, Japan, Iran, Malaysia, Netherlands, Poland | 11 | A1, A2, A10, A25, A28, A29, A30, A31, A37, A38, A44 |

| | | | |
|---|---|---|---|
| AIDAF (Adaptive Integrated Digital Architecture Framework) | Japan, Germany | 5 | A7, A14, A16, A39, A46 |
| Weil and Ross | Netherlands, India, Norway | 3 | A11, A42, A43 |
| CVI (Content Validity Index ) | Thailand, Iran | 2 | A6, A19 |
| Delphi Technique/method | Thailand, Iran | 2 | A9, A30 |
| Zachman's framework | South Africa, Brazil | 2 | A21, A36 |
| IDEFØ | Norway, Australia | 2 | A33, A45 |
| O-DA (Open Dependability through Assuredness) | Japan | 1 | A2 |
| ISO 42030 - Architecture Evaluation Framework | Australia | 1 | A3 |
| I-Tropos | Belgium | 1 | A4 |
| MoDrIGo standing for Model-Driven IT Governance | Belgium | 1 | A4 |
| NFR tree | Belgium | 1 | A4 |
| Design Science | Netherlands | 1 | A5 |
| i* framework | Thailand | 1 | A6 |
| JCI (Joint Commission International) | Thailand | 1 | A6 |
| Kappa | Thailand | 1 | A6 |
| ADR (Action Design Research) | Belgium | 1 | A8 |
| BIE Generic Schema | Belgium | 1 | A8 |
| An e-health Enterprise Architecture framework | Thailand | 1 | A9 |
| DM (Design Matrix) | Netherlands | 1 | A11 |
| FEAF (Federal Enterprise Architecture Framework) | Canada | 1 | A13 |
| ESIA Method | Indonesia | 1 | A15 |
| ANT (Actor–Network Theory) | Ethiopia | 1 | A17 |
| BPAOntoEIA framework | Jordan | 1 | A18 |
| Riva Method | Jordan | 1 | A18 |
| Expert Panel Method | Iran | 1 | A19 |
| ISO TR 14639 | Iran | 1 | A19 |
| Gartner | Portugal | 1 | A20 |
| MBJT (Model Based Jobs Theory) | Japan | 1 | A22 |
| FAIR (Factor Analysis of Information Risk) | Japan | 1 | A29 |

| | | | |
|---|---|---|---|
| AHP (Analytical Hierarchy Process) | Iran | 1 | A30 |
| ANOVA (One-way Analysis Of Variance) | Iran | 1 | A30 |
| Kendall's W | Iran | 1 | A30 |
| BSC (Balanced Scorecard) | Malaysia | 1 | A31 |
| Malaysian Public Sector Enterprise Architecture Framework - 1 Government Enterprise Architecture (1GovEA) | Malaysia | 1 | A31 |
| Enterprise architecture planning (EAP) | Germany | 1 | A34 |

Source: Own authorship

### 3.4.2. RQ3 – What are the most used tools and models for the development of the Enterprise Architecture in Healthcare systems?

In Table 6, there are tools and models used in the development of EA in Healthcare environments, corresponding to RQ3. The most applied software was Archimate EA; it was found in nine studies, representing 17% of the applications, followed by BPMN with 6% and 3LGM² with 4%. Some studies combine different tools and models in a unique Enterprise Architecture strategy. As can be seen in A38, this paper applies the Archimate tool, BPMN, and CMMN models to perform the modeling of EA for hospitals.

Table 6 - Most used tools/models

| Tool / Model | Country | Nº Papers | Identified studies |
|---|---|---|---|
| ArchiMate EA | Indonesia, Belgium, Japan, Poland | 9 | A1, A2, A8, A12, A22, A25, A29, A35, A38 |
| BPMN (Business Process Model and Notation) | Thailand, Norway, Poland | 3 | A26, A33, A38 |
| Likert scales | Thailand, Iran | 2 | A9, A19 |
| Ampersand | Netherlands | 2 | A11, A37 |
| 3LGM² (Three Layer Graph Based Meta Model) | Germany | 2 | A34, A40 |
| CASE (DesCARTES Architect) | Belgium | 1 | A4 |
| DyAMM | Netherlands | 1 | A5 |
| ZiRA | Netherlands | 1 | A5 |
| SWOT | Thailand | 1 | A6 |
| Node-RED | Thailand | 1 | A7 |
| Ptolemy | Thailand | 1 | A7 |

| | | | |
|---|---|---|---|
| ReMMo (Responsibility metamodel) | Belgium | 1 | A8 |
| RBAC | Belgium | 1 | A8 |
| Reference domain model for Hospitals | Netherlands | 1 | A11 |
| V Model | Netherlands | 1 | A11 |
| Consolidated Reference Model (by FEAF) | Canada | 1 | A13 |
| BTEP (Business Transformation Enablement Program) | Indonesia | 1 | A15 |
| Java-based OWL APIs | Jordan | 1 | A18 |
| Limesurvey | Iran | 1 | A19 |
| The Essential Project EA tool | Portugal | 1 | A20 |
| Troux EA tool | Norway | 1 | A24 |
| Service Blueprint (SB) | Thailand | 1 | A26 |
| CPM (Configurable Process Model) | Malaysia | 1 | A31 |
| SOA (Service-Oriented Architecture) | Pakistan | 1 | A32 |
| CMMN | Poland | 1 | A38 |
| STRMM (STrategic Risk Mitigation Model) | Japan | 1 | A39 |
| OAIS (Open Archival Information System) | Germany | 1 | A40 |

Source: Own authorship

### 3.4.3. RQ4. – What are the criteria for choosing the methodology, framework, and tool used for application of the EA in Healthcare systems?

In order to answer the RQ4, the researchers faced particular difficulty in the extraction of the excerpts because not all selected studies demonstrated which criteria they used to choose the framework, methodology, or tool to develop the Enterprise Architecture in the Healthcare system. Since it is a subjective question, it is necessary to deepen further the practical results achieved by these selected studies to answer this specific research question.

Eleven studies chose TOGAF as Enterprise Architecture methodology with different choice criteria, but some do not explicitly state it. In Nugraha et al. (2017), TOGAF is the selected framework because it has TOGAF ADM with several phases that facilitate the construction of enterprise architecture. The method is detailed, flexible, and adjustable according to changes and demands of engineering, in addition to being open-source. According to Eldein et al. (2017), TOGAF describes required business and Information and Communication Technology (ICT) architecture. Also, it provides a step by step approach in building and implementing enterprise architecture.

Handayani et al. (2019) developed a corporate architecture (EA) for a health referral information system (HRIS), including individual healthcare in Indonesia. They decided to choose TOGAF based on empirical and exploratory studies conducted in healthcare organizations. Tarenskeen et al. (2018) decided on the application of TOGAF because it is relevant for matching existing applications to a Radical Business Requirements Change. It serves as a roadmap for the transformation of a Base Architecture (AS-IS) to a Target Architecture (TO-BE). Herdiana (2018) concluded that TOGAF could be used to develop a wide range of enterprise architecture in conjunction with any other framework that focuses on a particular sector as designed as a generic framework.

Yamamoto & Traoré (2017) propose the O-DA (Open Dependability through Assuredness) standard, which applies in a case study on the African Healthcare Information System. O-DA was used to mitigate risks, for modeling dependencies, building assurance cases, and achieving agreement on accountability on the complex interoperable systems. Memon et al. (2019) recognized that ISO 42030 contributes to the maturity of architecture governance because it systematizes the elements to be considered by a process that supports architectural decision making.

Wautelet (2019) developed a framework called MoDrIGo, standing for Model-Driven IT Governance. It considers business IT services in as-is and to-be specifications to specifically support governance decisions, as well as, is made to perform at best in pure organizational i* modeling. Mayakul et al. (2018) justified the i* methodology is suitable to help them understand the primary resources and information flow within the enterprise at an early stage. The i* can present the relationship between entities and the contribution to the visibility of the information. At the same time, they used the international standard and quality control JCI because that is a global gold standard to perform as a standard regulator, advising and facilitating a healthcare organization towards better performance and outcome. Masuda et al. (2018) and Masuda et al. (2017) choose the Adaptive Integrated Digital Architecture Framework (AIDAF) based on adaptive enterprise service system logic expanding on the system of systems (SoS) and agility. At the same time, Toma et al. (2019) consider AIDAF an adaptive EA cycle that makes provisions for project plan and architecture design documents for new Digital IT related projects drawn up on a short-term basis. In addition to the fact that AIDAF is capable of flexibly adapting to new Digital IT projects continuously. Mayakul & Kiattisin (2018) use the method to information systems research, called technique Delphi, which has benefits for planning, needs assessment, policy determination, and resource utilization.

Lessard et al. (2017) present an architecture framework for LHS (Learning Health Systems), based on the Federal Enterprise Architecture Framework (FEAF) because the FEAF captures an organization's or system's human and technical components, enabling the alignment of multi-stakeholder goals within an organization's structure and technical systems. According to the author, the FEAF provides an ideal basis for LHS architectures situated in multi-professional health systems, such as hospitals or health maintenance organizations. Ahmad et al. (2018) state that Enterprise Architecture methods lack the knowledge of business processes in an enterprise. Therefore, the authors applied the BPAOntoEIA framework, which provides a semi-automatic semantic derivation of information categories from the Riva-based business process architecture of an organization. Rijo et al. (2015) decided, according to the goals for a proof of concept, to follow the aspects of the Gartner pragmatic approach, which is to create a shared vision among business owners, information specialists, and the technology implementer to drive profitability.

Adenuga et al. (2015) propose an Enterprise Architecture solution considering integration and interoperability issues while Vinci et al. (2016) describe an evaluation model to a regional health network management, both use in its solutions the Zachman's framework. The first justified the choice because the framework helps managers communicate efficiently and map enterprise architecture as a foundation for discussion that facilitates change. The second study considers Zachman's framework most suitable due to its clarity and objectivity to acquire information in a healthcare system. Yamamoto et al. (2019) use the Model-Based Jobs Theory (MBJT) because it fosters consistent visual modeling methods and integrates innovation and enterprise architecture using the ArchiMate tool, in addition to easily integrating MBJT and ConOps. Traoré & Yamamoto (2018) applied Factor Analysis of Information Risk (FAIR) methodology because it helps enterprises communicate on their risk information, thus aligning with the enterprise's needs through risk scenarios analysis and assessment analysis. Fossland & Krogstie (2015) adopted a top-down generic model IDEF0 since it is the best practice for logical/generic/conceptual process models. Stäubert et al. (2015) adopted enterprise architecture planning (EAP) because it is a method capable of designing or changing an information system according to the strategic goals of an enterprise. They also chose 3LGM2 because element types or using wildcards in the name or description fields enables the user to find IHE (Integrating the healthcare enterprise) concepts and because Enterprise architecture planning (EAP) tools like the 3LGM² tool help build up and analyze Information System models.

Beštek & Stanimirović (2017) applied the openEHR tool and the systematized terminology of Medicine SNOMED to define clinical data used for exchange over Integration Health Enterprise (IHE). OpenEHR tooling supports the modeling of core artifacts that are publicly available and consider SNOMED as the central terminology for mapping other existing terminologies because it is an ontology that enables complex relationships between the terms. They also adopted the guidelines of Continua Health Alliance in combination with IHE to exchange data between Electronic Health Record (EHR) and Personal Health Record (PHR) in a more suitable way, despite identified gaps and limitations. Lessard et al. (2017) analyzed that BSC is a method that helps identify the most important goals for an organization's performance and then enables the organization to monitor their achievement and impact on one another through a set of measures. Ahmad et al. (2018) adopt the Riva BPA design, an object-based approach with its foundation in the classical business analysis phase of the information engineering paradigm. They consider Riva BPA indicated for enterprise business process architecture.

Archimate was the most used model in the selected studies. Nugraha et al. (2017) selected Archimate to define a model to describe the development and operation of the business process, organization structure, and information path. It is a modeling standard language for enterprise architecture, and it is distinguished for its openness and independence. Its specification helps many enterprise architects explain, analyze, and visualize the relationships across business domains in less ambiguous ways. Furthermore, it can model general enterprise architecture in different areas. Traoré & Yamamoto (2018) emphasize that ArchiMate is an Enterprise Architecture visual language with a set of default iconography for describing, analyzing, and communicating many EA's concerns as they change over time. According to Pankowska (2015), the ArchiMate Canvas Model allows us to catch intangible requirements and emphasize the stakeholders' place in the system architecture. Pankowska (2018) chose it because its language and software tools are the most suitable for strategic issues visualization and analysis. Zwienen et al. (2019) adopt DyAMM as it is an existing model to serve as a basis for tailoring and also because

ZiRA incorporates the DyAMM. They consider that the ZiRA components are mostly product-oriented.

Mayakul et al. (2018) chose to use SWOT analysis, considering it is a standard analytical tool for strategic planning and policy implementation in various businesses. The BTEP was used in Purnawan & Surendro (2016) as a preferred methodology by TOGAF to assess business transformation readiness. Mousavi et al. (2018) chose Limesurvey because it is an online open-source tool for conducting a survey and performing the analysis. In Rijo et al. (2015), the choice was for the "The Essential Project tool," instead of ArchiMate, because the alignment between ArchiMate and TOGAF, making the use of this walkthrough more difficult, once of the framework used in this work was that of Gartner. The Essential Project was also chosen because it is open source.

It has found selection criteria for BPMN in three papers. Ahmad et al. (2018) mentioned that Business process models of the enterprise enrich semantically using the instantiated BPMN 2.0. Ateetanan et al. (2017) described that BPMN is a business process modeling standard and, indeed, the most used language for diagrammatically representing processes. It provides a standard business process model notation for describing and analyzing the business process in detail. Pankowska (2018) emphasizes that BPMN is dominant for business analytics, assuming BPMN can support business process orientation, as a more detailed analysis of researchers' tasks. This paper also used the CMMN, which reported that CMMN modeling provides some essential values to the business architecture modeling. Sometimes, in the domain of business process, modeling a certain degree of flexibility is required.

Winter et al. (2018) used $3LGM^2$ for modeling health information systems, especially trans-institutional information systems, and, therefore, the entire information system of SMITH (Smart Medical Information Technology for Healthcare). Winter et al. (2018) also used OAIS and justified that this model provides a framework, including terminology and concepts, to describe and compare architectures and operations of archives. Thus, for sharing their content, OAIS is the most common standard for archival organizations (ISO Standard 14721:2012). Masuda et al. (2017) applied the STRMM (STrategic Risk Mitigation Model) model as the Risk Mitigation model in the Architecture Board. It is based on the case study research Masuda et al. (2018) that verify that the Architecture Board can control the Solutions with "STRMM model for Digital Transformation."

### 3.4.4. RQ5 – What problems or challenges the application of EA in Healthcare systems face?

In response to RQ5, the researchers listed the main problems and challenges found in the selected studies related to the application of EA in Healthcare Systems, and grouped them into macro-categories according to the context of the issues, as shown in Table 7. They conducted the categorization through semantic congruence between the extracted excerpts. For instance, in A3, the author describes that "the health enterprise is a complex evolving system of systems (SoS) both on national and global scales." In A4, they suggest the administrative activities became more and more complicated. Therefore, given the semantic congruence of these segments, the category "organizational/cultural complexity of health environments" was created.

Table 7 - Main problems and challenges in implementing EA

| Problem/Challenge Category | Nº Studies | Study Reference |
|---|---|---|
| Organizational complexity of health environments | 13 | A3, A4, A10, A12, A15, A20, A23, A24, A26, A28, A31, A34, A43 |
| Difficulty in integrating/accessing data of various kinds | 8 | A2, A6, A9, A12, A14, A15, A20, A32 |
| Heterogeneous stakeholder interests; Communication problems | 7 | A12, A14, A15, A20, A24, A27, A31 |
| There is no clear definition of the organization's objectives/goals/processes. | 7 | A15, A20, A21, A24, A26, A27, A43 |
| Privacy and data security | 6 | A3, A14, A17, A21, A23, A29 |
| Lack of an appropriate model to the needs of the organization | 6 | A1, A8, A13, A14, A24, A32 |
| Organizational / IT capacity | 4 | A15, A17, A20, A31 |
| Lack of skilled professionals | 4 | A3, A17, A21, A31 |
| Political instability, laws, rules | 4 | A3, A6, A24, A31 |
| Costs | 3 | A15, A20, A21 |

Source: Own authorship

The researchers found several problems and challenge to implement EA in health systems, in which it was possible to abstract that the 4 main problems affect 21 of the 46 publications, that is 45%. Among them, organizational complexity is the most revealed among all the problems encountered, especially when the environments are hospitals, as they are usually organizations that are constantly changing for adaptations necessary to patient care. Regarding the difficulty in accessing or integrating data present in different sources, it is also a problem that has been widely commented on in publications, since health systems usually work with segregated data or from systems that do not have standard data and that do not integrate easily, which takes a lot of effort so that EA can capture consistent data to assist in decision making.

Communication problems and stakeholder interests are very common, as there are many conflicts regarding the definition of priorities, since managers from different areas compete with each other for investments in their sectors, believing that they are more important than the others. Another major problem mentioned is that the definition of goals, processes and objectives is something common to find in health sectors, as managers are usually very busy in solving recurring and current problems. This means that a lot of effort and time is concentrated in these activities considered urgent, making activities of strategic planning and process improvement to be considered in the second plan. Data security and privacy issues were a concern reported in 6 articles, which emphasized that normally healthcare environments work with sensitive patient data. This data may not always be available since there are ethical issues in the health field that prevent EA from analyzing this personal data to generate inputs for governance.

As for the lack of a model appropriate to the needs of the organization, mentioned in 6 articles, it summarizes the fact that the vast majority of EA frameworks and tools are very generic, and requires a very laborious adaptation process, as healthcare environments are usually complex and constantly changing. Therefore, finding a more suitable methodology has become one of the challenges for EA professionals in the health field.

Another important challenge is about the capacity of the organization or IT, as it was mentioned in 4 articles the difficulty that exists when a health system decides to implement EA, as it requires a lot of dedication in investing in infrastructure and professionals. In healthcare environments, it is common for there to be no inclination of top management to align IT to the business, so the IT sector has concentrated efforts on providing operational subsidies to serve the other sectors, which causes a gap between IT and strategic management, hampering the ability of IT and consequently of the organization, to start an EA implementation process. In addition, the lack of qualified professionals has been another relevant factor, because, even if there is an organization's interest in improving its governance through EA, barriers have been found in relation to the qualification of its IT professionals.

It was also mentioned the difficulty in finding suitable training sources and in some cases in the professional's commitment and dedication to acquire learning, which often makes the organization need to hire extra consultancies or outsourcing, which generates a cost that is sometimes considered very high and unviable by managers. Another problem encountered is the constant political changes, laws or rules that impact health systems. This has been mentioned mainly in publications in which EA has been applied in public hospitals, or public health systems, as political instability directly affects the goals and objectives of these organizations, causing their processes to be constantly changing, deviating the planning process for implementing EA.

### 3.4.5. RQ6 – What are the main positive impacts achieved with the application of Enterprise Architecture in Healthcare systems?

RQ6 sought to capture the main positive impacts achieved with the application of EA in Healthcare systems. In Table 8, the authors extract 68 excerpts from 19 studies that clearly explained findings for this research question. As in Table 7 - Main problems and challenges in implementing EA), the authors grouped the categories that had semantic congruence into categories, listed in order of the most cited positive impacts. Among these, the three most reported are: "Describes and categorizes the architecture and operation of business processes, organizational structure, and data to facilitate the acquiring information," mentioned in 20% of studies. Second, "it benefits from change management, process and quality improvement," present in five reviews (11%), followed by "systematizes the elements to be considered for decision making," in 5 (11%).

Table 8 - Positive Impacts

| Positive Impacts | Nº studies | Reference Studies |
|---|---|---|
| Describes and categorizes the architecture and operation of business processes, the organizational structure and data to facilitate the acquiring information | 9 | A1, A2, A4, A13, A19, A20, A28, A31, A42 |
| Improvement in change and process management | 5 | A13, A18, A19, A36, A43 |
| Systematizes the elements to be considered for decision making | 5 | A3, A13, A20, A42, A43 |
| Contributes to the maturity of management and governance | 4 | A3, A5, A13, A20 |
| Link business strategy, business operations and IT | 3 | A2, A4, A36 |
| Assists in the development and management of projects and processes | 3 | A8, A13, A28 |

| | | |
|---|---|---|
| Offers greater consistency and comprehensibility | 3 | A2, A10, A20 |
| Improves alignment between standards, security controls and legislative privacy measures | 2 | A2, A13 |
| Contributes to cost reduction | 1 | A1 |
| Facilitates the revolution and application of technology system | 1 | A1 |
| Contributes to problem management | 1 | A2 |
| Determines new organizational needs | 1 | A2 |
| Assists in the alignment and identification of goals and objectives | 1 | A13 |
| Allows simulation of possible business strategies as problem-solving | 1 | A20 |
| Collect lessons learned | 1 | A20 |
| Enables better alignment between stakeholders | 1 | A33 |

Source: Own authorship

Collecting information on positive impacts is challenging, as it requires that the EA has been in place in the organization long enough for the improvements to be noticed by managers. The benefits brought by EA, as most of the 19 articles selected for this question emphasize, are not always linked to tangible gains, such as cost reduction, reveled in just 1 article. But yes in abstract aspects, such as increasing organizational maturity, improving and documenting its processes, defining project needs and priorities, contributing to governance in general and mainly aligning IT to the business, which is one of EA's main objectives. However, when comparing Table 8 with Table 7, it is possible to observe that only 1 article mentioned that EA has contributed to a better alignment among stakeholders, while this is one of the main challenges for implementing EA. That is, at first we can see that aligning communication and understanding between stakeholders is a very challenging task that cannot be promised by EA. It is important for the organization to seek other means to try to close this gap, which has proved to be quite challenging.

### 3.4.6. RQ7 – What is the context for the application of Enterprise Architecture in healthcare systems?

RQ7 sought information about the Healthcare environment or context of Enterprise Architecture application. In Table 9, it presents that the most significant application was found in hospitals, followed by implementations of EA in digital health (e-Health) and Health Information System. The number of studies carried out in hospitals adds up to a total of 14 (30%); for applications in e-Health, 11 studies (24%), and 8 (17%) studies in HIS.

Table 9 - EA Environment /Application Context

| EA Environment/Application Context | No. studies | Reference Studies |
|---|---|---|
| Hospital | 14 | A4, A5, A6, A8, A11, A15, A16, A18, A20, A23, A26, A30, A37, A38 |
| Digital health (e-Health) | 11 | A10, A12, A19, A21, A22, A25, A27, A29, A35, A40, A46 |
| Health Information System (HIS) | 8 | A2, A3, A13, A17, A28, A41, A43, A45 |
| Public health system | 7 | A9, A24, A31, A33, A36, A42, A44 |
| Healthcare community (pharmaceutical companies, healthcare companies, etc.) | 5 | A7, A14, A32, A34, A39 |
| Primary Health Care Unit | 1 | A1 |

Source: Own authorship

Some studies did not identify the organizational type of the hospital where the research was carried out, public, private, or university. Among the studies that provided information, three were in public hospitals, such as A8, A11, and A26; two in private hospitals, A6 and A15; and one in a university hospital, A30.

### 3.4.7. RQ8 – Who are the main publication channels and the most influential authors on the topic of EA in Healthcare systems?

In response to RQ8, the researchers listed the fifteen main publication channels, listed in Table 10. The order established was for the channels that had more publications on the theme proposed in this review, followed by relevance, considering their impact factor in May 2020. 37% of publications on the topic were made by the first five publication channels, with emphasis on Smart Innovation, Systems, and Technologies, with five studies published on the topic, representing 11% of the total.

Table 10 - Publication Channels

| Conference / Journal | Qty. of publications | % | Impact Factor (May/2020) |
|---|---|---|---|
| Smart Innovation, Systems and Technologies | 5 | 11% | 0.59 |

| | | | |
|---|---|---|---|
| IIAI International Congress on Advanced Applied Informatics (IIAI-AAI) | 4 | 9% | 0.42 |
| Procedia Computer Science | 4 | 9% | 1.26 |
| CEUR Workshop Proceedings | 2 | 4% | 0.34 |
| Studies in Health Technology and Informatics | 2 | 4% | 0.44 |
| Government Information Quarterly | 1 | 2% | 6.43 |
| Journal of Systems and Software | 1 | 2% | 4.02 |
| International Journal of Medical Informatics | 1 | 2% | 3.59 |
| Healthcare Informatics Research | 1 | 2% | 2.87 |
| Procedia CIRP | 1 | 2% | 2.10 |
| International Conference on Research Challenges in Information Science (RCIS) | 1 | 2% | 1.02 |
| Methods of Information in Medicine | 1 | 2% | 1.11 |
| European Conference on Information Systems, ECIS | 1 | 2% | 1.05 |
| International Journal of Biomedical Engineering and Technology | 1 | 2% | 0.57 |
| International Journal of Enterprise Information Systems | 1 | 2% | 0.71 |
| Others | 19 | 41% | - |
| Total | 46 | 100% | - |

Source: Own authorship

Also, in response to RQ8, 144 authors who published the 46 selected studies were found. Table 11 lists the authors who published two or more articles from this selection, including the area of application of Enterprise Architecture in Healthcare Systems in which their publications addressed. As can be seen, nine studies (20%) were published by the three principal authors, addressing Enterprise Architecture in the Health Information System, e-Health, Hospital, and Community of Health. These authors had some publications together. Authors Seiko Shirasaka and Yoshimasa Masuda were also present in some publications by Shuichiro Yamamoto.

Dr. Shuichiro Yamamoto is currently a professor at the Graduate School of Informatics at Nagoya University. His current research includes Digital Balanced Scorecard toward Digital Transformation, DX Visualization Approach Using ArchiMate, and Tailoring Approach on Enterprise Architecture Framework towards DX. Dr. Yoshimasa Masuda currently works at the Computer Science Department, Carnegie Mellon University. Their current project is 'Digital architecture framework,' and MSc.

Seiko Shirasaka is a professor of the Graduate School of System Design and Management (SDM), Keio University. His fields of specialty include systems engineering, innovation, innovative design, concept engineering, model-based development, space systems engineering, system assurance, functional safety management, and standardization.

Table 11 - Main authors

| Main authors | Nº papers | Papers | EA application context |
|---|---|---|---|
| Shuichiro Yamamoto | 9 | A2, A7, A12, A14, A16, A22, A29, A39, A46 | Community of Health, e-Health, Hospital, HIS |
| Yoshimasa Masuda | 4 | A7, A14, A16, A46 | Community of Health, e-Health, Hospital, HIS |
| Seiko Shirasaka | 3 | A7, A14, A39 | Community of Health |
| Ovidiu Noran | 2 | A3, A45 | HIS |
| Tetsuya Toma | 2 | A16, A46 | e-Health, Hospital |
| Thomas Hardjono | 2 | A14, A39 | Community of Health |
| Malgorzata Pankowska | 2 | A35, A38 | e-Health, Hospital |
| Mariam Traoré | 2 | A2, A29 | e-Health, HIS |
| Rui Pedro C. Lopes Rijo | 2 | A20, A36 | Hospital, Public Health System |

Source: Own authorship

3.4.8. RQ9 – What are the main critical success factors mentioned for the application of Enterprise Architecture in Healthcare systems?

The RQ9 aimed to capture the critical success factors (CSF) reported by the authors in the implementation of Enterprise Architecture in Healthcare systems. Among the 46 studies analyzed, only two mentioned eight factors listed in Table 12. Other studies have had successful cases in the implementation of EA in Healthcare. However, the authors did not demonstrate the critical success factors, even the researchers considering lexical research supported by MaxQDA tool to reinforce the term's capture.

Table 12 - Critical Success Factors

<table>
<tr><th colspan="2">Critical success factors</th><th>Papers</th></tr>
<tr><td colspan="2">Commitment from CIO and top management</td><td rowspan="2">A14</td></tr>
<tr><td colspan="2">Collaboration between the architecture and PMO communities on Digital platforms</td></tr>
<tr><td>Internal Process Perspective</td><td>1. business driven approach; 2. clear communication; 3. strong governance; 4. mutual understanding; 5. clear planning, scope and coverage; 6. standard rules and EA process</td><td rowspan="2">A31</td></tr>
<tr><td>Learning and Growth Perspective</td><td>1. systematic assessment mechanism; 2. complete documentation; 3. learning culture; 4. skillful architect; 5. relevant training and certification.</td></tr>
</table>

| | | |
|---|---|---|
| Authority Support Perspective | 1. continuous support; 2. EA recognition; 3. mandated EA rules and processes; 4. positive political influence; 5. stakeholder participation | |
| Cost Perspective | 1. enough resources financial allocated; 2. economic pressure; 3. enough supply of other resources | |
| Technology Perspective | 1. Easy to use EA tools; 2. Standard tools, methodology, EA model or artefact | |
| Talent Management Perspective | 1. Retention of expertise | |

Source: Own authorship

The two CSFs mentioned in A14 for the application of EA in global healthcare companies (GHE) are focused on an approach linked to stakeholders. In other words, they reveal the importance of the commitment of key people in decision-making and their alignment with the other areas of the organization, so that the implementation of the EA has the necessary drive to be engaged in the strategic objectives. The commitment of the CIO and top management and the collaboration between the architecture and PMO communities on digital platforms were CFS's mentioned to solve problems and mitigate the risks related to architecture during the implementation of AIDAF in the GHE. The authors formulated the useful elements of the risk mitigation strategy with the Architecture Board and clarified the challenges and CSF's of digital architecture analysis on the Architecture Board for EA practitioners.

A31 described the experience of implementing EA in the public sector, in which a case study was conducted at the Malaysian Ministry of Health (MOHM) and identified six categories of critical success factors that allowed this implementation to be successful and that, according to the author, they can be guidelines for other public organizations. In what we can see in Table 12, the CSF's identified in A31 cover a larger scope of the organization, in which they are classified as perspectives. From an internal perspective, it is also emphasized, in other words, the importance of the performance of key people in the process of implementing EA. As well as the alignment of communication and mutual understanding are factors that are aligned with what was defined in A14. The perspective of growth and learning, in summary, seeks to solve questions about the qualification of professionals, in which it was mentioned as one of the challenges shown in Table 7. This perspective is also in line with the talent management perspective, where there is investment in hiring people with expertise in EA.

The perspective of authoritarian support considers factors that are also linked to political influence and rules that can directly affect the process of implementing EA. This CSF's seeks to solve a challenge that was also identified in A3, A6, A24 and A31 in Table

7, described as "Political instability, laws, rules". From a cost perspective, it is important that stakeholders understand the main objective of EA, and are committed to allocating the resources and inputs necessary for the implementation of EA, as well as for maintenance, which will require continuous investment for the EA is always up to date.

The technological perspective is directly linked to the challenge mentioned in A1, A8, A13, A14, A24, and A32, as shown in Table 7, in which there is a necessary effort to find the most appropriate frameworks and tools for the organization. This CSF requires that there is a clear definition of the organization's scope and needs and that it is aligned with what the available tools can offer.

### 3.4.9. Considerations of the systematic literature review

Enterprise Architecture is currently present in several business branches, and scientific literature discusses it widely, with professionals and researchers studying and applying its concepts worldwide. There is a diversity of methodologies, tools, and frameworks available, justifying the large number of diverse organizations that have used EA for management support and applied governance. Choosing what methodologies or tools are most appropriate could be costly and a complicated task. There are no standardized guidelines to implement Enterprise Architecture in a specific field (PURNAWAN & SURENDRO, 2016), which requires the ability to provide adaptations that meet the requirements of each company.

Most publications concerning the implementation of EA lack detailed and accurate information about the application environment or other data that could be relevant for the dissemination of good practices and the success achieved. Their inaccuracy and lack of detail often make the extraction of data a challenging job for conducting research. For instance, in some studies of this review, there was a lack of detail related to the characterization of the hospital where the research was conducted, leaving some question marks such as "is it a small, medium or large hospital?", or "is it a clinical or emergency hospital?". On the other hand, studies that have provided details about the nature of the health environment offered a significant scientific basis for other organizations that seek methodologies, methods, and tools to assist their management and governance.

These studies have the potential to become an essential empirical basis in selecting a set of good practices and making it possible to carry out studies with higher significance. Given the difficulties encountered concerning the detailed level of some studies, the researchers inferred that it occurs due to the insecurity of sharing certain types of data from companies or because of ethical or cultural reasons. The result of this SLR elucidates how researchers and professionals in the fieldwork with Enterprise Architecture applied the concepts and practices to healthcare systems and some criteria used for their choice. We also selected the main positive impacts that the authors described based on results achieved by an empirical approach, including critical success factors in some of these applications. Besides, this work brings the main publication channels and the most influential authors on EA in Healthcare Systems.

This SLR's primary motivation was to fill the gaps found in the current literature of systematic reviews and systematic mappings concerning success cases in the application of EA. Thus, this SLR described state of the art related to the application of Enterprise Architecture in Healthcare Systems, focusing on specific research questions that have made it possible to reveal practical aspects of EA implementation. This SLR contributes as a repository of relevant data to help researchers find successful EA cases in the healthcare environment and understand its implementation by answering these research questions. Therefore, the data collected can help researchers obtain information that will support them in spreading knowledge about EA, encouraging the production of new scientific and practical work in the field. Although we have a clearly defined scope of our work, the subject addressed is quite broad. It may stimulate the development of several other specific research questions that would further explain this phenomenon. Hence, we expect that this study will be a driving factor for researchers to conduct new SLRs and expand the understanding of the phenomenon of the application of Enterprise Architecture in healthcare systems.

This SRL culminated in two scientific articles published. One was presented at the 22nd IEEE 2020 International Conference on eHealth Networks, Applications, and Services (Healthcom 2020). This article is entitled Frameworks, Methodologies and Specification Tools for Enterprise Architecture Application in Healthcare Systems: A Systematic Literature Review (JÚNIOR et al., 2021), prepared with specific research questions RQ2, RQ3, and RQ4. The second article addressed the questions RQ5, RQ6, and RQ9. It was published in the journal IJEIS (International Journal Enterprise Information Systems), entitled “A Survey on the Application of Enterprise Architecture in Health System: Challenges, Positive Impacts, and Success” (MEDEIROS et al., 2021).

# 4. CASE STUDY

The case study sought to answer the question: "How methodological, technological, and innovation aspects of information technology management at HC-UFPE can be organized through an information systems architecture to guide, through well-established guidelines, the strategic objectives that IT must follow in its projects, processes, and services for the hospital?". For this, a case study was carried out at HC-UFPE, where data collection methodologies were applied to support the construction of current (AS-IS) and future (TO-BE) architecture models for the Information Technology Process Management Sector (ITPMS) of the hospital. The AS-IS models express current processes and services that the ITPMS performs, including its relationships with other hospital departments. On the other hand, the TO-BE models were the result of the interrelationships between stakeholders' views (collected through semi-structured interviews with senior management and ITPMS employees) and the policies defined in the Information and Communications Technology Strategic Plan for (ICTSP). ICTSP is the organizational document that guides, through well-established guidelines, the strategic objectives that IT must follow in its projects, processes, and services for the hospital.

The case study at HC-UFPE followed strict safety protocols, given that it was carried out during the COVID-19 pandemic. There were interviews with key stakeholders, consultations, and analyses of institutional documents from HC-UFPE. These documents were specifically the Strategic Plan for Information and Communications Technology (ICTSP), the Strategic Master Plan (SMP), documentation of the ICT Service Desk software, documentation on IT process flow, and information available on the HC-UFPE website[1], such as governance and organizational structure.

For the construction of the AS-IS and TO-BE architectures, the following data collection methods were addressed:

*AS-IS architecture:*

- Interviews with key stakeholders;
- Consultation with the Strategic Master Plan (SMP) of HC-UFPE;

[1] https://www.gov.br/ebserh/pt-br/hospitais-universitarios/regiao-nordeste/hc-ufpe

- Consultation of internal documents of strategic sectors that demonstrate flows of activities and processes that use services provided by IT;
- Consultation of internal documents of the IT sector, such as documentation of the TIC Service Desk software and documentation on the flow of IT processes;
- Collection of public data on the HC-UFPE website , related to the governance and organizational structure of the hospital;
- Participant observation in the IT sector;
- The researcher experience, given that he is an employee in the IT sector;

*TO-BE architecture:*

- Interviews with key stakeholders;
- Consultation of the Strategic Plan for Information and Communications Technology;
- Participant observation in the IT sector
- Researcher experience

The TO-BE architecture identified insights provided by stakeholders and participant observation, which demonstrate the main problems and challenges faced by the IT sector and possible solutions to these problems. This information allows the construction of the architecture of stakeholder views and a proposal for the future architecture of IT services.

The architecture of visions aims to align problems and challenges that impact user satisfaction (a critical success factor for IT management) with IT actions that are also aligned with the ICTSP. The future architecture of IT services offers a proposal that focuses on changes in the internal organization of the IT sector so that it can contribute to the organizational business, through alignment between hospital technology services and the needs of stakeholders.

Importantly, stakeholders were consulted each time the models were created, based on data collection. Each constructed part of the model was presented to the stakeholder responsible for the information to assess whether the construction matches what was said in the interview or consulted in the institutional documentation. They were also asked if they would like to propose changes until the final model is delivered.

## 4.1. Data collection

Researchers divided the data collection with managers and key employees into two stages - the first recorded interviews with senior management and strategic sectors members. It is said that strategic sectors are those sectors that are directly linked to hospital governance. People were chosen for the interviews for convenience, given that they participate in strategic decision-making and have their sectors with a high demand for technological resources. IT employees were also interviewed and observed. It is worth mentioning that the choice was intrinsically linked to the researcher's experience and observation, given that he has been a hospital employee for six years.

The second stage encompassed participant observation with the management and employees of the Management of Information Technology Processes Sector (ITPMS), including a document analysis. According to Jorgensen (2015), participant observation is a method through which the researcher participates actively with people in ordinary situations and environments of everyday life while observing and collecting information in another way. The researcher gains direct access to the physically observable environment and its primary reality as humanly significant experiences, thoughts, feelings, and activities. Through participation, it is possible to observe and gather many forms of data that are often inaccessible from a non-participating external observer. There is considerable consensus that participant observation is more appropriate when certain minimal study conditions are present:

a) A primary research interest concerns human meanings, feelings, and interactions seen from the perspective of native members of these situations and settings.
b) The phenomenon to be investigated is observable in some situations or the natural environment of everyday life.
c) The researcher can gain reasonable access to people and their activities in an appropriate environment.
d) The studied phenomenon is sufficiently limited in scope, size, and location to be examined through a case study design.
e) The issues or problems to be addressed are appropriate for the case studied.

In addition to the conditions mentioned above in which the research fits, the author is an Information Technology analyst at the ITPMS. He has specific access to employees of the sector itself. This research chooses the participant observation method to enrich the data collection from the hospital technology sector. The lead researcher consulted the ITPMS employees and made observations of their work routines, which allowed the model construction process to be carried out incrementally, in which adjustments were made as employees requested or suggested corrections or adaptations to the model built.

The semi-structured interviews conducted with managers and employees followed the qualitative research methodology proposed by Cormac (2019). This reference emphasizes that qualitative interviews allow researchers to explore, in-depth, issues that are unique to the interviewees' experiences, allowing for insights into how different phenomena of interest are experienced and perceived. Semi-structured interviews are based on scripts, and researchers can adjust them throughout the interview.

This type of interview is preferable when the researcher strives to understand the respondent's subjective perspective of a phenomenon rather than generating generalizable understandings of large groups of people. According to Reeves et al. (2015), the availability of time of the interviewees should be considered and, therefore, only include as many participants as necessary in the research project and who may have perceptions or experiences of the phenomenon in question.

The open coding method was chosen and used to analyze the transcribed responses from the interviews. In open coding, which is considered the first stage of data analysis (Hoda et al., 2012), the researcher explores the data through a thorough examination of what seems relevant after intensive reading of the texts (Serrano et al., 2020). In this research, it was possible to carry out the coding without the need for a qualitative analysis tool and other coding modalities, given that the transcribed answers were short and concise and the total number of answers was not high.

This research was approved by the Research Ethics Committee (REC) of the HC-UFPE (CAAE: 40066720.2.0000.8807) and the IFPB (CAAE: 40066720.2.3002.5185), and its registration was submitted to Plataforma Brasil[2], in addition to having been carried out in compliance with all protocols related to the prevention of COVID-19, as it was carried out during a pandemic period. The Free Informed Consent Term (FICT) was submitted to all interview participants (Appendix A), who allowed the audio to be

[2] https://plataformabrasil.saude.gov.br/login.jsf

recorded using a cell phone. The recordings and FICT's are stored under the researcher's care in a personal cloud platform. The interviews focused on capturing information about technical processes and services provided by ITPMS, for the construction of the AS-IS model, which refers to the current state of the architecture, in addition to seeking insights for the construction of the TO-BE model, which aims to deliver a future information systems architecture model.

Two scripts guided the interviews, one to interview stakeholders who are not part of the ITPMS staff and the other to interview ITPMS staff. The first script included questions about: the position and length of professional experience in the area in which the stakeholder works; collecting insights about the IT services/processes used by the department; and how IT can improve the delivery of value to the hospital. The script followed for these participants is shown in Table 13:

Table 13 - Script to semi-structured interview stakeholders who are not part of the ITPMS staff

| | |
|---|---|
| 1. | Position: ______________________________________________ |
| 2. | Time of experience: ______________________________ |
| 3. | Do you consider IT essential to your industry activities/activities? |
| 4. | Does your sector have processes that use IT services (systems, equipment)? |
| a. | What are the main processes? |
| b. | Are there documents/diagrams that record the flows of these processes? |
| c. | If not, who knows and can give you a step-by-step report on these processes? |
| 5. | How can IT improve service delivery? |

Source: Own authorship

Interviews lasted an average of 15 minutes. When answering the question "How can IT improve service delivery?" all respondents mentioned recurrent problems and gaps involving IT processes and services. They also reported probable solutions to these problems/gaps that can improve the delivery of IT services, in addition to promoting greater alignment of IT with other areas of the hospital. In the second script, for interviews conducted with ITPMS employees, researchers used questions that sought more details of internal IT processes in addition to the position and professional experience. Given that the built model refers to the architecture of information systems, the model's services and processes are inherent to the hospital's technology sector. The interviews followed the script, according to Table 14:

Table 14 - Script to interview stakeholders who are part of the ITPMS staff

1. Position: ______________________________________________
2. Time of experience: ______________________________________
3. What are the main services/processes provided by your department/area?
   a. Are there documents/diagrams that record the flows of these services/processes?
   b. Can you describe the flow?
      i. If not, who knows and can give you a step-by-step report on these processes?

4. How can IT improve the delivery of services provided by your department/area?

Source: Own authorship

However, despite interviews with some employees in the technology sector, the participant observation methodology for the ITPMS prevailed. It was possible to obtain a larger quantity of data, given that employees were frequently consulted to provide information and verify the constructed models. The interviewed stakeholders and their respective professional experience times are shown in Table 15:

Table 15 - Respondent List

| Stakeholder (Position/function) | Experience time (years) |
|---|---|
| Superintendent | 12 |
| Healthcare Manager | 12 |
| Teaching and Research Manager | 10 |
| Head of the Strategic Health Projects Sector | 15 |
| Head of the Quality Office | 4 |
| Head of the People Development Unit | 10 |
| Administration assistant (ITPMS employee) | 32 |
| Computer network technician (ITPMS employee) | 7 |

Source: Own authorship

Participant observation had the collaboration of 3 more analysts and 1 IT technician, in addition, the main researcher of this work is an IT analyst with 13 years of professional experience. The second stage of conducting this research is a case study, which according to Yin (2005), is an empirical scientific research method investigating data within a real context through an in-depth analysis of one or more analysis objects, which fit the investigated context. The case study has three main characteristics:

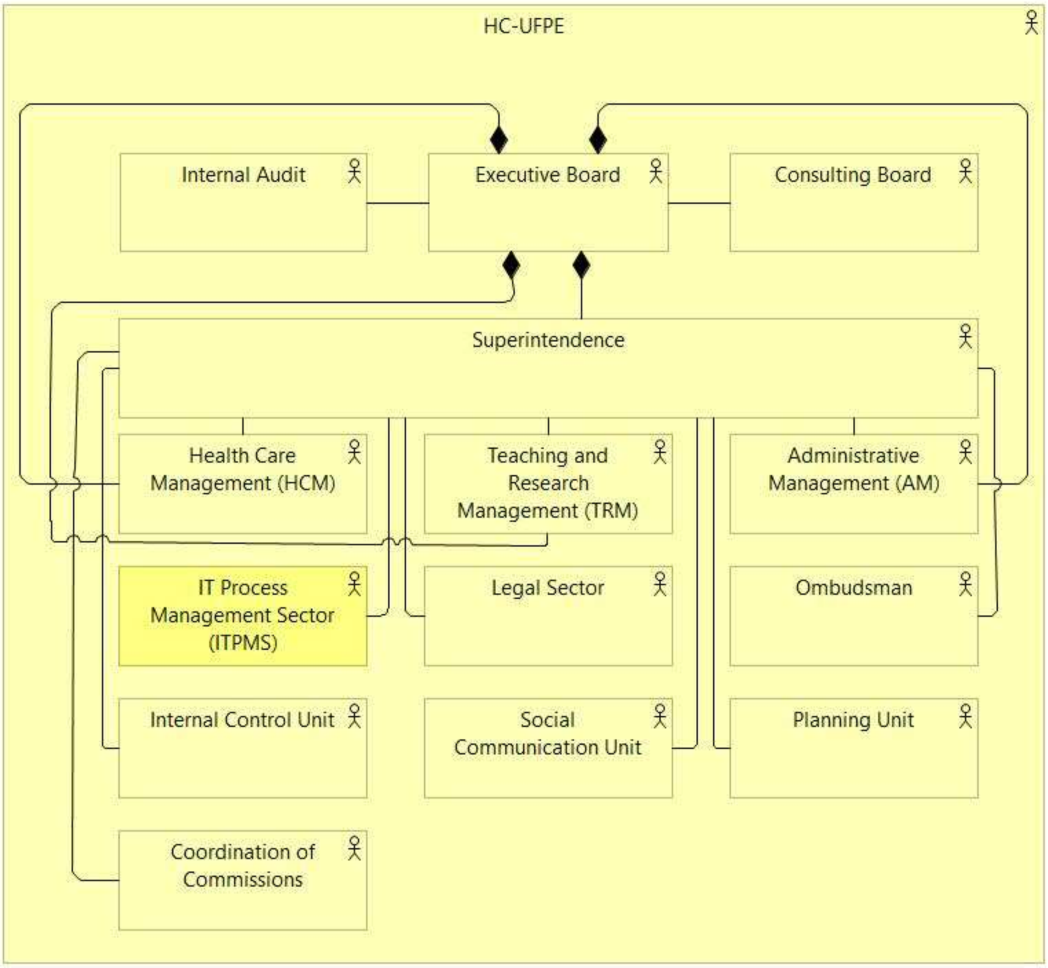
1. Deals with the technically distinct situation in which there will be many more variables than data points.
2. The result depends on several sources of evidence, with the data needing to converge in a triangular shape.
3. The result benefits from the previous development of theoretical propositions to guide data collection and analysis.

Participant observation data collection included the open coding methodology and data triangulation observed during ITPMS employees' working hours. The observation of the processes and services provided by the sector culminated in the transcription and notes useful for the construction of the Information Systems Architecture, which was presented to the responsible stakeholders. Suggestions for changes or additions were noted during the presentation of the created models, and then corrections were made. The build process was incremental until all models were in accordance with what the stakeholders suggested. Doubts about conflicts of observed and collected information were resolved through dialogues with the process owners until there was a consensus on the functioning of each process in the department.

## 4.2. Construction of the Information Systems Architecture of the Hospital das Clínicas at UFPE

Before starting the construction of the information systems architecture model at HC-UFPE, a set of process modeling and organizational architecture will be presented, built using the concepts of EA, with the Archi tool, for a better understanding of the role of IT at the hospital. Figure 6 illustrates the current summary organization chart of the HC-UFPE, built from the documentation on the current organizational structure of the hospital. The executive collegiate is the highest body, composed of the superintendent and the three managers, and is responsible for directing and administering all of the unit's activities.

Figure 6 - Organizational structure of HC-UFPE



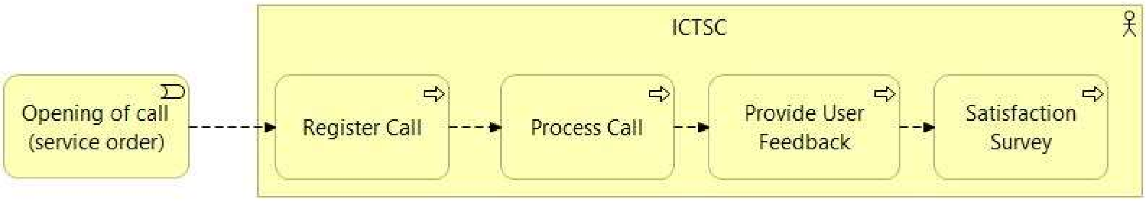

Source: Own authorship

The Superintendence is where ten departments are subordinate, including the managers and the Information Technology Process Management Sector (ITPMS). The total number of departments at HC-UFPE is 185, of which 171 are subordinate and distributed among the three managements. Superintendence is the hospital's top executive position, followed by management, divisions, sectors, units, and services. However, departments do not follow the pattern of the organizational levels presented, such as, for example, still in Figure 6, the Planning Unit, Legal Sector, and others directly linked to the Superintendence instead of being subordinated immediately higher levels.

## 4.3. Information Technology Process Management Sector (ITPMS)

The ITPMS is the sector responsible for providing Information and Communication Technology services for the entire hospital and is directly subordinate to the Superintendent. The sectors' demands for IT services are diverse, and, to improve the service, the Information and Communication Technology Service Center (CSTIC) was recently implemented. It is responsible for centralizing the service orders (opening of calls) of users and tracking resolution status, providing feedback, and collecting satisfaction surveys. Figure 7 illustrates the current processes (AS-IS) of CSTIC, from the moment it receives a call to the satisfaction survey.

Figure 7 - CSTIC's key processes




Source: Own authorship

ICTSC is composed of service levels 1, 2, and 3 and uses the knowledge base of ITIL[3] Version 3. Level 1 (L1) is the initial service, in which the attendant performs the registration (when the service is by telephone) or call capture (when the user himself makes this call through a shortcut available on his institutional computer, which gives direct access to the system). When the demand cannot be resolved by L1, then it is passed on to level 2 (L2), which is composed of the team of technicians and analysts, or directly to level 3 (L3), in cases where the resolution must be made directly by external suppliers. The user's call can be of two types, "Incident" or "Requisition." "Incident" is the type of call registered in the system when it is a problem in the Information and Communication Technology (ICT) service, whether a failure or a decrease in performance, and the "Request" when dealing with other demands. The system used is GLPI[4], an open-source system based on free software, customized by the ICTSC team to meet the specificities and needs of HC-UFPE.

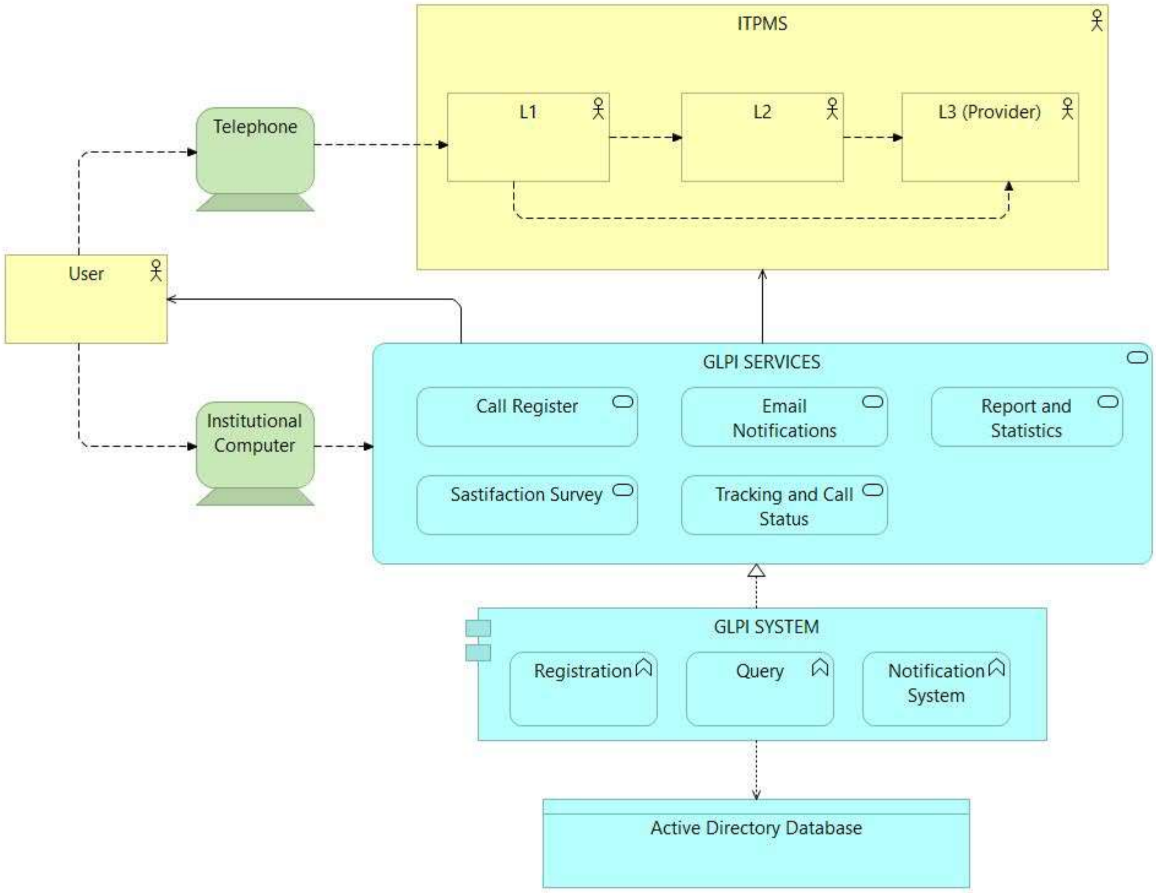
The GLPI registers all HC-UFPE units, the catalog of services, and the L1 and L2 attendants (technicians and analysts) of the ITPMS. This system also consults the database of users in the Active Directory domain network. Only users registered in the HC-UFPE

[3] Available in https://www.axelos.com/best-practice-solutions/itil

[4] Download and documentation available on site https://glpi-project.org/pt-br/

network can register calls directly in the system. In Figure 8, there is the call processing structure, including the services and functions performed by GLPI.

Figure 8 - Call processing structure

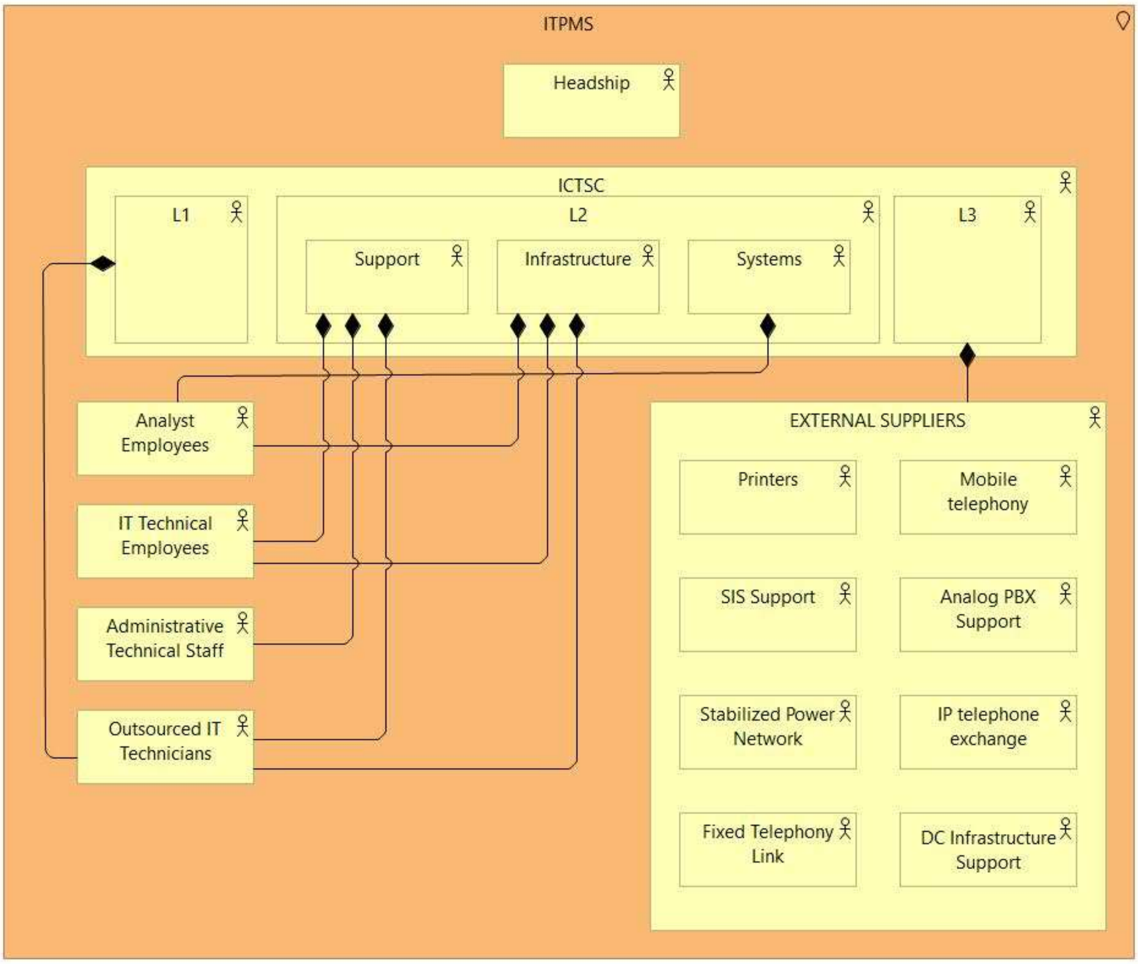



Source: Own authorship

The L1 currently comprises outsourced IT technicians; the L2 comprises a team of outsourced technicians, analysts, and permanent (employees) technicians from HC-UFPE. The L3 encompasses technology service providers contracted by the ITPMS in a total of eight; they are: printer's provider, stabilized electrical network provider, Health Information System (HIS) provider, support provider of health information system, analogic telephony (PABX) provider, IP telephone exchange provider, fixed telephony links provider, mobile telephony provider, and and specialized service of Data Center (DC) maintenance.

L2 has three areas of operation, one of support, one of infrastructure, and the other of systems. The support area handles incidents and requests usually related to IT equipment or software used by users, such as computers, printers, software, etc. In general, the support area provides service through direct contact with the user. The infrastructure area deals with calls related to computer and telecommunications networks. Usually, the infrastructure team does not contact the user directly and handles incidents that impact multiple users or sectors, such as failures in network switches and servers. The systems area handles incidents and requests related to HC-UFPE's HIS's and generally provides user service remotely, such as creating or resetting passwords for the HIS and user registrations. In Figure 9, the compositions of the entire technical staff of the ITPMS are shown, including ICTSC and the external suppliers that provide services to the ITPMS.

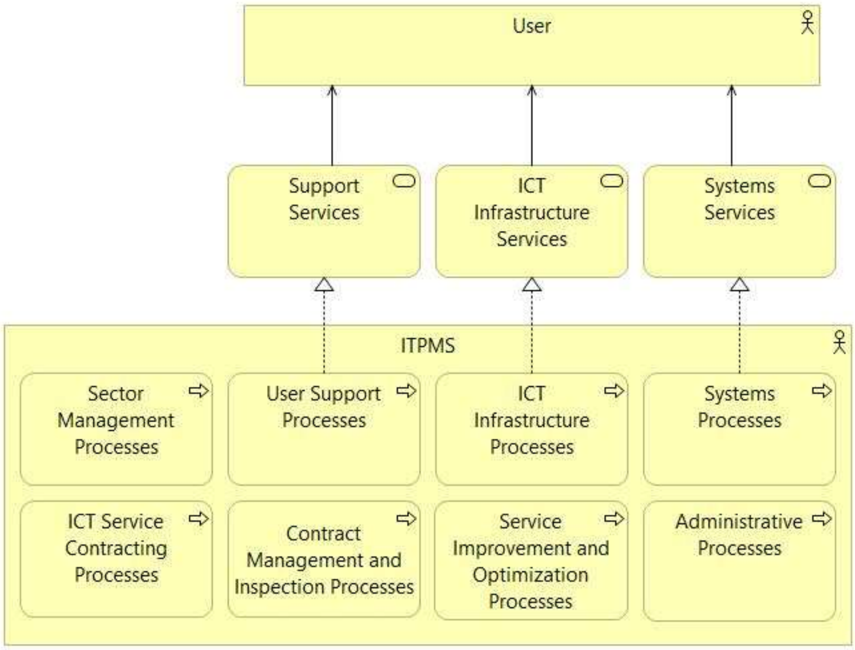
Figure 9 - Composition of the technical staff of the ITPMS




Source: Own authorship

The ITPMS service catalog contains 105 types of services provided to users and is available in GLPI. However, these services are aggregated into three major areas: user support services, ICT infrastructure support, and systems support. Internal activities of the sector are also carried out, such as those of ICT hiring, which involve planning, preparation of Terms of Reference, management, inspection of contracts, and activities to optimize the infrastructure and ICT resources, administrative processes, and management of the sector. Figure 10 represents the internal activities of the ITPMS and those that provide services to the user.

Figure 10 - ITPMS business processes




Source: Own authorship

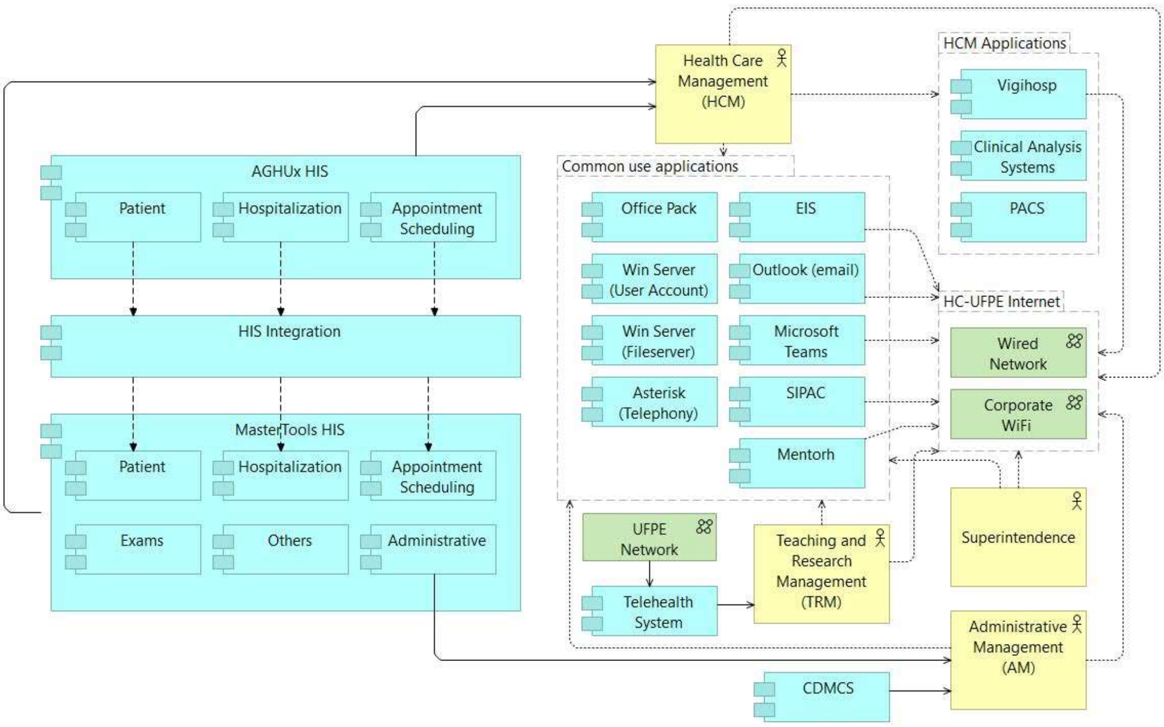
## 4.4. ITPMS systems and applications portfolio

The health information systems (HIS) maintained by the ITPMS are Mastertools and AGHUx, which have hospital administration modules, such as patient data, hospitalization, medical data, and financial data. Other software also provided by the IT sector are: Microsoft Teams; Windows Server; Active Directory; Windows Office Package; EIS (Electronic Information System), for document processing; Electronic mailbox (Outlook); PACS (Picture Archiving and Communication System, used to store medical images); CDMCS (Competency Development Monitoring and Control System, used to issue certificates for courses administered by the hospital); and Asterisk (IP telephone central system). ITPMS also provides File services, such as shared folders and user folders. Some sectors use specific software that is not maintained by the ITPMS, only the infrastructure to access them. These systems are SIPAC and Vigihosp.

Furthermore, external suppliers' systems are also hosted on ITPMS' servers but maintained by the suppliers themselves, such as the Clinical Analysis Systems that provide services to the Laboratory sector, Telehealth Systems that are supported by the Telehealth Center (TC) of UFPE. Other services provided by ITPMS are wired Internet and Wi-Fi access. Each of these services, software and HIS are under the supervision of the ICT systems and infrastructure teams.

To simplify the HC-UFPE hierarchy, researchers considered four large groups: Superintendence, Administrative Management (AM), Health Care Management (HCM), and Education and Research Management (TRM). The other units subordinated to the Superintendence were considered part of the Superintendent itself. Although it is subordinated to the superintendence, in this research we considered the ITPMS as a separate sector, a provider of IT services for the superintendence and other mentioned managements. This abstraction is necessary to distinguish the role of the ITPMS in the hospital. Figure 11 illustrates the applications provided by ITPMS and their relationships with users. Applications in common use by all hospital users, applications accessed only by the HCM, and types of Internet access were grouped. Users access some applications via the Internet, such as EIS and Outlook. All other applications are accessed through the internal network (Intranet), such as File Server and PACS.

Figure 11 - Portfolio of Applications provided by ITPMS

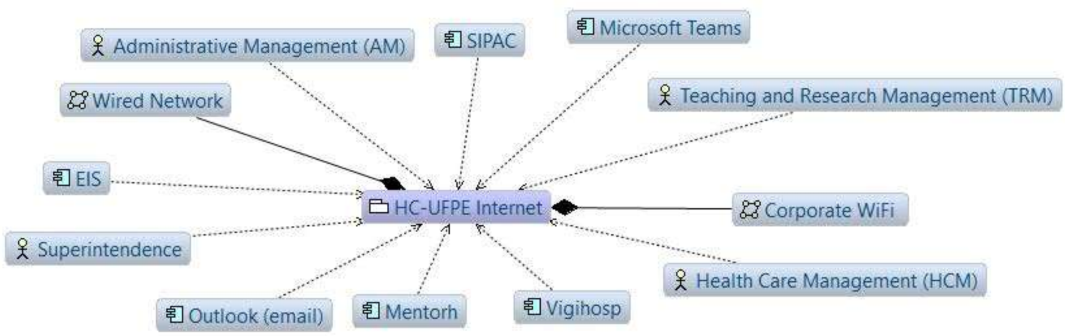



Source: Own authorship

There are two Health Information Systems (HIS) in operation. AGHUx, an open-source HIS with modules aimed at patient administration (hospitalization, appointment scheduling), and MasterTools, a completely private system, with administrative modules (billing systems, registration of equipment and supplies) and also modules for the administration of the patient. The ITPMS developed a system that integrates these two HIS's, capturing data from patients, hospitalization, and appointment scheduling from Mastertools HIS and feeding this data to the AGHUx HIS. Currently, the hospital is running a project to use only AGHUx HIS for patient-related tasks. Mastertools HIS should only operate administrative modules, which are accessed by AM.

A particularity of the application portfolio in Figure 11 is the Telehealth System. Although hosted on ITPMS servers, it uses its own Internet network provided by the Federal University of Pernambuco (UFPE) outside the hospital's domain network. The CDMCS system is used by the Human Resources department (subordinate to the AM) to issue certificates for personnel training courses. The Internet service provided by the ITPMS, consisting of the wired network and corporate Wi-Fi, in Figure 12, from the "visualizer" icon of the Archi tool itself. It is possible to verify through this functionality of Archi that the Internet is the technological resource most accessed by applications and users of HC-UFPE. This fact highlights its importance in a scenario where there is great demand from the hospital for access to this resource. Therefore, having a stable, available, secure, and capable of meeting the needs of the HC-UFPE Internet is a critical success factor for the functioning of the hospital's various applications.

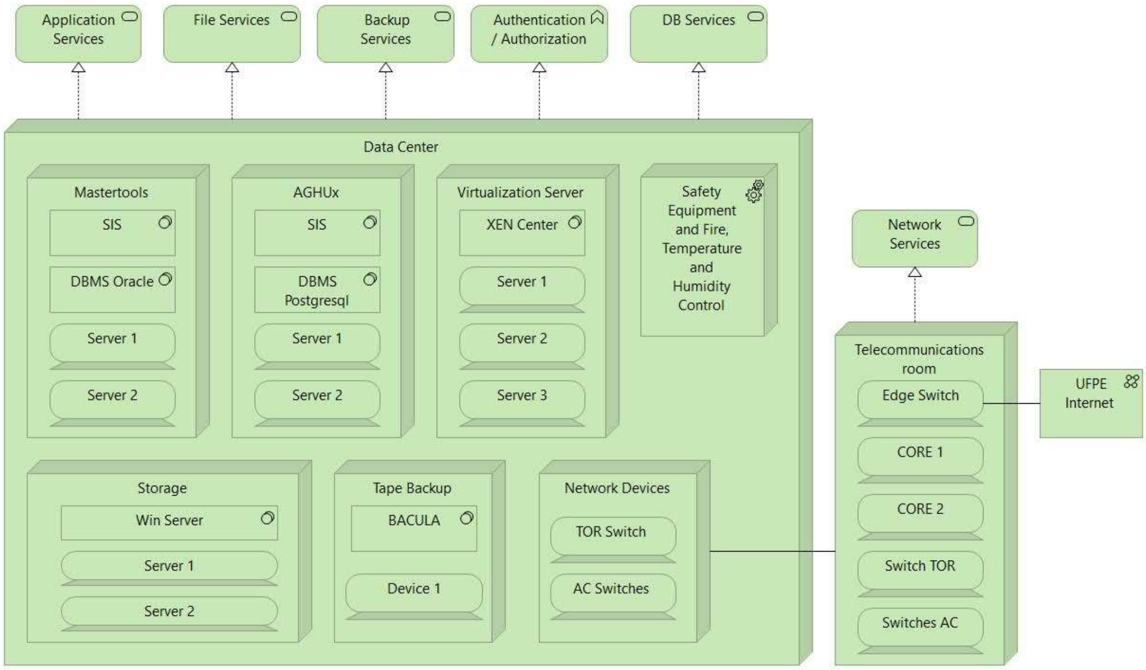
Figure 12 - Applications and users using the Internet network




Source: Own authorship

The Data Center (DC) architecture comprises a set of devices that aggregate all application services provided by ITPMS. Its infrastructure is housed in a safe room, with fire, humidity, and temperature control, in addition to access control and security devices. There are three main blocks of servers within the DC, one for HIS Mastertools, another for HIS AGHUx, and another for the virtualization servers, which hosts the other applications provided to the hospital. There is also a Storage and Tape backup infrastructure for the file server, in addition to a set of network devices, to establish communication between the DC infrastructure and the Telecommunication Room (TR). This TR is located within the ITPMS, is external to the DC, and receives the Internet access link from UFPE. In the TR are found devices responsible for network services and access to the Internet and DC. Figure 13 illustrates the architecture of the DC and the TR.

Figure 13 - Data Center infrastructure and ITPMS network




Source: Own authorship

## 4.5. Future Information Systems Architecture (TO-BE)

The interviews carried out with the key stakeholders of the HC-UFPE also allowed the mapping of processes, motivations, and views that helped elaborate the future information systems (IS) architecture model (TO BE). The new IS architecture seeks to add more value to the business and increase user satisfaction, given that gaps and challenges were found that can influence the perception and performance of the ITPMS in the hospital. The central physical infrastructure of IT, consisting of the Data Center and the Telecom Rooms, have, for the most part, equipment of good technical quality capable of meeting the hospital's high demand. However, the interview and document analysis observed that the hospital still lacks IT equipment for the user's desktop, such as computers, notebooks, tablets, webcams, and headsets.

There are still many computers with more than five years of use, which are pretty slow, which causes dissatisfaction to the user when carrying out their activities with the computer. The limitation of budget resources prioritizes acquisitions of equipment that impact several systems and users simultaneously, such as access points for Wi-Fi networks, storage modules, servers, network switches, etc. As HC-UFPE is a hospital maintained by the federal government and is not for profit, the raising of budgetary resources depends on the federal government's distribution and external policies.

In the question "how can IT improve service delivery?" carried out during the interviews, two principal codes were identified: (i) gaps/challenges and (ii) possible solutions proposed by the stakeholders or identified by the researcher, in Table 16.

Table 16 - Problem identification and possible solutions

| ID | Gaps/ Challenges | Possible solutions proposed by stakeholders or identified by the researcher (IT Analyst) |
|---|---|---|
| 1 | Too many services and dispersed applications, which makes monitoring difficult | Use of integrated systems that allow an integrated view of processes and services. |
| 2 | Abrupt changes to systems and processes without adequate training for users | Systematize changes. Divide change processes into stages. |
| 3 | Lack of transparency of IT capacity and service catalog | Disclosure of the capacity plan/service catalog/alignment of the IT portfolio with stakeholders |
| 4 | IT is more operational than strategic | Expandir o alinhamento estratégico com outras áreas do hospital |
| 5 | Projects proposed by managers are often denied by IT for various reasons | When a request is not readily enforceable by IT, seek solutions together with the requesting area, and, if necessary, with actors outside the institution |
| | | Creation of a space within IT to discuss strategic and innovation projects |
| 6 | IT ill-defined processes | Define processes, document them, and make them available. |
| 7 | Outdated and incomplete patient data | Acquire electronic medical record system |
| 8 | Failures in communication with the patient. Sometimes the hospital is unable to contact the patient. | Create/hire an application that allows effective communication with patients, including issuing announcements, updating records, etc. |
| 9 | Electronic documents are stored manually, in spreadsheets, folders, etc. | Evaluate document management system acquisition |
| 10 | Delay in resolving incidents and problems | Optimize incident and problem management plan / Evaluate SLA of services provided by IT and suppliers |

| | | |
|---|---|---|
| 11 | Excessive bureaucracy in requesting services | Evaluate and optimize call opening and resolution processes |
| 12 | More dedication and commitment to the user is needed | Mobilize the team and delegate responsibilities with meeting deadlines and resolving user requests |
| 13 | Lack of planning in the execution of services | Intensify the planning culture / mobilize teams and define processes for the execution of services |
| 14 | Undocumented processes performed based on professional experience | Define standards, create processes and design flows. |
| 15 | Lack of transparency in carrying out processes | Document and make available processes |
| 16 | Indefinite or missed deadlines | Define deadlines for processes and services and demand compliance with them |

Source: Own authorship

The gaps, challenges, and possible solutions shown in Table 16 for this research were categorized to build the TO-BE model of the stakeholders' view. The categorization was aligned with IT employees and represented in Table 17.

Table 17 - Categorization of gaps and challenges, and solutions/goals

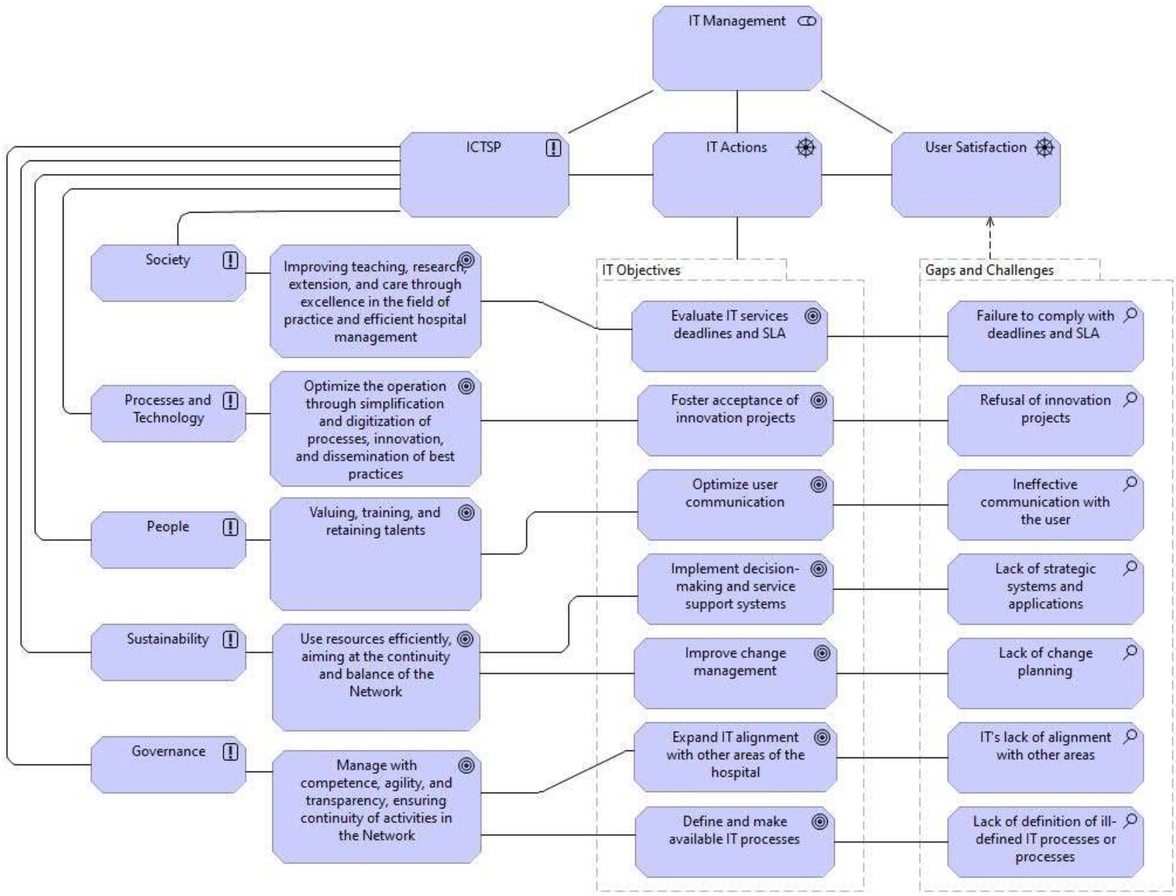
| **Gaps and challenges** | **Possible solutions / goals** |
|---|---|
| Lack of strategic systems and applications | Implement decision-making and service support systems |
| Lack of change planning | Improve change management |
| IT's lack of alignment with other areas | Expand IT alignment with other areas of the hospital |
| Refusal of innovation projects | Foster acceptance of innovation projects |
| Lack of definition of ill-defined IT processes or processes | Define and make available IT processes |
| Failure to comply with deadlines and SLA (Service Level Agreement) | Evaluate IT services deadlines and SLA |
| Ineffective communication with the user | Optimize user communication |

Source: Own authorship

Following the methodology proposed by the researchers, the identification of gaps and challenges and possible solutions to these problems, identified in the interviews and participant observations, were transformed into actions that contribute to the improvement of IT service delivery. These actions, in turn, were aligned with the strategic objectives of the Information and Communications Technology Strategic Plan (ICTSP). The ICTSP of the EBSERH is composed of five pillars: (1) society, (2) sustainability, (3) governance, (4) processes and technology, and (5) people. Each of them has a strategic objective (SO), respectively: (1) Improve teaching, research, extension and care through excellence in the field of practice and efficient hospital management, (2) use resources efficiently, aiming at the continuity and balance of the Network, (3) manage with competence, agility, and transparency, ensuring continuity of activities in the Network, (4) optimize the operation through the simplification and digitization of processes, innovation, and dissemination of best practices and ( 5) valuing, training and retaining talents. Therefore, projects and actions must be carried out to align with the strategic objectives contained in ICTSP.

The stakeholder view proposed model seeks to align a critical IT success factor, which is user satisfaction, with IT actions that can correct or improve service delivery and at the same time be aligned with ICTSP's strategic objectives. User satisfaction is intrinsically linked to the gaps and challenges, identified and categorized in Table 17. The actions to be carried out must start from the possible solutions and objectives, in the same table. These, in turn, were aligned, through contextual analysis, with the ICTSP. Figure 14 illustrates a proposed stakeholder vision model to improve IT management processes, providing visions that allow directing future actions and projects (TO-BE) for the ITPMS.

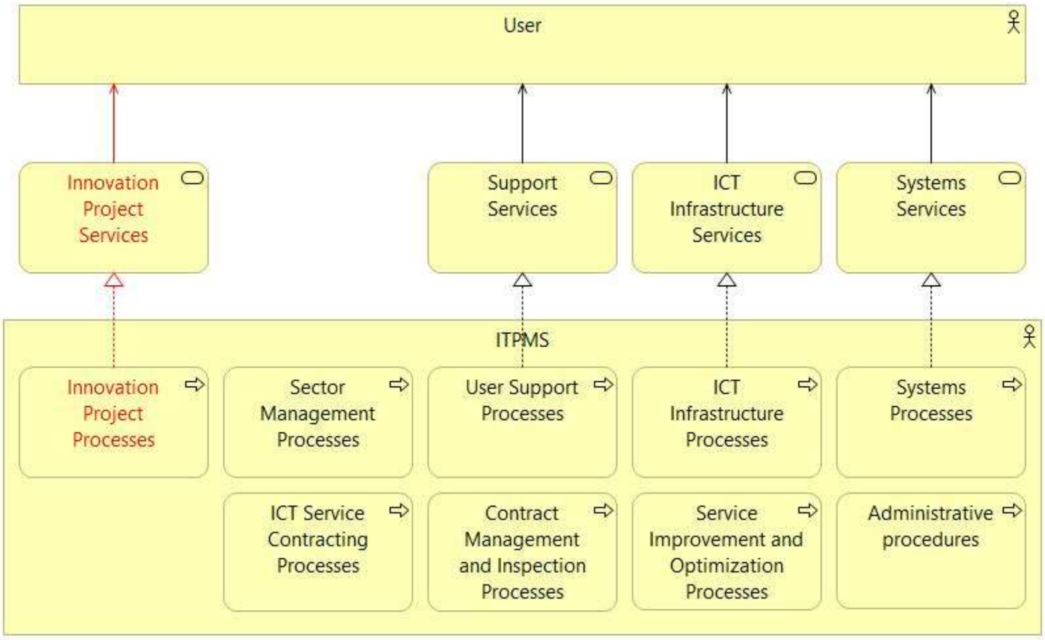
Figure 14 - Stakeholder view model




Source: Own authorship

Based on the stakeholder view model in Figure 14, focusing on the objective "Fostering the reception of innovation projects," this case study resulted in the future architecture model (TO-BE) for the services provided by IT. In this new model, represented in Figure 15, the offer of services to the user was expanded. The icons "innovation project processes" were added, in which they will perform "innovation project services."

Figure 15 - Future architecture (TO-BE) for ITPMS services




Source: Own authorship

The future architecture shown in Figure 15 aims to create IT processes that seek to stimulate the reception of innovation projects reported by stakeholders, where space within IT is suggested, created by a trained team, aiming to discuss and implement beneficial projects for the institution. This proposal expects to contribute to the alignment of IT with the other areas of the HC-UFPE, approximating the IT sector from the demands of innovation and even optimizing communication with the user.

It is a welcoming space where IT will hear demands for technological innovation from other sectors that want to improve their processes and services. The interviews with the stakeholders mentioned the difficulties in innovation, as it is currently expected for innovative ideas and suggestions not to be taken as the main agenda in IT processes. So, as a suggestion from the stakeholders, creating a space for this specific purpose can help to stimulate the reception of ideas and innovation projects.

## 4.6. Threats to research validity

Merriam (2009) suggests different methods and procedures improve findings' internal and external validity, such as triangulation, verification, adequate engagement in data collection, peer review, and researchers' position internal validity of qualitative research increases. Therefore, to minimize threats to validity, the research was carried out strictly following the referenced protocols and methodologies; however, some threats to validity must be discussed and presented. As part of the Systematic Literature Review, the specific research questions RQ4 "What are the criteria for choosing the methodology, framework, and tool used to apply the EA in Healthcare systems?", RQ5 "What problems or challenges the application of EA in Healthcare systems face?" and RQ6 "What are the main positive impacts achieved with the application of Enterprise Architecture in Healthcare?" they required greater attention because they were qualitative questions that were not always directly answered by the authors, thus requiring that the articles be read and discussed with the team several times so that there was an acceptable consensus.

In the case study, some threats to validity are more prominent, especially in interviews with hospital stakeholders. Variables such as time availability of the interviewees, fear of saying what they wanted, or even forgetting some detail are limitations to the analysis process that could be important for constructing the presented model. The participant observation methodology can also bias the observer researcher, who may not have correctly understood some details of the observed processes or even have inserted points of view that are not the most appropriate to the context.

To minimize the impacts of threats to the validity of the research, the models created were presented together with the stakeholders interviewed and observed, as well as changes suggested by some stakeholders, to build an information architecture model for the ITPMS the closest to reality. It is important to emphasize that this work does not commit to changing the HC-UFPE processes' structure but only offers an empirical TO-BE and AS-IS architecture view. The Information System Architecture is based on research, methodologies, and tools that can help in hospital management and thus bring benefits to the population and the public administration of university hospitals.

## 4.7. Discussion

The methodology that this research used to build the architecture of information systems at HC-UFPE, although it was carried out specifically in this hospital, we understand that it can be replicated in other UHs managed by the EBSERH network. The organizational structure and ICT policies are similar across the 41 UHs.

EBSERH's Information and Communications Technology Strategic Plan (ICTSP) is a document that provides guidelines and strategic objectives to guide ICT projects and processes for the network's UHs. Each of these hospitals has its particularities, especially when we refer to problems/gaps and challenges faced by IT departments. However, the methodological steps for building the architecture of information systems are scalable and adaptable for each environment, to meet the specificity and complexity of each UH .

The experience with the use of the Archimate language and the Archi tool to build the hospital's Information Systems architecture was positive since it is an intuitive tool with a large amount of material available on the internet for consultations. It was possible to model the architecture without great difficulties, so that the building blocks available in the tool met, at this first moment, the research needs. The results provided an initial model of the information systems architecture of HC-UFPE. The AS-IS and TO-BE architectures were presented to stakeholders, who showed some enthusiasm for the research results and also for the tools used.

The implementation of new methodologies to assist in hospital governance requires a certain amount of time and stakeholder engagement, especially when it comes to public organizations, which commonly have a certain resistance to changes or are guided by external policies. However, we understand that the initial step has already been taken and that further research can be carried out, in order to incorporate EA practices into hospital governance, so that it is possible to collect data and feedback on the benefits achieved and challenges faced, and even compare these results. with those collected in the SRL performed in this research.

# 5. CONCLUSION

Although there are several works on the construction of Enterprise Architecture in hospitals, it still lacks in a great part of these works, details of the construction processes of these architectures. It is understandable that there are companies that choose not to disclose their internal processes, either because they consider their data confidential, or because of internal policies, mainly due to the wide competition in the market. However, the construction of the Enterprise Architecture is something very peculiar to each company, as there are several variables that may require the use of specific methodologies and tools.

The purpose of this work was to initiate a culture of use of business architecture concepts, starting from the construction of information systems architecture for university hospitals, with a case study carried out at the Clinics Hospital of the Federal University of Pernambuco (HC-UFPE), in which concepts from the TOGAF 9.2 framework, and as a model building tool Archi version 4.7.1, in line with the Archimate 3.1 language standard.

This work aims to contribute to the alignment of the ITPMS with other areas of the hospital. The construction of information systems architecture can help in governance by offering a holistic view of the ITPMS processes, including their relationships with other areas of HC-UFPE. It is also possible to verify how each service provided impacts other sectors, which can provide substantial information so that improvement projects are made feasible and prioritized more efficiently. For the construction of the AS-IS and TO-BE models of information systems architecture, feedbacks were collected from senior management, from strategic sectors, as well as from the technology sector itself, through interviews and participant observation. Some difficulties were encountered in carrying out this research, such as the availability of the agenda of some managers and employees to conduct interviews, and also because this research was carried out during the COVID-19 pandemic period, and many sectors have changed their work routines to adapt to security protocols. During this same period, there was a reduction in face-to-face activities and an increase in remote activities, requiring technological adaptations such as the use of remote access, collaboration tools and online meetings, etc.

It is expected that the results can contribute to a holistic view of ITPMS processes, providing more transparency and improving communication between other areas of the hospital, in addition to providing insights for prioritizing projects and actions that can bring improvements in hospital processes, positively impacting patient service and even on the satisfaction of HC-UFPE users.

As future work, it is suggested the implementation of enterprise architecture for the hospital, encouraging strategic sectors to adopt the culture of the concepts covered in this work, and even start a discussion on the use of other tools presented in the systematic review carried out. in this research. It is also plausible that, after the adoption of EA in the hospital, an assessment of the challenges faced and benefits achieved with the implementation of EA is carried out and a comparison with the results presented in the systematic literature review performed in this work.

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# APPENDICE A

## TERMO DE CONSENTIMENTO LIVRE E ESCLARECIDO

(PARA MAIORES DE 18 ANOS OU EMANCIPADOS)

Convidamos o (a) Sr. (a) para participar como voluntário (a) da pesquisa (Proposta de Modelo de Arquitetura de Sistemas de Informação para Hospitais Universitários: um estudo de caso no Hospital das Clínicas da UFPE), que está sob a responsabilidade do (a) pesquisador (a) (Silvano Herculano da Luz Júnior, com endereço na Av. Marcos Freire, nº180, Santo Aleixo, Jaboatão dos Guararapes e CEP: 54140-390 – Telefone (81)99857-3859 e e-mail para contato silvano.junior@academico.ifpb.edu.br / silvanojunior.luz85@gmail.com.

Também participam desta pesquisa os orientadores: Profº. Dr. Francisco Petrônio Alencar de Medeiros) Telefones para contato: (83)99662-0000, email: petronio@ifpb.edu.br e Profª. Dra. Heremita Brasileiro Lira, Telefone: (83)99982-4889, e-mail heremita@ifpb.edu.br.

Todas as suas dúvidas podem ser esclarecidas com o responsável por esta pesquisa. Apenas quando todos os esclarecimentos forem dados e você concorde com a realização do estudo, pedimos que rubrique as folhas e assine ao final deste documento, que está em duas vias. Uma via lhe será entregue e a outra ficará com o pesquisador responsável. Você estará livre para decidir participar ou recusar-se. Caso não aceite participar, não haverá nenhum problema, desistir é um direito seu, bem como será possível retirar o consentimento em qualquer fase da pesquisa, também sem nenhuma penalidade.

### INFORMAÇÕES SOBRE A PESQUISA:

- **Descrição da pesquisa**: Justificativa: O papel da Tecnologia da Informação (TI) é fundamental nesses hospitais, pois é fácil observar a crescente imersão da tecnologia na saúde, alavancada por meios automatizados que facilitam os procedimentos médicos e otimizam os processos de gestão administrativa e governança, agregando valor ao negócio hospitalar. Porém, por se tratarem de órgãos públicos cuja principal área de atuação é, na verdade, a saúde, ainda é comum encontrar resistências quanto aos investimentos em tecnologia, além da falta de alinhamento estratégico da TI com as demais áreas hospitalares. Esse problema tem se refletido na prestação de serviços ao paciente e na aquisição e gestão de recursos tecnológicos que agilizem e aprimorem os processos de negócios do hospital. Portanto, há uma grande necessidade de entender esses gargalos para que os processos de negócios no campo estratégico, tático e operacional sejam realizados de forma eficiente. Para isso, ter uma visão holística dos processos-chave desses hospitais, por meio de modelos que norteiam as implementações da Arquitetura Empresarial (EA), pode auxiliar a gestão na tomada de decisões. De acordo com Varveris e Harrison (2004), a EA representa todo o comportamento em uma organização, os dados processados, quem faz o quê, onde as coisas estão e por que as coisas são feitas. O objetivo da EA é atingir o alinhamento entre a estratégia da empresa e a configuração de seus ativos de TI (WEIL, 2007). O objetivo desta pesquisa é propor um Modelo de Arquitetura de Sistemas de Informação para Hospitais Universitários por meio de um estudo de caso no Hospital das Clínicas da Universidade Federal de Pernambuco. A coleta de dados será realizada através da entrevistas com membros da alta gestão do HC-UFPE (superintendência e gerências), e também com o gestor e funcionários (analistas e técnicos de TI) do Setor de Gestão de Processos TI (SGPTI-HC-UFPE). Serão realizadas consultas de documentos públicos do próprio HC-UFPE, tais como Plano Diretor de TI (PDTI), Plano Estratégico de Tecnologia da Informação e Comunicações (PETIC), ou documentos e informações contidas no site do próprio HC-UFPE.
- **Esclarecimento do período de participação do voluntário na pesquisa, início, término e número de visitas para a pesquisa**: Será realizada uma entrevista semi-estruturada com cada participante, visando obter dados que auxiliem na construção do modelo de Arquitetura de Sistemas de Informação para o HC-UFPE, com foco na análise de macroprocessos de TI na gestão hospitalar e na identificação de problemas, desafios, limitações e fatores críticos de sucesso na prática de gestão hospitalar usando tecnologia da informação.
- **RISCOS diretos** para o voluntário: O entrevistado pode sentir desconforto para mencionar dados sobre processos ou infraestrutura de TI que estão diretamente relacionados consigo ou com o setor na qual trabalha. **Porém, para amenizar os riscos do desconforto, bem como possibilidades relacionadas a indenizações por danos morais e/ou materiais, a pesquisa não fará utilização nem divulgação de dados pessoais**.
- **BENEFÍCIOS diretos e indiretos** para os voluntários: A construção do modelo de arquitetura de Sistemas de Informações visa beneficiar a instituição (HC-UFPE) com o início da utilização de boas práticas de Arquitetura Empresarial para a gestão hospitalar. O modelo a ser criado permitirá auxiliar

na gestão de recursos e processos de TI, assim como identificar gargalos que impactem diretamente e indiretamente os demais setores que utilizam os serviços oferecidos pelo setor de TI.

- **SOBRE ARMAZENAMENTO E UTILIZAÇÃO DE MATERIAL BIOLÓGICO:** Não haverá coleta de material biológico.

Todas as informações desta pesquisa serão confidenciais e serão divulgadas apenas em eventos ou publicações científicas, não havendo identificação dos voluntários, a não ser entre os responsáveis pelo estudo, sendo assegurado o sigilo sobre a sua participação. Os dados coletados nesta pesquisa (por meio de entrevistas e consultas a documentos públicos tais como PDTI, PETIC e PDE do HC-UFPE), ficarão armazenados em plataformas de nuvem (onedrive e google drive) pessoal, sob a responsabilidade do pesquisador Silvano Herculano da Luz Júnior, no endereço acima informado, pelo período de mínimo 5 anos. Será utilizado durante a entrevista o recurso de gravador de áudio, na qual será utilizado um programa gratuito a ser instalado no celular do pesquisador. Caso haja a necessidade da entrevista se realizada por meio de recursos de webconferência (Google Meet, Zoom ou Microsoft Teams), não será feita a gravação da webconferência, e sim do áudio emitido nos alto-falantes do computador, por meio do celular do pesquisador.

O Sr./Sra. poderá solicitar, se assim quiser, o relatório final da pesquisa que fez parte. Também, cópias de todos os resultados dos exames complementares realizados nesta pesquisa poderão ser solicitadas ao pesquisador.

Nada lhe será pago e nem será cobrado para participar desta pesquisa, pois a aceitação é voluntária, mas fica também garantida a indenização em casos de danos, comprovadamente decorrentes da participação na pesquisa, conforme decisão judicial ou extra-judicial. Se houver necessidade, as despesas para a sua participação serão assumidas pelos pesquisadores (ressarcimento de transporte e alimentação).

Em caso de dúvidas relacionadas aos aspectos éticos deste estudo, você poderá consultar o Comitê de Ética em Pesquisa Envolvendo Seres Humanos do HC/UFPE no endereço: **(Avenida Prof. Moraes Rego s/n – 3º Andar- Cidade Universitária, Recife-PE, Brasil CEP: 50670-420, Tel.: (81) 2126.3743 – e-mail: cephcufpe@gmail.com).**

Esta pesquisa também foi analisada e aprovada pelo Comitê de Ética em Pesquisa do IFPB (CEP-IFPB), o qual tem o objetivo de garantir a proteção dos participantes de pesquisas submetidas a este Comitê. Portanto, se o(a) senhor(a) desejar maiores esclarecimentos sobre seus direitos como participante da pesquisa, ou ainda formular alguma reclamação ou denúncia sobre procedimentos inadequados dos pesquisadores, pode entrar em contato com o CEP-IFPB. Comitê de Ética em Pesquisa do IFPB.
**Av. João da Mata, 256 – Jaguaribe – João Pessoa – PB. Telefone: (83) 3612-9725 - e-mail: eticaempesquisa@ifpb.edu.br**. Horário de atendimento: Segunda à sexta, das 12h às 18h.
Durante o período da pandemia, ou seja, de isolamento social, a comunicação com o CEP se dá exclusivamente por meio do e-mail acima divulgado.

________________________________________________
(assinatura do pesquisador)

**CONSENTIMENTO DA PARTICIPAÇÃO DA PESSOA COMO VOLUNTÁRIO (A)**

Eu, ________________________________________, CPF __________________, abaixo assinado, após a leitura (ou a escuta da leitura) deste documento e de ter tido a oportunidade de conversar e ter esclarecido as minhas dúvidas com o pesquisador responsável, concordo em participar do estudo Proposta de Modelo de Arquitetura de Sistemas de Informação para Hospitais Universitários: um estudo de caso no Hospital das Clínicas da UFPE, como voluntário (a). Fui devidamente informado (a) e esclarecido (a) pelo(a) pesquisador (a) sobre a pesquisa, os procedimentos nela envolvidos, assim como os possíveis riscos e benefícios decorrentes de minha participação. Foi-me garantido que posso retirar o meu consentimento a qualquer momento, sem que isto leve a qualquer penalidade (ou interrupção de meu acompanhamento/ assistência/tratamento).

Local e data __________________________

Assinatura do participante: ____________________________

**Presenciamos a solicitação de consentimento, esclarecimentos sobre a pesquisa**
**e o aceite do voluntário em participar. (**02 testemunhas não ligadas à equipe de pesquisadores):

| | |
|---|---|
| Nome: | Nome: |
| Assinatura: | Assinatura: |

OBS: A folha com as assinaturas não pode estar em folha separada do texto do TCLE.