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Enterprise Architecture in the Higher Education sector - A Case Study

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Master Degree in Computer Engineering

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TECNOLOGIAS
E ARQUITETURA

Department of Information Science and Technology

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To my family and friends. To God.

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Resumo

As organizações vivem num ambiente em constante mudança, onde é necessária uma arquitetura robusta para fazer face a tais mudanças, mantendo simultaneamente os padrões necessários para se manterem competitivas. A Arquitetura Empresarial é a disciplina que estuda a arquitetura de uma organização, os seus componentes, a sua relação uns com os outros e com o contexto exterior. É uma disciplina que tem sido investigada nos últimos 40 anos, mas só recentemente começou a mostrar interesse em explorar e aplicar as *frameworks* e métodos desenvolvidos no sector do ensino superior. Por conseguinte, esta investigação visa explorar a utilização de tais práticas no sector do ensino superior, aplicando-as a um cenário da vida real. O Iscte, uma universidade sediada em Portugal, como qualquer outra organização passa por mudanças regulares para se adaptar ao ambiente envolvente o que pode causar disfunções no contexto sócio-cultural da universidade, bem como nos sistemas de informação. Este trabalho aplicará a *Framework de Zachman* à universidade, mais especificamente no âmbito dos serviços de informática a fim de ajudar a gerir as transformações em curso e a detetar potenciais problemas que já existem e que podem ainda surgir na arquitetura da universidade. Será desenvolvida uma plataforma de estilo *wiki* para acolher a *framework* e permitir que os intervenientes se envolvam. Uma série de entrevistas com atores-chave é conduzida a fim de perceber as suas perspetivas sobre as atuais dimensões sociais e tecnológicas da universidade. Recomendações para a atual arquitetura organizacional do Iscte são feitas com base nos resultados da *framework* e nas entrevistas.

Palavras-Chave: Arquitetura Empresarial, Framework de Zachman, Sistemas de Informação, Setor do Ensino Superior.

Abstract

Organizations live in an ever changing environment where a robust architecture is needed in order to cope with such changes while maintaining the required standards to stay competitive. Enterprise Architecture is the discipline which studies an organization architecture, its components and their relationship with each other and with the outside context. It is a discipline which has been researched for the last 40 years but only recently started to show interest in exploring the frameworks and methods developed in the higher education sector. Therefore this research aims to explore the use of such practices in the higher education sector, applying it to a real-life scenario. Iscte, a university based in Portugal, as any other organization goes through regular changes to adapt to the outside environment which may cause dysfunctions in the university's social-cultural context as well as in the information systems. This work will apply the Zachman Framework to the university, more specifically in the scope of the IT services in order to help them manage the on-going transformations and spot potential issues that already exist and may yet appear in the university architecture. A *wiki* style platform will be developed to host the framework and to allow stakeholders to get involved. A series of interviews with key players are conducted in order to get their perspectives into the current social and technological dimensions in the university. Recommendations to the current Iscte architecture are done based on the results from the framework and the interviews.

Keywords: Enterprise Architecture, Zachman Framework, Information Systems, Higher Education Sector.

Contents

List of Figures

List of Acronyms and Abbreviations

ADM - Architecture Development Method
ARM - Application Reference Model
BR - Behavioral Research
BRM - Business Reference Model
BSP - Business Systems Planning
CIMOSA - Computer Integrated Manufacturing Open System Architecture
CIO - Chief Information Office
DRM - Data Reference Model
DoD - Department of Defense
DoDAF - Department of Defense Architecture Framework
DSR - Design Science Research
DSRM - Design Science Research Methodology
DT - Digital Transformation
E2AF - Entended Enterprise Architecture Framework
EAF - Enterprise Architecture Frameworks
EA - Enterprise Architecture
EAF - Enterprise Architecture Frameworks
EAP - Enterprise Architecture Planning
EAQA - Enterprise Architecture Quality Attributes
EATIEC - Equipa de Apoio Técnico e Informático aos Espaços Comuns
EM - Enterprise Modeling
ESI - Equipa de Segurança e Informática
FEA - Federal Enterprise Architecture
FEAF - Federal Enterprise Architectural Framework
GDSI - Gabinete de Desenvolvimento de Sistemas de Informação
GEPQ - Gabinete de Estudos, Planeamento e Qualidade
GERAM - Generalized Enterprise Reference Architecture and Methodology
GF - Gartner Framework
HE - Higher Education
IBM - International Business Machines Corporation
IEC - International Electrotechnical Commission
IEEE - Institute of Electrical and Electronics Engineers.
IRM - Infrastructure Reference Model
IS - Information System
ISO - International Organization for Standardization
IT - Information Technology
MoDAF - Ministry of Defense Architecture Framework
NAF - NATO Architecture Framework
NAU - Núcleo de Apoio ao Utilizador

PRM - Performance Reference Model
RACI - Responsible, Accountable, Consulted and Informed
RAM - Responsibility Assignment Matrix
RM-OPP - Reference Model of Open Distributed Processing
SAM - Strategic Alignment Model
SEAM - Systemic Enterprise Architecture Methodology
SIIC - Serviços de Infraestruturas Informáticas e de Comunicações
SIP - Simple Iterative Partitions
SRM - Security Reference Model
SRP - Systematic Review Protocol
TAFIM - Technical Architecture Framework for Information Management
TOGAF - The Open Group Architecture Framework
UAF - Unified Architecture Framework
UEML - Unified Enterprise Modelling Language
UML - Unified Modelling Language
URCS - Unidade de Redes, Comunicações e Sistemas
VRF - Value Realization Framework
ZF - Zachman Framework

CHAPTER 1

Introduction

1.1. Motivation and Objectives

Enterprises and organizations live in an ever-changing environment where they need to adapt to survive, to perform according to the industry standards. and stay competitive. Alignment between the business side and the information technology (IT) is key for success [**1, 2**] since IT is one of the cores of the organizations and necessary in this digital era to thrive.

The information systems (IS) developed by the IT grow ever so more complex so it is vital to manage them accordingly. As Zachman [**3**] said "The cost involved and the success of the business depending increasingly on its information systems require a disciplined approach to the management of those systems". It is necessary that these systems make sense together and that they correspond to the requirements of the business so it doesn't cause disarray inside the organization and hampers productivity.

This is no easy feat and organizations face problems dealing with it. This is where Enterprise Architecture (EA) comes in [**4**], a field that studies the enterprise and how its components are built and organized, improving the alignment between IT and business. As Lapalme *et al.* [**5**] states, there are numerous definitions for EA as it is an area that takes input from other "domains and disciplines". This work follows the footsteps of Gampfer *et al.* [**6**] and uses the definition given by the ISO/IEC/IEEE 42010:2011 standard for architecture which says "The fundamental organization of a system, embodied in its components, their relationships to each other and the environment, and the principles governing its design and evolution" [**7**] which was revised and confirmed in 2017 by the International Organization for Standardization (ISO). This definition may be used for EA when the word "system" is seen as enterprise/organization.

The Enterprise Architecture discipline when applied produces a lot of artifacts and documentation vital to the enterprise organization and producing them without structure and coherence between each other may be hazardous and undermine the whole basis of EA. If the artifacts produced by EA are incorrect the system is doomed to fail before being built [**8**]. To resolve these problems there are the so-called Enterprise Architecture Frameworks (EAF) that provide assistance in building an EA, guiding the architect in building the architecture with principles, meta-models, and artifacts. The most famous and used EAF are: Zachman Framework (ZF) [**3, 9**], The Open Group Architecture Framework (TOGAF) [**10, 11**], Federal Enterprise Architectural Framework (FEAF) [**12**], Gartner Framework (GF) [**13**] and the Department of Defense Architecture Framework (DoDAF) [**14**].

The *Serviços de Infraestruturas Informáticas e de Comunicações* (SIIC) from Iscte – Instituto Universitário de Lisboa (Iscte), a university based in Lisbon, have as an objective to implement, integrate, provide, optimize and maintain the technological infrastructures of the university [**15**], they are the computer and communications infrastructure services. Being an organization that seeks to give Iscte students, researchers and the management area the best conditions, SIIC is always seeking to upgrade into the latest technologies released, which makes EA a key point for the organization success.

At the moment of writing and developing this research, SIIC and Iscte itself are going through important changes which can be divided into 3 categories: internal, external and technological. At Iscte, there is also a *Gabinete de Desenvolvimento de Sistemas de Informação* (GDSI) that is independent from SIIC, which has as an objective to develop and maintain the Iscte information systems [**15**]. These two

organizations are going to suffer changes regarding work responsibilities and how they are connected to each other in terms of "who does what", so both are able to have a clearer goal of their objectives. This is considered to be one example of internal change.

With the surge of the COVID-19 pandemic which affected the whole world, SIIC were and still are, at the moment of this research, forced to change their systems and the organization as a whole to adapt to the current world pandemic situation. These are changes forced by external factors to the university.

As a consequence of the external and internal changes going on, as well as the aim to provide the university with the best conditions, SIIC will also be doing technological changes. Which are, for example, changing and upgrading the academic management system, adding single sign-on and multi-factor authentication in order to improve security in the university systems. Iscte is preparing as well to open a new school away from the main campus which will host a number between 2500 and 3000 new students and a Technology Valorization Center which will require extra effort from the services. These are all examples of changes which might generate problems inside the organization, both technological and business related.

Motivated by this, this work aims to use and apply EA practices and EA Frameworks in order to help SIIC and Iscte manage their organization and respond to change more effectively. From the social and cultural to the technological aspect, is key that all the aspects are synchronized with the organization's goals in order to function as a unit and to be as dynamic as possible while producing the correct documentation to keep the EA practices in place.

It is important to represent the organization with a holistic view as well as its components. To design something that has to work as a unit, one must understand it as a whole [**16, 17**]. In order for the operations of SIIC to run smoothly, one must also need to be able to make sense of how his own work contributes to the organization as a whole and how it connects to the work of others [**3, 9**].

It is not enough to produce these artifacts and throw the concept of EA to the side, as Sessions and DeVadoss [**18**] states it is indifferent which architecture you choose if one does not understand that EA is a path and not a destination. It is a practice that an enterprise needs to adopt through its life-cycle, it isn't a one-time utilization product. Otherwise, the artifacts/documentation will become obsolete quickly and the enterprise won't be able to respond to change once again as it is hard to change a system without knowing its building plans. How do we safely change and upgrade an airplane model without knowing a descriptive representation of the old version? This example works for any complex object you want to change, enterprises and systems included [**19**].

In order to help SIIC and based on the literature review presented in Chapter 2, this work will use the Zachman Framework [**3, 9**] along with some other features inspired in other popular frameworks to document, and get an holistic vision of SIIC and their systems to help find ways to better their practices and technologies to guarantee their alignment with the organization's goals.

To complement, a series of interviews will be made with identified key players in this complex environment to better understand their feelings and perspectives towards the IS, their interaction with them (input/output) and the general workflow they have to experience. This will allow for a better insight into the As-Is state of the university and problems that already exist or might exist in the future as the process of Digital Transformation (DT) progresses. It will also be possible to compare some evidence taken from the Zachman Framework with the key players opinions.

1.2. Research Questions

To form the basis of this research, five questions were established as guidelines to help conduct this work.

(1) *Is there any form of Enterprise Architecture in place in Iscte?*
(2) *Which Enterprise Architecture practices or frameworks are being used in Iscte?*
(3) *Which Enterprise Architecture Frameworks and practices should be used for this research?*
(4) *How does one measure the benefits of the practice of Enterprise Architecture at Iscte?*
(5) *If any dysfunctions or problems were detected, how can one solve them?*

Question 1 establishes the basis for this research and the start point for the work developed. Only after understanding what Enterprise Architecture is in place at Iscte, if any, one can try to look into the EA methods and practices being used at Iscte in order to get a better understanding of what is being done concerning the EA discipline in the university which is the core of Question 2. Question 3 comes after determining the answers to Questions 1 and 2, which is what are the best practices to implement at Iscte considering what was uncovered with the previous two questions. Question 4 will help discover how one can measure the impact the practice of Enterprise Architecture has on organizations, more specific to the context of this research, at Iscte. The premise of question 5 is that if any problems were detected what solutions would be viable to correct them.

The goal of this work is by the end of the research conducted to be able to answer all the research questions proposed above. The aim is to understand the Enterprise Architecture discipline, what are the best practices, how to apply them and evaluate the results. The objective is to use this knowledge and apply it to SIIC and Iscte, implement EA practices and frameworks so that the organization is able to cope with the changes that are taking place at the moment and in the future and, in the end, to be able to measure the impact of this research in SIIC. Understand if the practices and frameworks introduced were able to help the organization reach its goals in a way that wasn't possible before.

1.3. Methodology

The methodology that this research follows is an "hybridization" and strongly inspired in the Design Science Research (DSR) which in its essence is a problem-solving paradigm [**20**]. DSR differs from the traditional Behavioral Research (BR). While BR seeks to find the "true" nature of things while observing the cause-effect relationship between them, DSR on the other hand has its intent focused on the "utility" of things, how it can develop and evaluate means-ends relationships [**21**]. DSR at heart is a methodology which helps to structure and to build artifacts which aim to solve practical problems in real life scenarios [**22**]. The work developed by Hevner *et al.* [**23**] presented 7 guidelines to help one understand better what DSR aims to do:

(1) Design as an artifact
(2) Problem Relevance
(3) Design Evaluation
(4) Research Contributions
(5) Research Rigor
(6) Design as a Search Process
(7) Communication of Research

This work follows a client/context initiated approach as seen in Peffers *et al.* [**24**], which starts at phase 4 (Demonstration) of the proposed method for the Design Science Research Methodology (DSRM) since it started after a proposal by SIIC to develop a research in the Enterprise Architecture area after observing that solutions developed by this disciple worked. To apply rigor to this research as Peffers *et al.* [**24**] suggests one then proceeds to go back to the previous phases of DSRM, which start with a problem identification and motivation phase, where the researcher needs to identify the problem at hand

and the motivation to resolve it. The next step is formulating the objectives of the solution projected to solve the problem. Once that is completed one needs to design and develop an artifact which will tackle the problem. The fourth phase ties directly into the previous one, it consists of applying the artifact to solve the problem on a suitable context. Afterwards one needs to evaluate how the artifact performs, if the researcher isn't happy with the results, it may go back to phase 2, formulating the objectives of the solution, and work on another iteration of the research. Last but not least, one needs to communicate the results, in a publication for example.

For this work, the problem is indicated by the research questions stated in the previous section, with the objectives being the ones discussed previously as well which aim to solve the problems enunciated by the research questions. The artifact considered by DSR will be comparable in this work to the EA practices and frameworks to be developed and introduced in SIIC, which will try to resolve the research questions. Question 4 and 5 prompt a work that is comparable to phase 5 of the DRSM which is to evaluate how our "artifact" performs. The development will also go through some *ad hoc* phases when the DSR methodology is deemed non-applicable to the problem in hand.

In order to have a better understanding of the topic at hand and to be able to answer the research questions established in Section 1.2 one needs to perform a literature review. There are several methodologies and protocols one could follow to carry out this task with examples being: Narrative Reviews, Mapping Reviews, Scoping Reviews, Systematic reviews, Realistic Reviews, Critical Reviews and many others which may be similar to the ones listed [**25**].

It is also possible for one to create a new protocol or adapt from the existing ones. The literature review carried out on this research is based on the Systematic Review Protocol (SRP). According to Paré et al. [**26**] a systematic review is an "exhaustive literature search" in multiple databases which uses well defined and "highly sensitive" strategies to identify all available studies within a research topic using pre-defined criteria to choose only the relevant ones.

A SRP objective is to "aggregate, critically appraise, and synthesize in a single source all empirical evidence" to be able to answer the research questions and help to "support evidence-based decision-making" [**26**]. The SRP goes through several stages [**25, 27**]:

(1) Formulate research questions.
(2) Define inclusion and exclusion criteria.
(3) Develop a search strategy based on the previously defined criteria to identify eligible studies.
(4) Select the studies.
(5) Data extraction and evaluation of the quality of the studies (quantitative or qualitative methods).
(6) Summary of the results e evaluation of the findings.
(7) Dissemination of results in form of a publication.

Depending on the author and publication, the number of steps SRP has may change depending on how explicit the author wants to be but it consists however in the same tasks. Normally the SRP is conducted in teams or at least by two people so that factors like bias, subjectivity or systematic errors in the process from one member might be mitigated.

The Literature Review protocol used in this work is as mentioned previously based in the SRP, being more lenient and shorter but still following the same steps since a systemic literature review is not the goal of this research but one still needs to conduct one to partially be able to answer the research questions posed by this research and to support the decision-making during the project.

The research questions for the literature review protocol complement the ones proposed in Section 1.2 from a theoretical point of view and when answered will help the decision-making during the project and therefore answering the research questions from Section 1.2.

- What is Enterprise Architecture?
- What are Enterprise Architecture Frameworks?
- Which Enterprise Architecture Frameworks exist?
- Which Enterprise Architecture Framework is better in a Higher Education sector?
- What are the Enterprise Architecture benefits?

The criteria made for the inclusion/exclusion of the studies was the following:

- It has to be in English or Portuguese.
- Needs to be inserted in the Enterprise Architecture discipline.
- All types of studies can be included (example: literature review, case studies, frameworks, etc).
- It needs to be detailed enough. The steps taken in the study must be well defined so one can judge its content.

To search for the studies 5 different search engines were selected: ScienceDirect (Elsevier), Springer, ACM, IEEE Xplore and Google Scholar. Using these search engines keywords combined with logical operators were used as parameters to the search:

- Enterprise Architecture
- Enterprise Architecture AND information systems
- Enterprise Architecture Frameworks
- Enterprise Architecture Frameworks AND Higher Education
- Zachman Framework
- TOGAF

The search was also divided by year intervals: 2015-2021, 2010-2014, 2005-2009 and prior to 2005.

To understand if the studies met the pre-defined criteria and were relevant for the work at hand the abstract and the conclusion of the paper were read to decide if a study was included or excluded. After this process, citation searching was conducted to complete the set of papers and achieve a more comprehensive literature review. In total 106 studies were selected and summarized by date and topic in Table 1.

The first topic in the table is Enterprise Architecture which contains every study that isn't about a framework or a study in the Higher Education sector, therefore it contains for example studies about the benefits of EA, literature reviews, history of EA, what is EA, etc. The second topic, EA Frameworks, contains every study that describes or applies any EA Framework excluding the ones in the Higher Education sector. The third topic, EA in Higher Education, has every study about EA in the Higher Education sector, being a case study, a framework or simply describing EA in the sector.

There are some conclusions one could take from interpreting the results in the table. The papers that date prior to 2005 are mainly about EA Frameworks, this is the case as most of the frameworks were developed prior to 2005, even though later perfected. As such, much of the theoretical grounds for the today existing frameworks were laid before 2005. Enterprise Architecture in the Higher Education (HE) sector also wasn't a topic until 2005, and even then the evidence was scarce. Only recently has the discipline turned to the HE sector and done some research on EA applications due it being a fairly new sector to EA. A point could be made that the number of studies in the Enterprise Architecture is low, especially for the "Prior to 2005" and the "2005-2009" categories. This isn't the case because there was a lack of findings but EA and EA Frameworks are intertwined and therefore all the studies categorized as EA Frameworks could also be listed as EA. The time period was one that the discipline was more focused in developing frameworks. As seen on Table 1, the number of studies collected gradually increases as the

date moves forward. This allows this review to have the theoretical ground laid out and on top the most up to date work and research done in the discipline.

TABLE 1. Results of the Systematic Literature Review per date and topic.

Date	Topic	Number of studies
2015-2021	Enterprise Architecture	15
	EA Frameworks	22
	EA in Higher Education	13
2010-2014	Enterprise Architecture	13
	EA Frameworks	14
	EA in Higher Education	3
2005-2009	Enterprise Architecture	2
	EA Frameworks	6
	EA in Higher Education	2
Prior to 2005	Enterprise Architecture	3
	EA Frameworks	13
	EA in Higher Education	0
Total:		106

1.4. Contributions

This thesis resulted in a set of contributions which are:

- An holistic vision into the Iscte systems that didn't exist previously;
- A full functioning *wiki* that contains the Zachman Framework developed for Iscte which stakeholders can use and explore named Atlas (`https://atlas.iscte-iul.pt/`);
- A set of scenarios and recommendations to improve the university architecture and processes.
- A scientific article to be published in a journal/conference to make the results of this research known to the scientific community.

1.5. Structure

This thesis is divided into 5 chapters, with each chapter focusing on a different part of this work. The current chapter gives a brief introduction to the thesis glancing over at the motivation behind it, objectives, research questions and contributions given by this research. Chapter 2 marks the start of this research and is a literature review which rounded up important concepts and works in the area which this thesis is inserted in so one could have a better understanding and theoretical basis of the EA discipline. Chapter 3 describes the whole core of this work which is based on a case study. In Chapter 4 one goes over the results obtained from the case study in Chapter 3 to analyze and discuss them. Chapter 5 contains the conclusions of the work performed in this thesis, the future work required and some final considerations.

CHAPTER 2

Literature Review

2.1. Enterprise Architecture

The Enterprise Architecture subject has been around for quite some time, with Kotusev [**28**] attributing that the concept started with the Business Systems Planning (BSP) methodology [**29**] developed by the International Business Machines Corporation (IBM) in the nineteen sixties. In 1986, the first EA Framework was released, named PRISM [**30**] which described the enterprise according to four domains and four types, creating 16 categories to depict the enterprise [**28**].

However, most of the publications available and researchers consider John Zachman as the father and founder of the Enterprise Architecture discipline after his publications in 1987 [**3**] which aimed to define what EA is, also providing a framework, the Zachman Framework, which describes and organizes an enterprise from multiple viewpoints including their systems.

Until this day, there isn't a consensus on what is and defines Enterprise Architecture, as multiple interpretations of the discipline are made [**6**]. It is an area which combines input from multiple domains and disciplines [**5**] therefore each person makes their interpretation of EA depending on their background. To avoid confusion and subjectivity, in this research, the definition used to categorize EA is the one seen in Gampfer *et al.* [**6**] which uses the ISO/IEC/IEEE 42010:2011 standard for architecture, "The fundamental organization of a system, embodied in its components, their relationships to each other and the environment, and the principles governing its design and evolution" [**7**]. A definition needs to be adapted to make full sense in the context of EA. To accomplish that one must view the word "system" in the definition as an enterprise or an organization. Despite multiple opinions on what EA really is defined, almost all publications and researchers consider and view it as something important to an organization.

In his original work, Zachman, although his approach was more focused on Information Systems (IS), already claimed that with the complexity of IS increasing, one needed to use some "logical construct" to define, organize and control all the components of the system [**3**]. This view has been supported and expanded by most publications and there is a consensus that EA can't only be an IT endeavor. EA must include the business side for one to really benefit from it. As Buckl *et al.* [**2**] mention, "As long as EA is only an IT topic it is doomed to fail, as it is expensive to collect the data and the benefit can only be gained if the business is incorporated". Business and IT need to be synchronized with each other to communicate successfully. Only by speaking the same language will they be able to use the IT resources to improve results and productivity [**31**].

In this highly competitive environment we live in, filled with constant change, enterprises need to be able to adapt quickly. Organizations need to fully understand the way they operate to be able to readjust their structure when facing changes forced by the environment they work in [**32**].

Alignment between business and IT is one of the most talked aspects when the topic of Enterprise Architecture is discussed [**1, 4, 33**]. In 1992, Henderson and Venkatraman developed a conceptual model for alignment, called Strategic Alignment Model (SAM) [**4, 33**]. Following work on the alignment subject has been strongly influenced by SAM and expanded from it [**4, 33**]. The concept of alignment has become one of the center points of EA, even making into many descriptions authors make of EA, for example, the case of Buckl *et al.* [**2**] which defines EA as a "continuous, iterative (and self maintaining) process seeking to improve the alignment of business and IT in an enterprise".

EA produces knowledge in the form of artifacts. Those artifacts are what help organizations in their decision making. Therefore, good and well-defined artifacts are vital for a good organization management [**34**]. Artifacts are models produced by modeling languages which have also been a field of study in the EA discipline, called Enterprise Modeling (EM).

In the EM scope, models are information produced that helps enterprises understand how they work and how they are built. One could say they form the blueprints of the enterprise. It helps explain the situation the enterprises live in and describe the operational processes [**35**]. They represent knowledge that is to be transmitted without vagueness [**36**].

In order to create these artifacts, several modeling languages have been created. These languages can be informal (natural language like English), semi-formal (graphics and schemes) and formal (mathematical theorems for example) [**35**]. Normally, informal and semi-formal languages are used to describe existing or future enterprises as a whole or their systems in a holistic view, formal languages are generally used to describe concrete properties of a system [**37**]. Several languages were developed since the introduction of the topic in the eighties, with some examples being MERISE [**35**], CIMOSA [**36**] and ARIS Toolset [**37**].

Vallespir and Ducq [**35**] makes an historic literature review about EM, and states that after the nineties, there weren't many languages being developed as a point of stability had been reached and emerging languages were inspired or expanded from previous ones. The goal was then to try to unify and standardize these languages.

One of the most notable tries to achieve this was the Unified Enterprise Modelling Language (UEML) [**32**], which isn't an attempt to "replace existing languages", but to form a conceptual base [**35**], it is a meta-model that tries to unify most of the other languages, being widely accepted by the general public.

These models and languages that compose the artifacts are then used in Enterprise Architecture Frameworks (EAFs). EAFs are a set of methodologies, practices and artifacts that serve to apply the principles of Enterprise Architecture to an enterprise or organization. They are the main topic of EA and are discussed in the next chapter.

Zachman said in 1996 that " we are on the verge of seeing architecture 'come into its own' and in the 21st Century it will be the determining factor" [**19**], however despite multiple kinds of research and hundreds of frameworks later many tries to implement EA still fail, with Gartner Group predicting that about 40% EA implementations fail [**39**].

There are multiple reasons for this, the main one being that isn't easy to apply EA, since there are hundreds of frameworks, methodologies and models as "the practical guidance available is plagued by the disparity in nomenclature as well as content" [**4**]. Anyone that wants to practice EA methodologies is faced with a lot of information with no common ground, language and orientation [**4**]. Vernadat [**32**] mentions that there is a "Tower of Babel situation" when talking about EM where there are many similar but different languages and tools, and inconsistency in the vocabulary used. The same applies to the EA scope.

Other factors might be social aspects in the enterprise when applying EA, as most of EA focus on artifacts and documentation, but EA is a process that might take some time to show some benefits. Considering EA is a path, not a destination [**18**], is a process which demands commitment from its practitioners [**2**]. As Sessions and DeVadoss [**18**] states: "Methodologies cannot solve people problems; they can only provide a framework in which those problems can be solved".

However, according to Gartner Hype Cycle from 2018 Enterprise Architecture is now "emerging from the trough of disillusionment" with new researches and practices [**40**]. Gerbet *et al.* [**40**] also considers that the "role and value of EA is often misunderstood". Practitioners often expect too much from EA, and demand immediate results which often doom EA to fail.

Despite that, the EA discipline is still an area of a lot of research with new topics of research emerging, either from the social aspects [**5**] or from a technological standpoint. Gampfer *et al.* [**6**]

states that according to their analysis Cloud computing is and will continue to be the trend in EA-related publications. It caused a big impact on EA, since Cloud computing change the way we look into architecture, with different ways to build and design.

2.2. Enterprise Architecture Frameworks

Enterprise Architecture Frameworks (EAFs) are descriptions of values, methodologies and conceptual models which help provide a clear image of the enterprise [**41**]. They help understand how different components work together and if they are coherent with each other, assisting the enterprise in staying consistent across the board [**42**]. It produces knowledge to help stakeholders in the process of decision making. TOGAF [**10, 11**], a famous framework, describes EAF as a set of descriptions of methodologies that one should base the process of designing an architecture on and a description of the artifacts that outcomes of said process [**43**].

As Zachman and Sowa [**9**] states, EAFs aren't designed to replace programming tools or techniques. They're just a way of viewing the system (enterprise) from different perspectives and connecting them. It is important that every component, social (stakeholders) or technological (systems) play their correct roles so the organization isn't crippled by them [**4, 44**].

Since the end of the eighties, when Zachman released his initial paper describing his framework [**3**], there have been hundreds of publications describing other frameworks. Despite the consensus that Zachman founded and gave life to the term EAF, an historic research on EA and EAFs developed by Kotusev [**28**] states that the concept of EAFs, although not with that name, started in the sixties with the Business Systems Planning (BSP) methodology [**29**] developed by the International Business Machines Corporation (IBM). Kotusev [**28**] also argues that the "notion of an EA framework" started with PRISM [**30**], a framework published in 1986.

However, the term Enterprise Architecture and Enterprise Architecture Framework only started to see some use after Zachman publication [**3**]. One of the first EA methodologies that appeared was the one published in Spewak and Hill [**45**] in 1992, the Enterprise Architecture Planning (EAP). The authors claim that it was inspired by the initial BSP by IBM and in the Zachman's Framework (ZF). It follows a very basic practice of EA defining 5 steps which consist in documenting the current state of the organization, designing the future state, performing a gap analysis, designing how to perform the change to the future state and implement it [**28**]. Many USA government institutions started adopting EA practices early on and developing their own frameworks. The Technical Architecture Framework for Information Management (TAFIM) was developed for the Department of Defense (DoD) in 1994. TAFIM consisted in a step methodology much like EAP while also providing some guidance to produce the documentation [**28**]. The framework wasn't very successful and was replaced by the Department of Defense Architecture Framework (DoDAF), with the first version released in 2003. Similar to the Zachman's Framework, it features a set of multiple viewpoints [**46**]. It is still in place today, being one of the most successful frameworks. The version in place is the 2.02, and was released in 2010 [**14**].

Following the example of the DoD, the Federal Government introduced in 1999 the Federal Enterprise Architecture Framework (FEAF) [**12**]. Similar to TAFIM, FEAF is inspired by the methodology used by EAP, following the same steps. FEAF, however, advises that business, applications, technology and data should be described separately [**28**].

A lot of frameworks were starting to pop up and in an attempt to generalize them, the Generalized Enterprise Reference Architecture and Methodology, known as GERAM was developed [**47, 48**] in 1999 and formalized under the as ISO 15704:2000 in 2000. It combines a set of methods and models seen in other frameworks as a means of unifying them. Noran [**49**] defines it as a "bookcase" that provides "shelves" for content from the frameworks.

The Open Group Architecture Framework (TOGAF) [**10, 11**] is developed by The Open Group and is based on TAFIM. It also recommends splitting the description of the enterprise into the four classic areas, business, applications, technology and data. TOGAF also includes a methodology called Architecture Development Method (ADM). TOGAF is also the framework which sees more presence in publications, being present in almost every discussion about EAFs [**46**].

Another well known framework popularized in 2005 is the Gartner Framework [**13**]. It uses a completely different approach than other EAFs mentioned in this work, focusing on enterprise governance and processes. It doesn't make extensive descriptions [**50**].

There are countless other frameworks, many of them only covered by a low amount of papers and are not regarded as important as the ones stated previously. According to multiple publications [**2, 13, 28, 39, 46**] and the general consensus in the EA discipline are that the frameworks ZF, FEAF, DoDAF, TOGAF and Gartner are the ones with the most contribution to the area. It doesn't mean that other frameworks are less valid than the ones stated, they are however less covered in the literature.

2.2.1. Zachman Framework

The Zachman Framework (ZF) was developed by John Zachman in 1987 [**3**] and later extended and expanded by Zachman and Sowa [**9**]. It was named as a Framework but is considered more a taxonomy or an ontology since it doesn't feature a built-in methodology.

It is composed by a 6x6 matrix with 36 cells. It represents the enterprise from 6 perspectives and each of those perspectives is described with 6 fundamental questions [**51, 52**] which are represented in Figure 1. The 6 perspectives represent the Planner, Owner, Designer, Builder, Sub-contractor, and Functioning system. Some publications attribute different names for them. However, the ones mentioned above are the original classification by Zachman and Sowa [**9**]. Each of these perspectives is represented from 6 questions which are: What, How, Where, Who, When and Why. Zachman [**3**] says that each cell is different from the other and exists for a different reason even if they are related to the same object. And since different perspectives view the enterprise in different ways, each is represented differently. Despite that, each new model shouldn't be too different from the higher-row one as it should be possible to be reversed engineered from the lower-row one [**9**]. The ZF gives a holistic view to the whole enterprise representing as well all the stakeholders involved in the process. Each cell is unique and provides valuable information to the architecture [**16, 52**].

The perspectives:

- *Planner* – usually describes the whole scope of the enterprise, not just from a technological standpoint, but everything from rules, financial aspects and restrictions.
- *Owner* – the owner is normally focused on the end product of the enterprise, it describes the enterprise routines and day-to-day life, including restrictions and requirements to achieve the end goal.
- *Designer* – it represents the design envisioned by the designer of the IT and IS systems in an abstract way which meet the owner needs but which also can be executed by the builder.
- *Builder* – describes the IT and IS systems designed previously by the designer, it chooses what technologies and tools will be used to achieve the architecture.
- *Sub-contractor* – represents the actual components that create the system based on the information and tools provided by the builder.
- *Functioning system* – describes the enterprise from a literal standpoint, describes the data, processes, where, employees, the systems in place. All the literal components that exist in place in the organization.

The fundamental questions:

- *What* – It describes the data used by the enterprise and how that date relates to one another.
- *How* – Describes the processes that are used to accomplish the end product.
- *Where* – It shows how the information flows in the enterprise. It can be physical locations or locations in the network.
- *Who* – Defines what does what. It can be people, or systems.
- *When* – Relates when things happen from a given perspective, it could be represented as actual dates or time frames for a system to act for example.
- *Why* – Describes the motivation behind the work of every stakeholder to achieve the end goal. In its essence it basically asks why this is relevant to the enterprise.

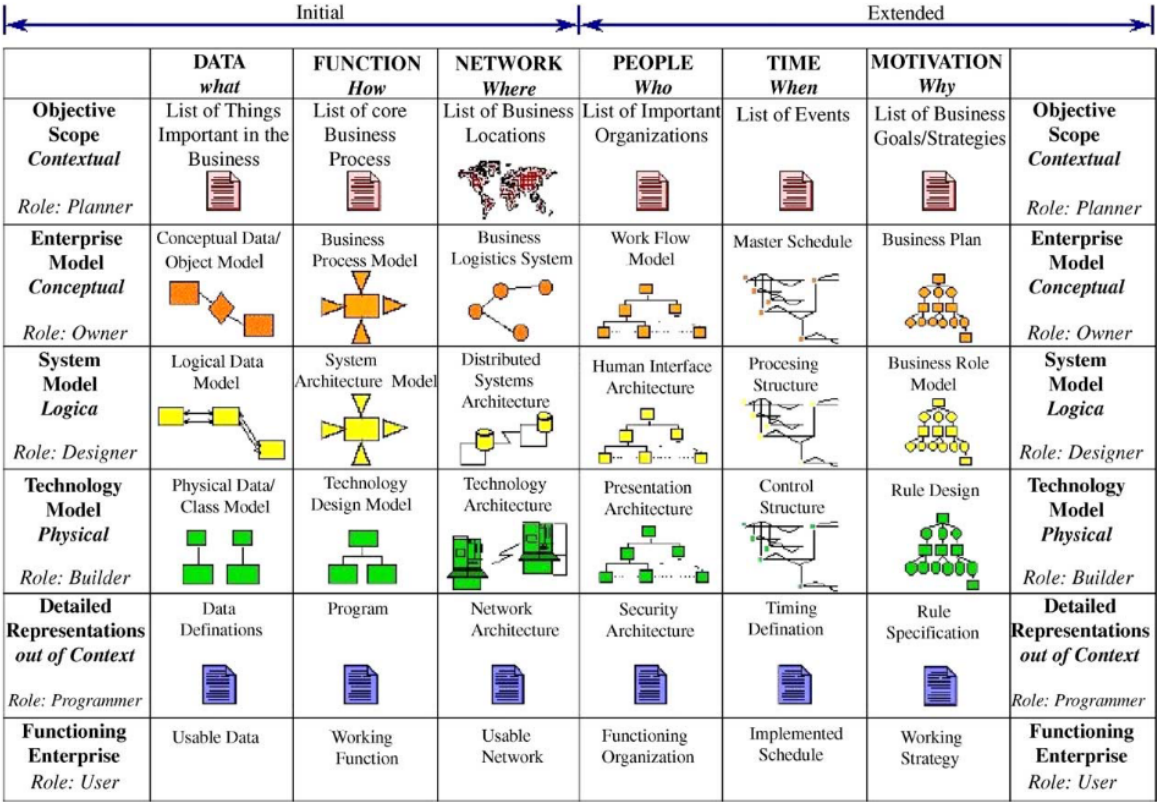

FIGURE 1. Zachman framework as seen in Noran [**49**].

Zachman and Sowa [**9**] also provide 7 rules to help develop the matrix. These rules can be viewed as more of guidelines:

- *Rule 1* – "The columns have no order", there is no order in which one needs to create the models for the framework, Zachman argues that order creates "bias" which makes some things more important than others.
- *Rule 2* – "Each column has a simple, basic model", each column represents an abstraction that respond to one of the fundamental questions, and the answer to these question are basic entities.
- *Rule 3* – "The basic model of each column must be unique", different columns can't use the same models if they aim to represent different things, therefore each column has its unique concept, but it is still related to other columns since they are part of the same system.
- *Rule 4* – "Each row represents a distinct, unique perspective", similar to rule 3, each row needs to be from a unique perspective. Otherwise the whole classification loses its purpose.

- *Rule 5* – "Each cell is unique", as a direct consequence of previous rules, if a column and a row are unique, that makes each cell unique, each providing its own value to the architecture.
- *Rule 6* – "The composite or integration of all cell models in one row constitutes a complete model from the perspective of that row", if we analyze all cells in one row we must get the complete vision from that perspective.
- *Rule 7* – "The logic is recursive", the framework can be applied to almost everything, meaning it can be used as a recursive tool, as for example, one could use a matrix to represent the enterprise and another to represent the product.

The ZF doesn't include any methodology or give away models to create the matrix. It just provides taxonomy to describe the enterprise, not suggesting an architecture for it [**50**]. The practitioner is free to use and describe the enterprise as he pleases which makes the ZF one of the most flexible and adaptable frameworks [**53**]. While this flexibility is a good thing, it also creates problems of its own, since there is no guide to fill the cells, knowing how to do it it's a challenge and may be "technologically daunting" [**50**].

There aren't many publications in the literature that help solve this problem. Vail [**51**] developed a method to decide which cells should be filled first. While it could be helpful, one could say it goes against the first rule proposed by Zachman as it assigns priorities to cells creating some bias. Noran [**49**] while trying to map ZF onto the GERAM, proposed some model languages to fill the matrix which can be seen in Figure 2. Wegmann *et al.* [**16**] proposed a way which defines some guidelines to build the models using a conceptualization based on the Systemic Enterprise Architecture Methodology (SEAM) [**54**].

	What	How	Where	Who	When	Why
Scope (Contextual)	RP / English	RP / English	RP / Map	RP / English	RP / English	RP / English
Enterprise Model (Conceptual)	ER(M), IDEF1, UML Class	IDEF0, IDEF3 UOB, UML Act, GRAI Nets	Graph	Org Chart, GRAI Grid	GANTT / PERT, IDEF3 OSTN, Timed Petri	Struct English
System Model (Logical)	ER, IDEF1x, UML Class	UML Use Case Data Flow Diag.	UML Component	GRAI Grid, UML Use Case	Data Flow, IDEF3 OSTN, Timed / Colored Petri	FOL, Struct English, Z
Technology Model (Physical)	Relational, UML Class	UML Class, Activity, Structure Chart	UML Deployment	UML Real Use Case, UI Design	UML Sequence, Collab, State, Statecharts	FOL, Struct English, Z
Components (Out of Context)	DB Schema	Programming language	URL, IP, TCP/IP	UI Programming language	Struct English	Rule spec. In Prg Lang
Functioning Enterprise	DD L(*SQL*)	Machine code (0/1)	Address, Comm language	User / Worker	English (Schedule)	English

FIGURE 2. Possible modelling languages as seen in Noran [**49**].

Zachman Framework is still one of the most regarded EAFs, since it provides a holistic view from the enterprise from different perspectives, it makes one of the most "comprehensible and comprehensive" frameworks [**43**].

2.2.2. FEAF

The Federal Enterprise Architecture Framework (FEAF) [**12**], is a framework first released in 1999 developed by the Chief Information Office (CIO) Council of the USA to be applied in government agencies. The last version FEAF v2 was released in 2013. It is inspired by the EAP [**45**] and the ZF [**3, 9**] and can be described as "combined framework", since like ZF it provides an artifact but also provides a methodology to follow to develop an EA [**34**]. FEAF makes use of the Federal Enterprise Architecture

methodology (FEA) and was developed to be applied to large enterprises and it works on the basis of segment-architecture [**13**] which divides the whole enterprise into smaller segments, for example one segment of an enterprise could be human resources [**18**]. It allows for the architecture of these segments to be designed separately but in coherence to the whole enterprise framework [**43**].

The methodology FEAF [12] uses consists in four steps:

- *Architectural Analysis* – describes the current segment and how it relates to the organizational plan.
- *Architectural Definition* – describes the future state of the segment, define performance goals, consider design alternatives and design an EA for the segment that contains business, data, services and technology architectures.
- *Investment and Funding Strategy* – Develops a funding strategy for the project.
- *Program Management Plan and Execute Projects* – Create a plan to execute and maintain the project which should include milestones and performance measures.

FEAF v2 also provides six artifacts. They are called the six FEA reference models, which try to unify the language and communication between stakeholders [**18**]:

- *Performance Reference Model (PRM)* – defines ways to measure the effects of EA. For example, to measure the technology quality one measures how the technology is performing and if stakeholders are happy with it [**18**].
- *Business Reference Model (BRM)* – helps align the different segments, giving a business view.
- *Data Reference Model (DRM)* – defines a standard way to represent the data inside the Federal Enterprises, so information could be exchanged smoothly.
- *Application Reference Model (ARM)* – it categorizes applications as well as their components, all the technological infrastructure from the segment belongs in ARM.
- *Infrastructure Reference Model (IRM)* – taxonomy reference model that contains the hardware infrastructure that supports the applications.
- *Security Reference Model (SRM)* – A model that is applied to the other reference models, which categorizes the security architecture for all the scope.

A summary of the reference models can be seen in Figure 3 and Figure 4 represents the whole concept of FEAF.

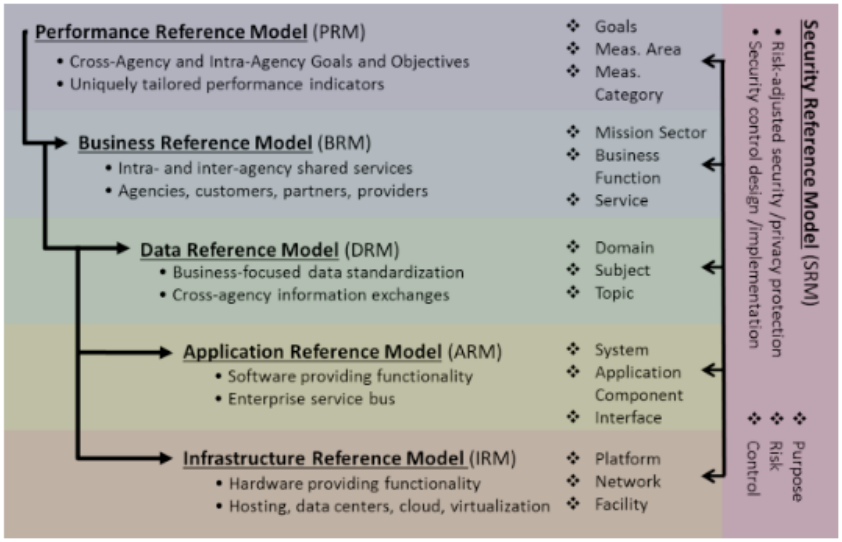

FIGURE 3. FEAF v2 six reference models [**12**].

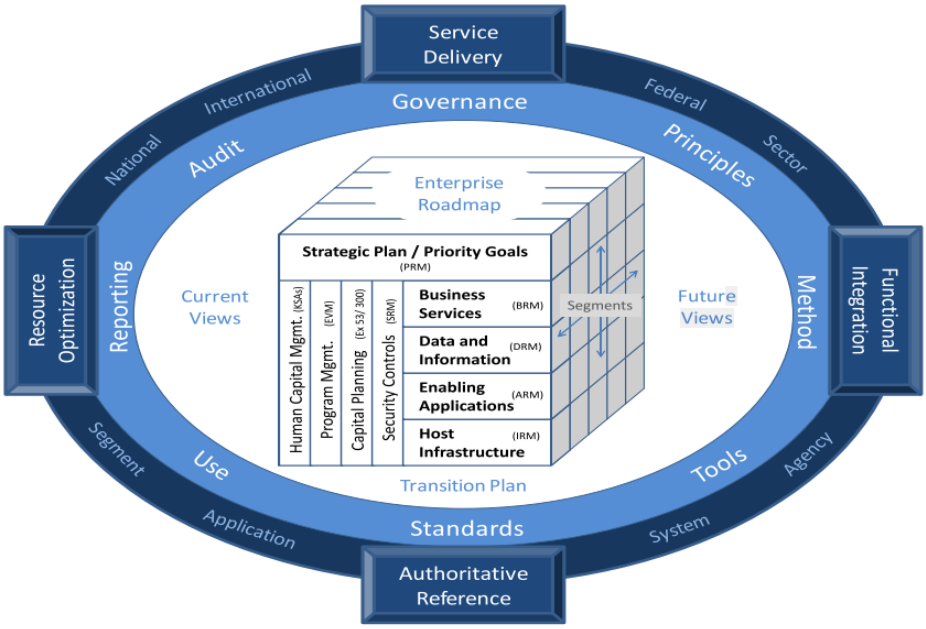

FIGURE 4. FEAF v2 [**12**].

2.2.3. DoDAF

The Department of Defense Architecture Framework (DoDAF) [**14**] was developed the USA Department of Defense (DoD) and released in 2003, it is an expanded version from its predecessor C4ISR [**55**]. It is current in version 2.02 which was released in 2010. It is quite different from other frameworks in terms of their use, since it was created for a specific scope, the DoD, and it is not prepared to deal with problems outside of that domain [**46**]. Like Zachman Framework the DoDAF could be defined as a descriptive framework [**34**] that produces models. Those models are components of views which bridging this concept to the ZF, could be considered the perspectives. Once the models prescribed by the framework for a certain view are all complete, we get the full scope of that view which is the same concept when we complete a row in ZF.

DoDAF 2.02 [**14**] prescribes 7 viewpoints:

- *All Viewpoint* – describes the overarching points of the architecture, which are related to rest of the viewpoints.
- *Capability Viewpoint* – describes the capability requirements, the deliver and deploying abilities.
- *Data and Information Viewpoint* – articulates and standardizes data relationships and aligns it with the rest of the architecture.
- *Operational Viewpoint* – describes the processes, activities and requirements that support the capability.
- *Project Viewpoint* – describes the various projects being implemented as well as the relationship between the operational and capability requirements.
- *Services Viewpoint* – describes the services and their relationships that support the enterprise.
- *Standards Viewpoint* – gathers the industry policies, standards, constraints and forecasts that are applicable to the rest of the enterprise.

The DoDAF is a data-centric approach which supports decision making in the DoD.

2.2.4. TOGAF

The Open Group Architecture Framework (TOGAF) [**10, 11**] is a framework developed by The Open Group which started being developed in 1995. TOGAF is based on the deprecated TAFIM and is current on version 9.2 which was released in 2018. It is one of the most famous frameworks and the one which features more frequently in the literature [**39**].

TOGAF provides an extensive and iterative method to design and implement Enterprise Architecture [**13, 56**]. TOGAF is supported by the Architecture Development Method (ADM). It is a methodology which makes a comprehensive description and how to develop an EA and maintain it. Kotusev [**57**] describes TOGAF as a five-step "iterative process", those steps are analyzing the current state of the enterprise, designing the future state, performing gap analysis, creating a roadmap and then implement it.

The ADM that composes TOGAF (Figure 5) has three phases: Preliminary, ADM Cycle (which has eight phases in itself) and the Requirements Management phase. TOGAF documentation also features some models to be developed during each phase.

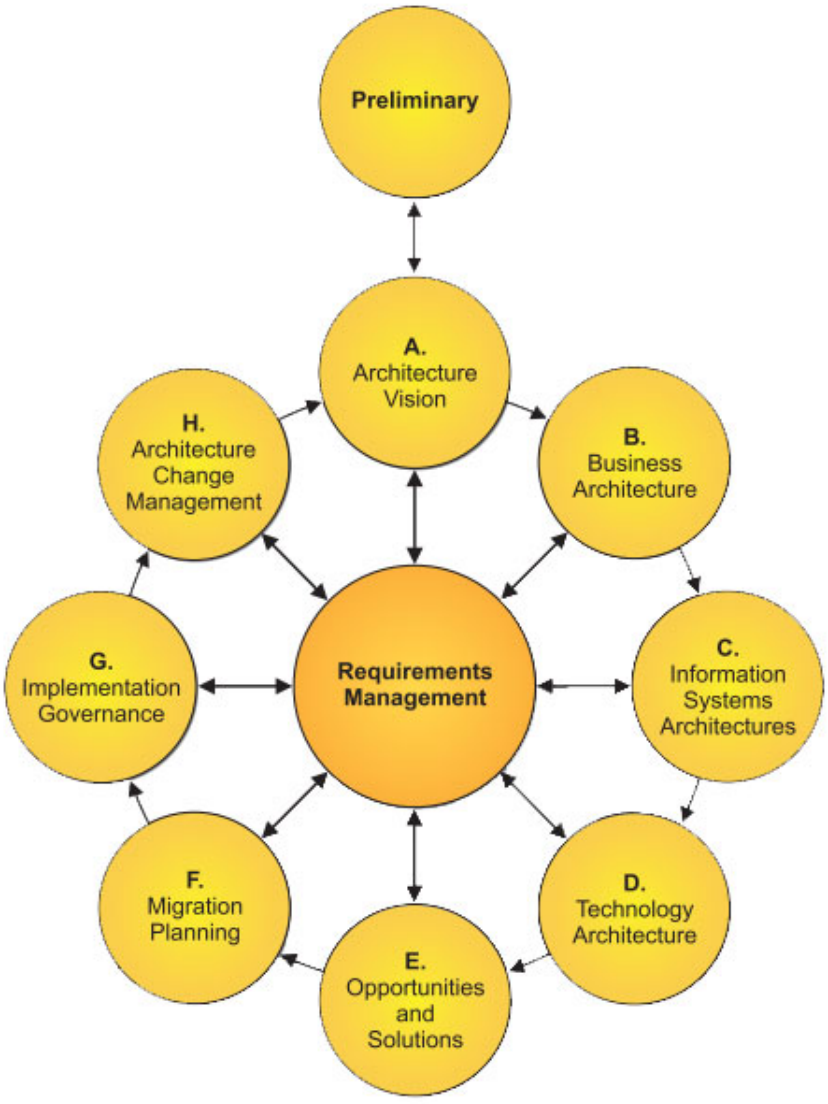

FIGURE 5. TOGAF ADM cycle [**11**].

The preliminary phase serves to document the current state of the enterprise and the current architecture in place. The ADM Cycle phase is composed by 8 phases:

- *Architecture Vision* – describes the current and future architecture from the viewpoint of business and IT.
- *Business Architecture* – maps the current business architecture versus the future one and perform gap analysis.
- *Information Systems Architectures* – describes the desired IS architecture.
- *Technology Architecture* – in this phase one defines and starts to build the basic technological architecture and infrastructure that will support the organization.
- *Opportunities and Solutions* – assessment of the implementation options available and choosing the most suitable ones.
- *Migration Planning* – describes how the organization will swap from the current architecture to the desired one formulating a migration plan.
- *Implementation Governance* – how the EA will be managed during the implementation, provides an overview of it.
- *Architecture Change Management* – defines how future changes will be managed.

The last phase, Requirements Management, is the process of managing future ADM Cycles and managing the requirements of the EA.

2.2.5. Gartner Framework

The Gartner Framework (GF) [**13, 58**] was introduced in 2005 and is developed by Gartner Group. The GF views EA in a different way and takes a different approach to architecture in comparison to the previous frameworks described. GF is focused on business and business value.

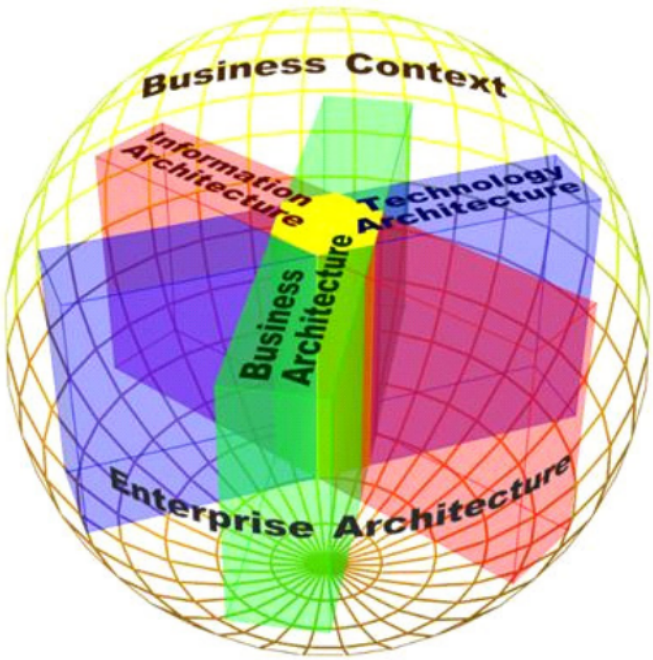

FIGURE 6. Gartner viewpoints as seen in Burton [**58**].

EA according to Gartner is about trying to reach and bring together the areas of Information Architecture, Technology Architecture and Business Architecture [**13**]. It is a strategy and is not concerned with engineering aspects [**59**].

GF is a continuous process of trying to change aspects of the current architecture to achieve a better business value. The goal is that all the stakeholders reach an understanding about what are the strategic plans and the business objectives. Then changes are made after analyzing the strategic plan and those changes are documented. It measures the outcome it had on business to understand if those changes were a success or a failure. It is an iterative methodology that focuses on processes and governance [**39**].

2.2.6. Framework Application

Before choosing a framework, one must first understand what is the goal to accomplish when applying the EAF. Only then one is able to pick the right approaches that are suitable for the organization needs [**17**].

However, there is also a consensus according to multiple publications that the direct application of an EAF in rarely witnessed in the real world. Buck *et al.* [**2**] did a survey with IT architects and found that almost no one uses an EAF "out of the box" and would adapt them to meet their needs. Many seemed to view the Zachman Framework to be helpful when starting practicing EA and would use it as a static model, but without many "far-reaching consequences". TOGAF was normally dismissed and it was seen as too complicated, since the description is about 800 pages [**2**]. Kotusev [**57, 60**] is critical of TOGAF, and corroborates the vision, as the really extensive documentation makes it harder for anyone to use it. Stating that no one the author knows uses TOGAF as prescribed by the Open Group, since it is too rigid and impractical, "If you are too rigidly following TOGAF you would never get anything done". However, the author still sees value in TOGAF and EAFs but recommends not following it blindly.

EAFs aren't magic wands one can throw at an enterprise and expect the organization to suddenly be more productive. Rocha and Santos [**52**] view them "tools to think". The practitioner needs to be aware of why and how to use them to provide benefits. Even Zachman in an interview from 2004 said "if you ask who is successfully implementing the whole framework, the answer is nobody that we know of yet." [**61**]. Gartner group supports this idea in a survey made in 2011, showing that the most popular frameworks are normally mixed with each other [**61**].

Most frameworks offer more guidance on the hard aspects of the architecture (technology, processes and systems) while offering little to no support for the soft aspects [**4**]. The humanistic side should also be included in ones application of a framework, as commitment from the stakeholders is vital for success [**56**] and their disregard for the framework and practice will "cripple" the application [**4**].

Summarizing, most of the frameworks are different from each other and focus on different aspects of the enterprise, it will be hard to choose one. As Sessions and DeVadoss [**18**] puts it "Choosing between Zachman and TOGAF, for example, is like choosing between spinach and hammers". To ensure a good application of EAFs one needs to choose frameworks which will suit their needs. The best option supported by the literature is to combine several aspects of different frameworks, since they complement each other [**18**].

2.3. Comparative analysis of EA Frameworks

Enterprise Architecture Frameworks are all different, some with similar features and methodologies but all propose their own envision of what is an EAF. Sometimes they aim to achieve different goals and are built for different purposes meaning it is hard to make an out-of-the-box comparison between them. Therefore one can't compare them directly but should do while viewing them from different dimensions.Several publications try to compare them and all follow this concept of using different dimensions.

Urbaczewski and Mrdalj [**8**] defines two dimensions for the comparison developed. A comparison by "Views and Abstractions" and one by "Systems Development Life Cycle". The publication features five frameworks, four of which are described in this paper, Zachman Framework, DoDAF, FEAF, TOGAF and TEAF (not described in this research). As already stated previously Urbaczewski and Mrdalj [**8**]

also alerts to the dangers of comparing EAFs since they are designed differently and for different goals. Nevertheless it concludes that ZF is perhaps the most comprehensive framework between the ones present in the study.

Lim *et al.* [**34**] compares 5 different frameworks, ZF, TEAF, DoDAF, FEAF and LTGAF. It defines four dimensions: View, Perspective, Scope and Time. Each of those dimensions are divided into several Enterprise Architecture Quality Attributes (EAQAs), creating thirty eight of them. Each framework is classified in three ways: supportive of the criteria, partially supportive and not supported. Lim *et al.* [**34**] doesn't compare them directly but analysis them according to the EAQAs.

Magoulas *et al.*[**4**] compares four frameworks in terms of their alignment, it compares the ZF, TOGAF, GERAM and E2AF. It defines different dimensions of alignment:

- *Socio-cultural alignment* – if the framework presents any guidelines in the social-cultural domain.
- *Functional alignment* – if the framework is clear about how Information Systems support the business.
- *Structural alignment* – if the framework characterizes the structure of the organization, describing responsibilities.
- *Infologic alignment* – If the framework is concerned of making use of the IS to satisfy the required informational needs of stakeholders.
- *Contextual alignment* – if the framework provides harmony between the external and internal environments of the organization.

Each framework is categorized in each dimension by being unclear or clear. It reached the conclusion that none of the frameworks possess socio-cultural alignment. TOGAF, GERAM and E2AF offer support in the functional domain with the situation repeating itself in the structural alignment. Only E2AF offers infologic alignment and contextual alignment is offered by TOGAF, GERAM and E2AF.

Rouhani *et al.* [**13**] also define three dimensions, concepts, modeling and process and compare the EAP, TOGAF, DoDAF, Gartner and FEAF. Each framework is categorized by H (if it has high consideration for the dimension), M (if it has medium consideration for the dimension) and L (if it has low consideration for the dimension). In the concept dimension all of the frameworks were attributed good classifications, in the modeling concept only EAP and FEA got a high grade and in process none of the frameworks got a positive grade.

Sessions and deVadoss [**18**] doesn't define dimensions but uses twelve criteria that it considers useful to compare frameworks. It categorizes the frameworks with a number from 1 to 4, 4 being the highest grade and 1 the lowest. The frameworks that feature in this publication are ZF, TOGAF, FEAF and VRF/SIP. In Figure 7 we can see the results achieved.

Sundaramoorthy and Devanathan [**50**] analyze between the ZF, FEAF, TOGAF, GF, 4+1, RM-ODP, CIMOSA and GERAM which is the best framework for software-driven enterprise. It follows the footsteps of previous publications in the literature and defines different criteria for the comparison. It concludes that the ZF is the best one for software-driven enterprises.

Bankauskaite [**42**] does a comparison between DoDAF, NAF, MoDAF, UAF, FEAF and TOGAF. It still defines different criteria like previous literature but it attributes different weights to different criteria. It defines Tool support with a weight of 0.3, Domain support with 0.3, Modeling languages openness with 0.2, Information availability with 0.1 and Prevalence by researchers also with 0.1. The overall score of the frameworks is: DoDAF 1.9, NAF 1.6, MoDAF 1.8, UAF 2.8, FEAF 1.2 and TOGAF with 2.3.

There are numerous publications that present comparisons between frameworks in the literature and almost all follow the same methodologies to compare them but attribute different criteria. The EAFs are all different from each other and it is impossible to choose one as the best or worst. Every framework aims at different goals and proposes different methodologies. One needs to first define what the goal to

achieve with EA is. Only then criteria can be defined to do some analysis on the performance of EAFs according to the strategic plan in mind to follow.

	Ratings			
Criteria	Zachman	TOGAF	FEA	VRF/SIP
Taxonomy Completeness	4	2	2	1
Process Completeness	1	4	2	3
Reference Model Guidance	1	3	4	1
Practice Guidance	1	2	2	4
Maturity Model	1	1	3	2
Business Focus	1	2	1	4
Governance Guidance	1	2	3	2
Partitioning Guidance	1	2	4	4
Prescriptive Catalog	1	2	4	2
Vendor Neutrality	2	4	3	1
Information Availability	2	4	2	3
Time to Value	1	2	1	4

FIGURE 7. Results obtained from the EAF comparison as seen in Sessions and deVadoss [**18**].

2.4. Measuring the impact of EA

Despite the EA domain being a target for a lot of research and publications with some hovering over benefits and impact of EA in an organization, there isn't much on the literature that empirically tests these studies, with evidence that testifies the benefits that outcome from having enterprise architecture practices being "sparse" [**62**].

It might be because measuring the impact of EA is personal for each enterprise and depends on many factors like the EAF adopted, methodologies followed and only the ones practicing can evaluate the impact since they are the ones who know the previous state and post state after applying EA of the enterprise [**63**].

However, Niemi [**63**] defines a comprehensive list of benefits which can be used to measure the impact of EA. The list of benefits is split into four categories:

- *Hard Benefits* – can be easily quantified, like monetary terms, time or other numeric values.
- *Intangible benefits* – cannot be easily quantified but can be attributed to EA, for example the documentation produced by an EA practice helping in decision making.
- *Indirect benefits* – can be measured but can't be attributed to EA, only partially. Like the enterprise better position in the market after applying EA.
- *Strategic benefits* – are positive effects that are felt in the long run and could happen because a lot of factors not necessarily because of EA. They can't be quantified. One example could be the improved alignment with business strategy.

The mapping of the benefits into these four categories is present on Figure 8.

Most of the benefits fit into the indirect or strategic category, making them hard to attribute to EA practices. The hard benefits could be used to measure short-term impact that EA provided to the enterprise [**63**]. Niemi also warns that even though one could use the benefit list to define EA goals, practicing EA focused only on some selected benefits could result in failure since there could be external factors that affect them.

Sessions and deVadoss [**18**] also lists eight benefits that might outcome of successful EA practices, with only one being able to be considered a hard benefit, "Reduced number of failed IT systems". The

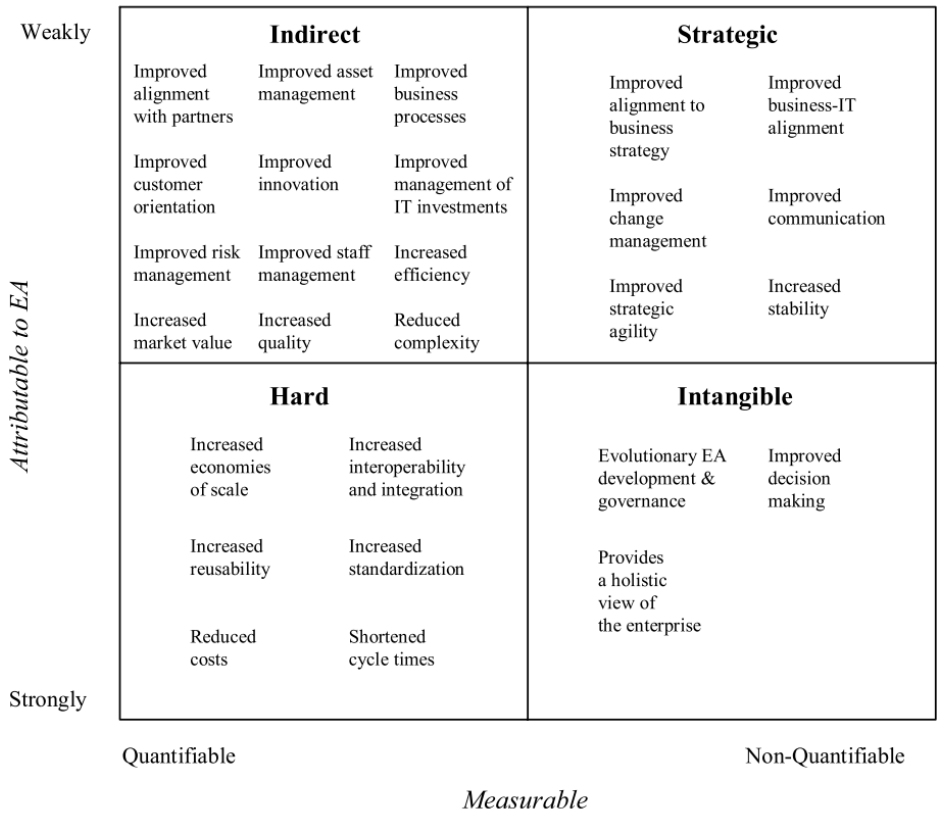

FIGURE 8. Mapping of the benefits into four categories as seen in Niemi [**63**].

rest would fall on indirect and strategic benefits and are already mapped in Figure 8. Hugoson *et al.* [**64**] state that the impacts of EA practices can be written in both extrinsic and intrinsic terms. The former is about "performance requisites" while the latter is measured by how happy are the practitioners and the ones affected by EA with the architecture.

Lagerström *et al.* [**62**] states that it doesn't matter how much time an EA architecture has been in place or if even the existence of one in the success of IT in organizations. It matters however how mature are the enterprise architecture practices to be able to see benefits.

A research framework was proposed by Espinosa *et al.* [**65**] that divides the benefits into different areas: Data, Application, IT infrastructure, Business and Organizational. The framework aims "to evaluate the organizational impact of EA."

C. Van Zijl and J.P. Van Belle [**66**] studies if there really is an empirical basis for the benefits that most of theoretical works claim to exist and be caused by enterprise architecture by studying South African organizations, reaching the conclusion that "there is a strong empirical basis for many of the claimed benefits of EA". Claiming that EA seems to help with process automation and agility while reducing costs at the same time.

While most of the academic research on EA evaluation and the benefits taken from it is from a theoretical point of view Andersen *et al.* [**67**] explores how to evaluate an EA in a practical context, using a university from Denmark as a case study. As suggested already from other publications Andersen *et al.* [**67**] also mentions that EA should be built and incremented project by project instead of trying to do it in one go as it reduces the chances of failure. The findings from this case study were that the university in question was doing well evaluating using *ad hoc* strategies and doing so project by project. Andersen *et al.* [**67**] was not able to conclude if more "formal procedures and measures" would work better for the university since the projects of today are so diverse. A case could be made that this type

of evaluation works better in this type of organizations, as universities, because the numerous types of projects and the different criteria and requirements needed for each one can be so different that it would be hard to apply a formal evaluation method. It is also argued that this may be due to the lack of "strategic direction" from the university and when the EA and IT matures the situation may change and the evaluation could adopt other practices. One should investigate their own organization and find what strategy works best as seen in previous cases, EA isn't a one-size-fits-all thing.

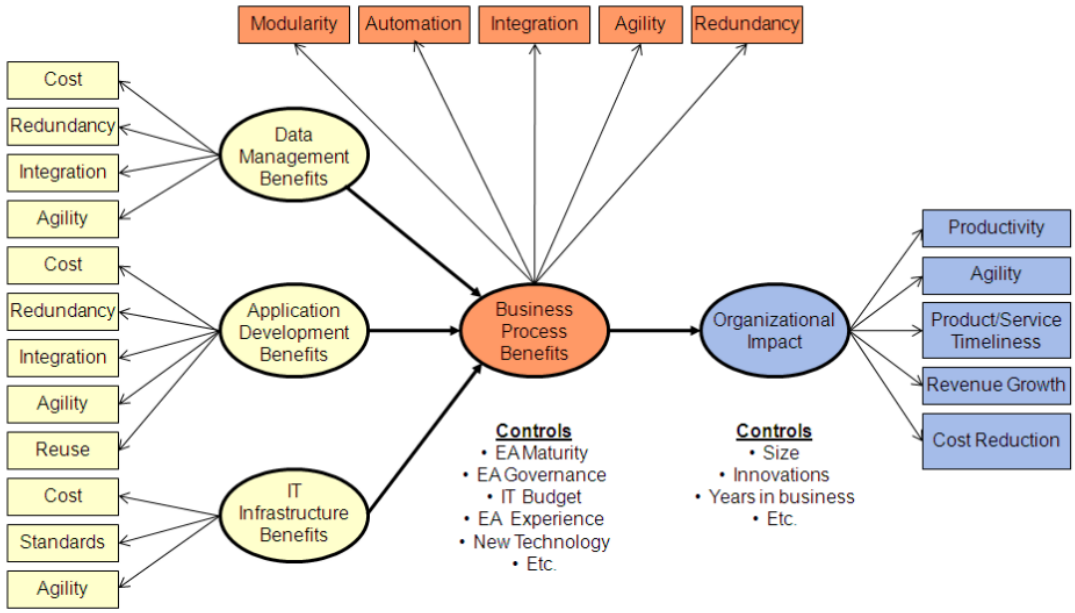

FIGURE 9. Espinosa *et al.* EA benefits research framework [**65**].

Another important thing taken from Andersen *et al.* [**67**] study is that EA evaluation should follow the famous quote, "Not everything that can be counted counts, and not everything that counts can be counted", as the evaluation should not focus only on quantifiable things as return of investment for example since EA should be investigated from different perspectives as numerous frameworks try to show it.

S. Castro and J. Jung [**68**] shows the results of a survey did in May 2020 to seventy two EA practitioners about the benefits they thought EA brings. The most obvious benefits stated were "Traceability", "Communication", "Transparency" and "Clarity". Showing that these benefits could be put in three big categories that classify what EA aims to do: "chaos prevention", "alignment of business and IT" and "benefits though the use of IT".

2.5. Enterprise Architecture in Higher Education

Higher Education normally possesses a very complex and large IS and IT systems that aim to support the many activities going in such spaces as teaching or researching. Education has become very competitive [**69**] with the systems being constantly changed and upgraded in order to stay up to date with the best ways to provide support to students, teachers, researchers and staff. To be able to do that, the information technology (IT) and the information systems (IS) need to be aligned with the business goal and strategy [**69**], which can be quite hard in such complex systems.

E. Amalia and H. Supriadi [**69**] tries to apply the TOGAF framework to an University in Indonesia where it doesn't exist any integrated systems or frameworks and a blueprint for the information systems is also inexistent which is not in line with the goal of the university. To follow the framework it gathers data from interviews with different stakeholders and from direct observation. In the end it proposes to the

university suggestions to implement in the university systems based on the research. Haghighathoseini *et al.* [**70**] searches for the best framework to use in a University Hospital, reaching to the conclusion that TOGAF or Zachman Framework would be the best. It proceeds to choose TOGAF and produces a conceptual model for the university to follow. The work of Nama *et al.* [**71**] and S. Soares and D. Setyohadi [**72**] is very similar to what was previously seen, it uses TOGAF as a framework to apply to a university. It develops a conceptual model of the framework which identifies the core business activities, supporting activities and the IS/IT system that supports them, it then proceeds to recommend changes to better align the university goals with the IT.

D. H. Olsen and K. Trelsgård [**73**] performs a study about enterprise architecture (EA) on the Norwegian higher education sector where it conducts a series of interviews to gather data. It found that the EA progress and development in such places was being "severely impeded" with the lack of guidance and instructions coming from the top level, particularly the ministry and also the not having people with experience on EA on the top management level. While it was clear that it could bring benefits, the concept of EA was not well understood at the top levels which would see it mainly as an IT task.

Digital transformation (DT) has an impact in enterprises as well as in Higher Education (HE) Institutions alike, as such it suffers from the same problems when responding to it. Past publications normally cover this topic from the teaching and education point of view and overlook the operational and organizational aspect of it. The work of Abbas *et al.* [**74**] proposes that it is easier to adapt to digital transformation by considering EA techniques or frameworks to overcome such aspects and dysfunctions caused by DT.

In 2008, JISC made a twelve-month Pilot program P. Anderson and G. Backhouse [**75**] where it investigated the viability and the application of Enterprise Architecture in the higher education sector. The Pilot main goal and guideline was to be able to answer these two questions:

- *How useful is EA to HE as a sector?*
- *How suitable is TOGAF as a framework for undertaking EA in an educational setting?*

The Pilot started with three universities, them being: King's College London, Liverpool John Moores University and Cardiff University. Roehampton University joined the Pilot mid-way through. The starting issue was the size and complexity of the universities and how to apply EA in this environment when some saying that it would be like "trying to boil the ocean". Some important questions were answered before starting the program which were:

- *What is the correct scope to initially work at: the whole institution, an individual department or a single project?*
- *Who should be involved in the process as stakeholders and what level of senior management commitment is required?*
- *Should an institution start with the 'as is' side of EA or the 'to be'?*
- *Does HE have the level of business planning and strategic vision required by the 'to be' phases of EA?*

The chosen approach was to apply EA on a small scale first, in small projects and departments and work slowly into a full Enterprise Architecture. The general conclusion from the Pilot is that EA in the higher education sector needs to be "brave and bold" which requires full commitment for it to be valuable. Being "likely" that the institutions in the higher education sector who start practicing EA early will gain an advantage over their peers when it comes to cope with change in the organization and developing IS and IT.

CHAPTER 3

Enterprise Architecture Study at Iscte

3.1. Context

As mentioned in Chapter 1 this work and research was developed and conducted in a university environment, in Iscte – Instituto Universitário de Lisboa. More specifically in the Computer and Communications Infrastructure Services (SIIC) which have as a mission, as previously mentioned, to implement, integrate, provide, optimize and maintain the technological infrastructures of the university [**15**]. As such it is key for SIIC to be able to manage all the IT and communication services which support the university operations in order to always offer students, teachers, researchers and staff the best conditions available in this ever-changing environment for them to develop and perform their daily activities.

In order to stay up to date to current technological and social-cultural standards SIIC are going through changes that will change the way their operations work as well as the university ones. The changes could be classified into 3 different categories: internal, external and technological.

At the beginning of this work there were no Enterprise Architecture Frameworks in SIIC or in Iscte in general. Most of the projects were done *ad hoc* but might in some cases display some Enterprise Architecture practices being unknowingly applied as it is common in project management. Therefore, SIIC wanted to try and use EA and EAFs to better cope with these changes.

After some meetings with the SIIC director, it was clear what the most troubled areas were. One of the biggest problems was documentation as the previous SIIC board didn't keep the documentation and data updated at all times so at the moment it was hard to know how things were done and new documentation had to be made in order to have a blueprint of the As-Is state. As previously seen, it would be impossible to change anything without knowing what we are changing [**19**]. Another area which required attention was the work responsibilities one. At Iscte, there is also an Information Systems Development Office (GDSI) as mentioned previously and work separately from SIIC being an office with a different agenda. GDSI mission is to develop and maintain the information systems at Iscte and while on paper and theoretically it's different from SIIC, in practice the boundaries where both offices operate are very blurred with work sometimes being tossed from side to side which hampers productivity and makes any change harder. This also makes alignment harder to achieve between the IT and the "business" side as IT isn't aligned within itself. Weekly meetings were scheduled with the SIIC director in order to develop this work and use EA and EAFs to help SIIC manage their organization.

3.2. Framework choice

Choosing the framework is one of the most sensitive decisions in this project and Enterprise Architecture as a whole as it impacts everything else. As such one needs to tread carefully when doing these considerations and try to factor in everything that may impact it.

To choose the framework we must first have a very well defined scope of where we want to apply it to. In this case, trying to apply a framework to the entire university might try to be, as seen in P.Anderson and G.Backhouse [**75**] trying to boil the ocean, since it would move with many pieces of the puzzle at once and if people would not be on board the EA work would fail even before it could start. It is better then to try to apply it locally and then try to branch it out than to do everything in one go.

As seen in Chapter 2, a direct comparison to choose the framework is impossible as they aim to achieve different things in different dimensions, so to make the choice one must be conscious of what the work in hands needs and what is best suited to it. In this case, we would want one that would tackle most of (but not limited to) these premises:

- Represents the As-Is state.
- Clears work responsibilities doubts.
- Solves alignment issues.
- Makes a friendly introduction to EA

As one of the most adopted frameworks, TOGAF [**10, 11**] was an immediate candidate for a possible framework to use. When the premises previously stated were factored in, it may seem like a good option but taking into account the last item, "Makes a friendly introduction to EA", and putting it versus TOGAF, the framework was discarded as a viable option. The social-cultural aspect of EA is considered as important as the technological one for the success of the endeavour, if the people aren't on board, the project would be doomed as previously stated. Therefore the methodology that TOGAF prescribes (the ADM cycle [Figure 5]) was seen as too complicated and extensive. As such the project might lose the people's support. These views support and check out with the ones in Buck *et al* [**2**] that states that TOGAF is normally put aside because of its 800 pages documentation which makes it too complicated. Kotusev [**57, 60**] who shares the same opinion, is critical of TOGAF because of the extensive documentation that it makes it hard for anyone to use it.

After TOGAF, Zachman Framework [**3, 9**] was considered and when put against the items on the list, it matched the criteria needed for this work. The matrix prescribed by Zachman gives an holistic view of the organization and as such it is able to represent clearly the As-Is state of Iscte/SIIC. The "Who" column on the matrix is also able to clear the grey areas and boundaries that exist in terms of responsibilities. When it comes to alignment, it is possible to solve a few alignment issues with Zachman by observing and interpreting the matrix following the cells either vertically or horizontally and finding incoherence's between them. Zachman Framework is also a great framework to introduce EA to the general public as it doesn't prescribe any methodology and it doesn't come with any extensive documentation so it doesn't antagonize the public as much as TOGAF. Not having any methodology associated can also be viewed as a bad thing as it leaves the practitioner almost in the dark on how to tackle the matrix and probably isn't the best framework to use when the level of EA in an organization is more mature. But for starters and on an introductory level to EA one could say it is one of the best still, a view which is also supported by several publications in the literature. F. Goethals [**43**] says it is still one of the most "comprehensible and comprehensive" frameworks, an opinion which is supported by the comparisons done by Urbaczewski and Mrdalj [**8**] and Sundaramoorthy and Devanathan [**50**]. As also mentioned before in Chapter 2 Buck *et al.* [**2**] also support the view of ZF being a good way to introduce EA with the practitioners interviewed saying it was one of the most helpful frameworks when starting practicing EA.

The FEAF was dismissed as it is meant for bigger organizations as the US government and since this work wants to start small and build an EA it would fall a bit out of the scope. The DoDAF was made specifically for the USA Department of Defense and it is not equipped to deal with problems outside of that scope. Gartner Framework is more focused on business and business value in enterprises which while it may be useful it is not the main goal in an institution in the higher education sector.

After all these considerations, the Zachman Framework was chosen to keep developing this work. This doesn't mean however that aspects of the other frameworks should be ignored and tossed aside as taking bits and pieces of other frameworks would also enrich the work at hand.

3.3. Zachman Framework

One needs to understand that as Rocha and Santos [**52**] states that an Enterprise Architecture Framework isn't a magic wand that will be applied and suddenly all of the organizations alignment and architectural problems will go away, especially using Zachman Framework as it doesn't provide any built-in methodology being more an ontology that anything else. Zachman Framework doesn't accomplish anything by itself bedsides representing the As-Is state being especially a "tool to think" [**52**]. The journey while completing the matrix from the ZF and the interpretation of it is what will provide the answers one is looking for rather than the artifact by itself.

Another consideration one needs to have, as stated on Chapter 2 , is that in practice, very rarely a direct application of a framework is made as one needs to adapt the framework to the context it is being applied to. One can recall the 2004 John Zachman interview where he said that no one he knew about was successful in implementing the whole framework [**61**].

Since Zachman Framework is a very flexible and easily adaptable framework [**53**] one should be able to perform the changes required to suit the needs of the project. As such this research, similar to many others found in the wild [**76, 77, 78, 79, 80**] adapts the Zachman matrix to the Iscte context. The matrix to be used is a 4x6 one, which can be seen in Figure 10, instead of the original 6x6 matrix prescribed by Zachman. The last two rows, the "Sub-contractor" and "Functioning system" views, as they don't quite fit to the matter at hand and aren't as relevant to the problem. Theoretically the "Sub-contractor" view also known as "out-of-context" is where a detailed representation of the implementation of the system is given. It might be a database schema, list of programs, a component architecture represented in a programming language. The view aims to represent the components used to make the core system or the total structure. Zachman in his original work [**3**] says that these are representations short of being the final physical product and could "technically be considered architectures" but they are of less value and less interesting architecturally as they don't show any representation of the final product. The "Functioning system" view depicts the final product of the matrix, the product being whatever is being depicted in the matrix, a literal physical object or a running enterprise as seen from the user perspective.

	Data (What)	Function (How)	Network (Where)	People (Who)	Time (When)	Motivation (Why)
Contextual (Owner)						
Conceptual (Planner)						
Logical (Designer)						
Technological (Builder)						

FIGURE 10. Zachman Framework matrix for Iscte.

Thus, in this research situation, there are a few reasons to omit these rows. The Higher Education sector doesn't operate like an enterprise and as so doesn't have a final product or viewed from another perspective it could be said that it has a lot of final products depending on what area of the university the focus is on. The university system being such a complex environment would be hard to represent from the out-of-context view as it wouldn't be possible to represent a primitive which would describe the

whole system. These types of information might also be the hardest type of information to obtain as an architectural point-of-view while trying to represent an As-Is state since it is very specific and most of the time not very well documented which might also introduce a time constraint. Employees might also not give it away for security reasons. Therefore it was decided that the matrix in this work would only feature the first 4 rows as it were the ones with more relevancy to the problem at hand. Zachman also considers the Owner, Designer and Builder to be the main ones to the design process of the architecture [**3, 81**].

3.4. Platform choice

An important decision one needs to make is where to host the framework, whether that place may be, physically or digitally, on a wall or in a website. There are several options one can take, but yet again one needs to choose what is better giving the context and the project circumstances. Since Enterprise Architecture is a work who requires engagement from the stakeholders, the framework needs also to be available for them to consult and take part in the project and not to be sidelined owing to the fact that as it was stated, the social-cultural aspect is as important as the technological one.

Givn the pandemic situation lived through the time-frame of this research due to the COVID-19 virus, a physical manner as a platform to host the framework was quickly discarded as most of the staff was on a work-from-home regime and was not coming to the university daily. Thus, one had to look into a digital medium to serve as a platform for the matrix. The option chosen needed to be one where stakeholders could take part in it rather easily so we could have the staff on board. It was decided that a *wiki* format would possibly be a good choice as it would facilitate the cooperation between stakeholders and one would be able to easily keep track of versions and changes to record a history of the project.

A search was then conducted to find what *wiki* would one use for this research. After looking at several options the most mentioned ones that would come up every time were: *DokuWiki*, *MediaWiki*, *ConcluenceWiki*, *Wiki.js*, *XWiki*, *TikiWiki* and *BookStack*. Most of the options were very similar in features and support so one used the website called *WikiMatrix* [**82**] which is an online tool to compare features and details between the different *wikis* and would be helpful in the process of choosing one. An excerpt from the *WikiMatrix* [**82**] comparison can be seen in Appendix A

After some analysis, it was then decided that the *wiki* to be used would be *DokuWiki*, as it was a free software made with PHP destined according to *WikiMatrix* to "personal, small to medium companies". It is regularly updated, has a plugin feature which lets one add plugins made by the community and it also has every security/anti-spam feature listed on the website.

A *DokuWiki* was then set up in an Apache webserver to host the framework. Only allowed users were able to edit or add new entries in the matrix but every cell has a comment section where everyone is allowed to give their input and insight into the given model, therefore allowing the stakeholders to participate and be kept up to date.

The name Atlas was given to the *wiki*. The main goal, after the completion of the models, is for the key players in dealing with the university architecture to be able to interact with the framework and get a blueprint of what the current architectural state of the university is. Having this vision easily accessible and concentrated in one platform will help not only the decision making but to stimulate the discussion between stakeholders for possible changes and improvements. This platform is a pilot test as it is something new that wasn't seen in other publications or researches.

Due to some of the information in the models inside the cells of the framework being sensible, the *wiki* is not available for everyone. The access is restricted to the university network and only selected users are able to access it. Access can be given by request. The Atlas is available on the following link: `https://atlas.iscte-iul.pt/`.

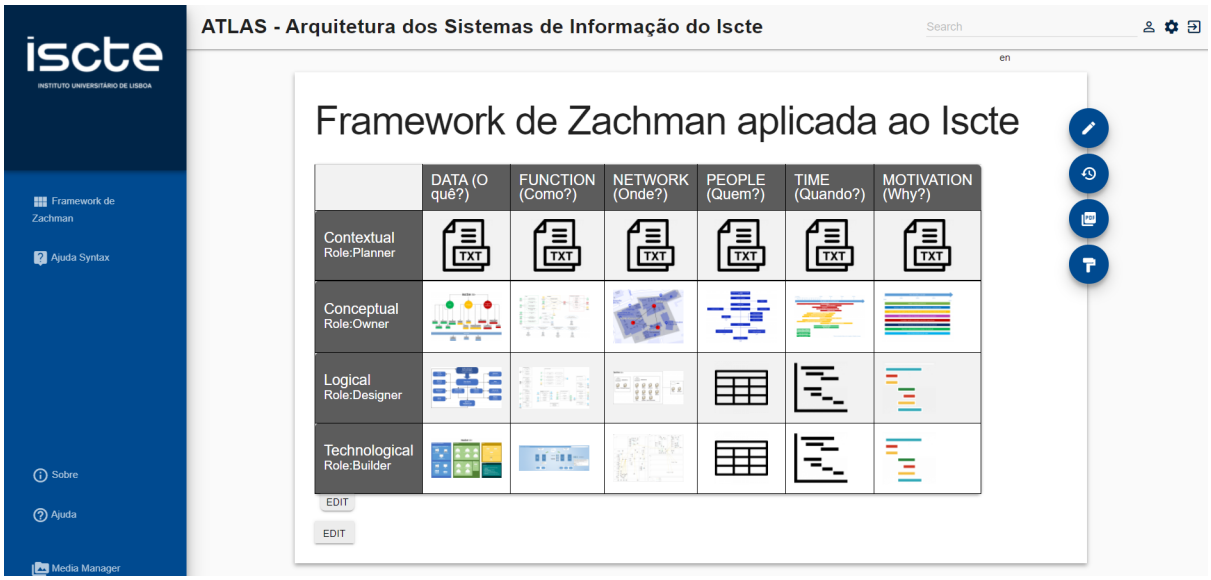

FIGURE 11. Excerpt from the *DokuWiki* that is serving as a platform to host the Zachman Framework.

3.5. Models

As mentioned in Section 2.2.1 , the Zachman Framework doesn't prescribe any modelling language or any guide on how to fill any given cell specifically. It does however provide some guidelines to fill the matrix.

While flexibility is a good thing which gives the practitioner freedom, it could also make it harder since there is no guide to follow, or modelling language to choose from as opposed to the TOGAF framework for example, which recommends the use of the ArchiMate modelling language for its framework. So it really is up to the architect to choose what it suits best the given project. A balance must be struck between comprehension and complexity as it needs to be able to describe the enterprise but also be understood by the target audience. Additionally, it is possible to create or adapt existing languages to achieve such balance [**49**].

There is also the matter of choosing a modelling language software, which might be easy once the modelling language is chosen. As following the example of the previous paragraph, Archimate comes with its own modelling software, which eliminates all choice, being worse for flexibility purposes. Due to the flexibility needed to use several modelling languages to fill the matrix, one needs to use software that supports it. In this work, Microsoft Visio was used as it supports several languages by default and has the possibility to add many more.

A practitioner might also find choosing where to start a daunting task since the guidelines provided by Zachman don't give any. However they say that there is no order to fill the matrix as creating one might insert some bias where some models are more important than others. One is left with the typical choices mentioned by Vail [**51**] which are:

- "Let's start at random and pick a cell."
- "Let's start with Row 1 and work our way sequentially across the matrix."
- "Let's start modeling with cell [X] because we have something available to capture."

All of these choices are valid and it's up to the practitioner to choose from. Vail [**51**] makes a case to use a methodology which selects the cells which have the most business value for the enterprise and start from there. But one could argue that choosing that pathway might go against the first guideline given by Zachman. As choosing the cells with the most business value we are considering that those same cells are more important and therefore creating some bias towards them. In this research one will go by column

order, as it is an option which seems to respect the guidelines provided by Zachman and it also seems the most convenient one where a practitioner doesn't have to overthink much where to start, and just do it in the "beginning" and go column by column. One could also follow another variation of this and do it row by row. No evidence was found of which option was better so one opted on the former rather than the latter.

3.5.1. Information gathering

One important step towards starting the modelling phase is gathering information for said models. A task that can be really hard to complete due to information being scattered, ill organized or simply non-existent. This was a previously known problem that one was suspected to find at Iscte and sometimes it wasn't clear who were the stakeholders who could help at such task. As such to streamline the process of information gathering, one first started to collect information that was available online and could be searchable in the Iscte systems.

For the first two rows, the owner and planer perspectives, which can be considered the rows which treat the more business/mission side of the university, the information was gathered from the Iscte platforms for example the website, MyISCTE (which is an intranet platform), *Fenix* (which is the Iscte academic system) and from the Quality Manual which is a manual done by the *Gabinete de Estudos, Planeamento e Qualidade* (GEPQ) that defines the organizational, structure, responsibilities, processes, objectives and indicators that integrate the Integrated Quality Assurance System of the Institute. All of this information had to be checked by stakeholders in a future step explained in Section 3.5.8 even though it was taken from official documents and sources to ensure the integrity of the information.

The process of getting information for the last two rows, the designer and builder perspectives, was simpler because SIIC, which is helping with this research, had direct access to the information required or was directly produced by them.

Despite that, there was still a lot of information missing that was needed to produce the content of the cells in the matrix. Consequently, one had to fill the gaps or leave them blank until an interview with a stakeholder was possible.

3.5.2. *What* column

The *What* column can be summed up as a catalogue that describes what is important for the organization, the information required so that the organization may function [**83**]. Each row from the *What* column represents the data required from a given perspective, it doesn't need to be more detailed than the previous row or expand the information already presented by the previous model, it is however the information or data necessary for the stakeholders of that perspective to describe the organization from their point of view and the information they use for their daily activities.

For the first row, the planner view, the cell contains a text in natural language. As is the case for the rest of the row in other columns as this is the most basic and abstract view that defines the scope of the organization. This approach is recommended by Zachman and seen in most of the works in the wild.

In the *Owner* viewpoint cell, a model was made in an original language made for the this specific cell loosely based in the entity–relationship model.

The model can be seen in Figure 12, representing the main areas in which the university operate, separated by colors and shapes, the circles and the big rectangle represent the areas which the university operates and the rectangles with the grey areas are key elements that constitute that area. The arrows connecting the different shapes represent the relationships between them.

From the *Designer* view a UML components diagram was used to represent the different systems, their interfaces and dependencies between each other which can be seen in Figure 14.

From the *Builder* perspective the goal was to make a diagram in which it could be possible to represent an inventory of the technological objects, from servers to computers for example. What exists in the university that enables the daily operations of the organization. For that purpose inspiration was taken from Adwan and AlSoufi [**84**] which creates EA models for an Educational Institution to create the diagram seen in Figure 13 which separates the items into different categories: IT equipment, Data-centers, Networks and Software. Each category containing sub-categories to represent with better accuracy the given items.

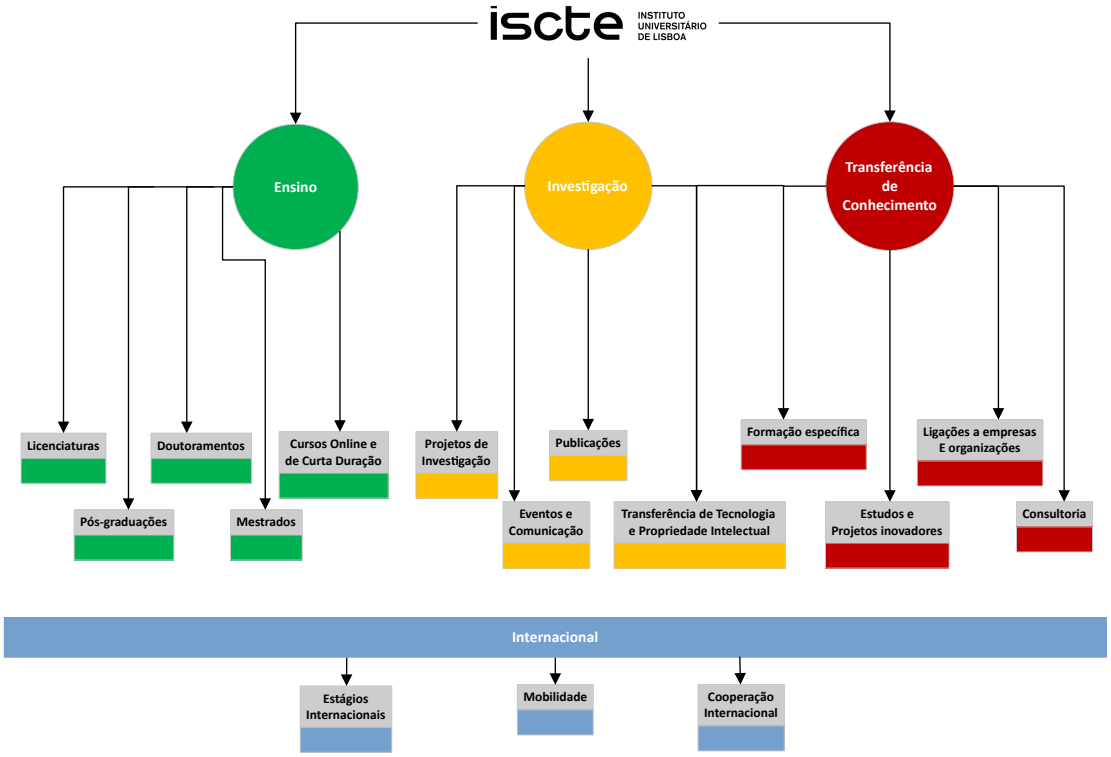

FIGURE 12. *Owner* view model in the *What* column.

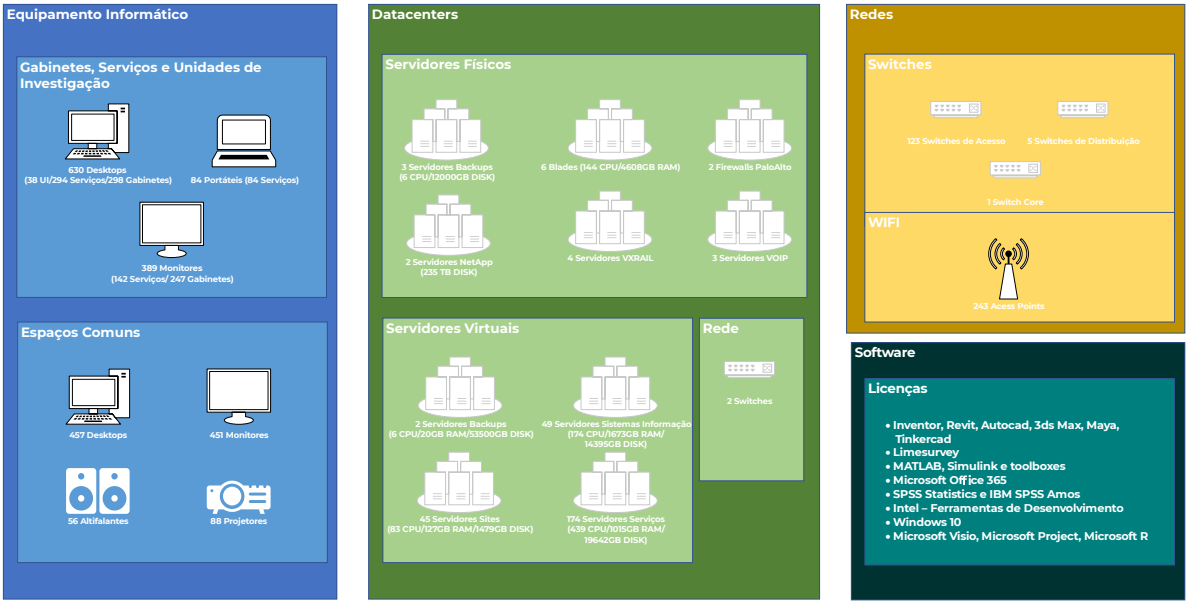

FIGURE 13. *Builder* view model in the *What* column.

3.5.3. *How* column

In the *How* column is where the processes to achieve the organization's goals are represented. It represents how a organization plans to achieve its mission which translates to how the operations function. As such it is important to identify and represent the key activities.

For the *Owner* and *Designer* rows a UML Use Case diagram was made for each perspective to represent the processes as well as the actors who take part in them. The color code used in Figure 12 was also used in both of these diagrams to maintain consistency along the matrix and improve readability. The *Owner* row diagram has represented in it the different key areas to the university mission that are also featured in Figure 12 along with the processes and actors in the given areas and can be seen in Figure 15. The *Designer* row follows the same logic where it features the systems represented in the diagram from the same row in the *What* column along with the processes that key actors perform with or on them and can be seen in Appendix B.

For the *Builder* row a custom made diagram was developed which contains the architecture of the Data-centers and how they operate and enable the rest of the technological side of the organization.

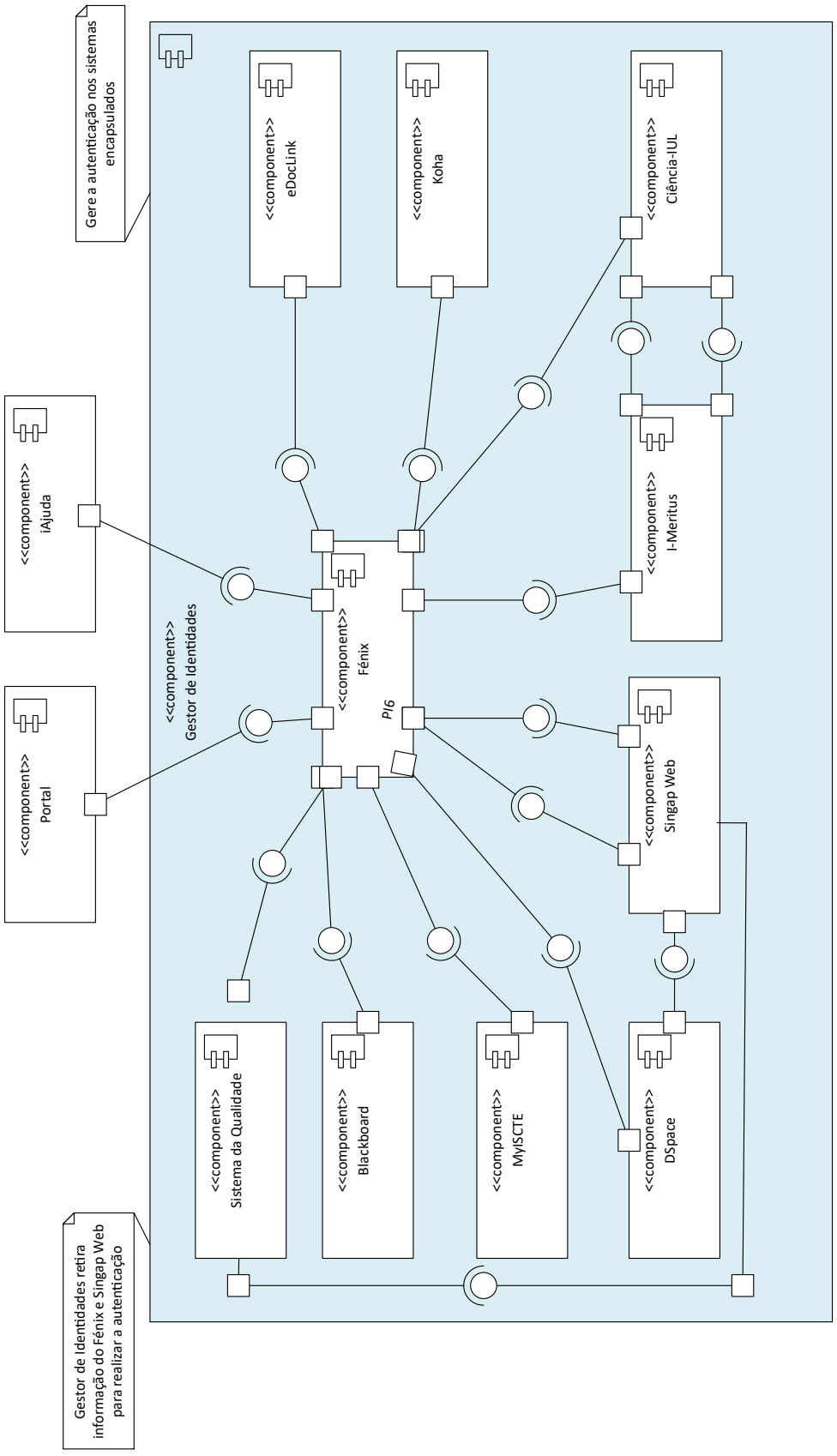

FIGURE 14. UML component diagram representing the different systems, their interfaces and dependencies between each other.

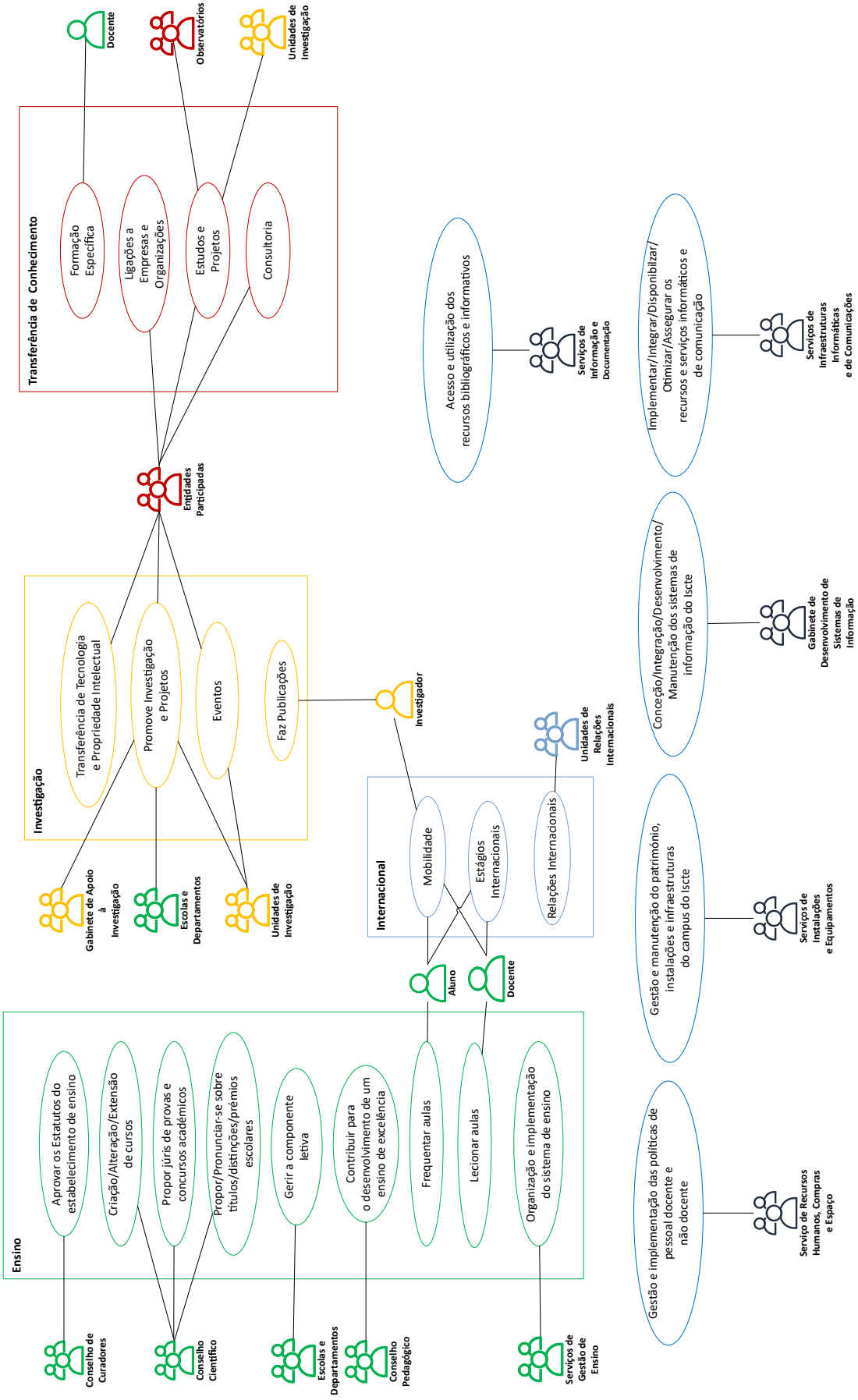

FIGURE 15. UML use case diagram for the *Owner* row.

3.5.4. *Where* column

In the *Where* column is where the "geographical distribution of the enterprise's activities" and how they are connected between each other [**83**] are represented. These locations don't necessarily need to be concrete physical spaces, can also be locations in the network or in the cloud for example.

For the *Owner* row a diagram was made representing the hard locations of the different buildings that compose the university and how they are connected between them. It can be described as a graph diagram with a map that has few nodes that represent the buildings and lines that portrait the connections between them.

For the *Designer* row cell features a diagram that contains the physical locations of the systems mentioned in the same row in previous columns and the relationship between those locations. The diagram can be seen in Figure 16

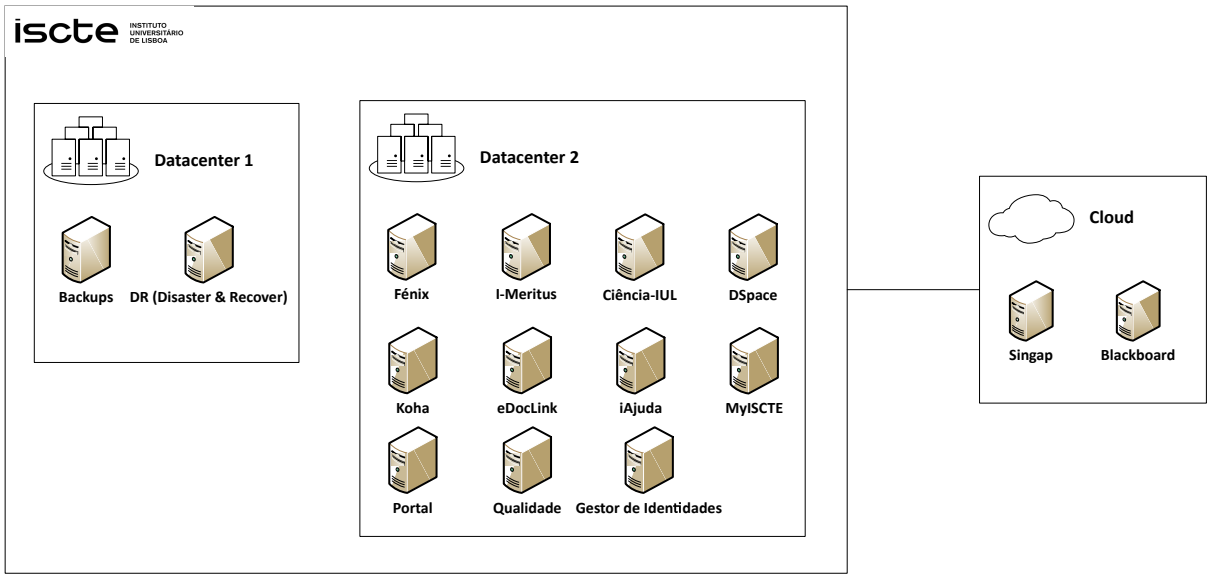

FIGURE 16. *Designer* view model in the *Where* column.

In the *Builder* row a diagram was made that contains all the physical locations of the network system in the university through the different buildings which enables the rest of the technological level to function.

3.5.5. *Who* column

This column is where all the stakeholders are identified. From the business perspective to how and who interacts with the systems. It lists all the individuals/organizations and their activities in the enterprise and how they are connected to each other. There can also be systems listed and the activities they perform.

The *Owner* cell contains a full organization chart for the university identifying every individual or service which takes part in the university activities.

For the *Designer* and *Builder* cells it was decided that a responsibility assignment matrix (RAM) widely known as a RACI matrix would be used to represent stakeholders and their responsibilities/activities. RACI stands for *Responsible*, *Accountable*, *Consulted* and *Informed*. These are the different roles that are assign to the players in the matrix that state their responsibility over something. It is used to assign "roles, responsibilities, and levels of authority" [**85**] in a given activity. It makes it easier for stakeholders in a project to communicate and plan, it is a very beneficial tool to management.

As it was feared that this would be a sensible area and where trouble might arise, doing a RACI matrix seemed one of the best options. Figure 17 displays an example of a RACI matrix used in the *Builder* perspective where the responsibilities between the teams inside SIIC: *Unidade de Redes,Comunicação e Sistemas* (URCS), *Núcleo de Apoio ao Utilizador* (NAU) and*Equipa de Apoio Técnico e Informático aos Espaços Comuns*(EATIEC) are set.

For the *Designer* row the matrix contained the different systems and the individuals/teams which have impact on them and for the *Builder* row the matrix contained the different technological categories and the individuals/teams who work or are responsible for it. The RACI matrix from the designer perspective can be seen in Appendix C.

Áreas e Responsabilidades	SIIC			
	URCS	NAU	EATIEC	ESI
Equipamento Informático Workstations	C	R/A	R	I
Equipamento Informático Servidores e Datacenter	R/A	I	I	I
Equipamento audiovisual e multimédia	C	C	R/A	I
Datacenter	R/A	I	I	C
Infrastutura de Comunicações	R/A	I	I	C
Software	R	R/A	C	I
Segurança	R	I	I	R/A

FIGURE 17. RACI matrix in the *Who* column.

3.5.6. *When* column

The *When* dimension shows how time "affects" the organization. It shows the time cycles that the organization has for its activities and how those cycles are related between them. It shows the different time-frames each perspective has to work with in order to reach the mission goals. It determines the order and synchronization of the activities but can also be a list of milestones or goals to be reached in a given time-frame.

For this column Gantt charts were made for every perspective although with different nuances. For the *Owner* view a Gantt chart was made which contains the different cycles and the different areas that the mission has to accomplish its goals. This chart, which can be seen in Figure 18 follows the same color code used in previous models.

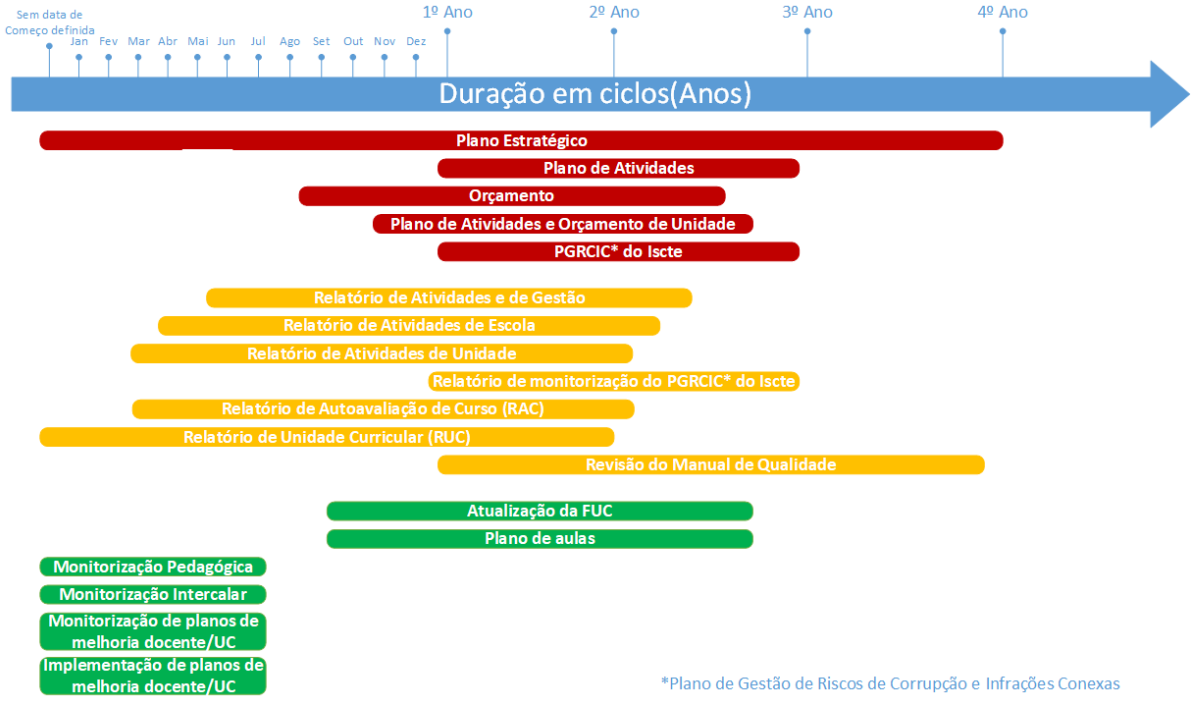

FIGURE 18. *Owner* view Gantt chart in the *When* column.

For the *Designer* and *Builder* rows Gantt charts were made that do not contain cycles but features projects and their time frames for the given view. In case of the *Designer* view it features projects that impact the existing systems or new ones and from the *Builder* perspective it features the projects which affect the technological side of the university. They are color coded to represent the different priorities in time for each project. One could say they're a kind of road map for the given view.

3.5.7. *Why* column

In the *Why* column is where one finds the goals and motivations behind the organization strategy. It lists and setups metrics and objectives for the organization [**83**]. It allows for one to get a view on the motivations behind every player in the organization, from the top to the bottom, getting everyone's perspective.

This is the column where examples and guidelines are more scarce on how to do it and what diagrams to choose from. Many of the examples found opted to do it in natural language using English for example. For the purpose of quick readability, the diagrams made for this column loosely follow the Gantt chart template as it list objectives or motivations from a given perspective into a time frame. In Figure 19 an example of this diagram can be seen, from the *Owner* perspective where strategic plans are listed in a yearly time frame.

FIGURE 19. *Owner* view Gantt chart in the *Why* column.

3.5.8. Validation

As stated previously in Section 3.5.1 some information used in the models needed to go through validation so one could be certain it was modelling the right thing, as even though it was obtained from official sources, it was not from stakeholders.

As such after the first two rows were completed a meeting was scheduled with the *Gabinete de Estudos, Planeamento e Qualidade*(GEPQ), which is responsible for the management of Iscte's Internal Quality Assurance and Sustainability System, the elaboration of studies, the management of the evaluation process and international ranking, and the technical support to the governing bodies, Schools, Research Units and Iscte services in the planning and monitoring of their activities. Therefore, they deal with the information present in the models daily and have a deep insight on it. The meeting served to fact check the information, going over the models to test readability and make an introduction to the project and the *wiki*.

For the last two rows, weekly meetings were scheduled with the SIIC director who was directly connected to the project and therefore could provide information "on the fly" and also had easy access to GDSI, the office which develops the information systems of the university as it meets with them regularly. This way, one could be sure that was dealing with factual information and also integrated the stakeholders into the development of the framework.

3.6. Interviews

As previously mentioned in Section 1.1 a series of interviews were conducted with some key players that interact with the IS, which were identified based on their roles in the organization as their perspective provides their plausible causal nexus and helps make sense of the entire system by piecing their views together. It is also possible to get their perspective based on the role they play with the IS on potential

problems that exist and ones that still might arise. This view on their workflow and how they interact with the IS and other people in the organization will give a much needed insight on the social-cultural aspect of the university which is crucial to the enterprise architecture mission and is something that the Zachman Framework might fail to give us. Despite that, some assessments taken from doing the ZF could be used in the interview to compare them with real stakeholders views and opinions. Four interviews were done with four different key players.

3.6.1. Interview Methodology

Qualitative research has been used in many distinct disciplines and uses many different techniques but only in the past decade has it started to be slowly introduced into information systems research as the research paradigm changes from the technological aspect into "managerial and organizational issues" [**86**]. According to Jabar *et al.* [**86**] the qualitative approach is important to IS research as is able to capture and explain what really happens in real organizations and helps one understand the social interaction and IS.

The qualitative method differs from the quantitative because while quantitative methods are objective and replicable as data is quantified, the qualitative method tries to understand social and cultural phenomena [**87**]. Cresswell [**88**] defines it as the process of understanding a human or social problem based in a complex natural setting. Normally the quantitative research uses methods as laboratory experiments or numerical methods [**86**] while qualitative methods uses observation, interviews or questionnaires. According to Myers [**87**] the motivation behind this method is "if there is one thing which distinguishes humans from the natural world, it is our ability to talk!".

As the goal of these interviews is to explore the social aspect related to IS that Zachman Framework can't quite reach, one will use a qualitative research approach so one can capture the social context between key players and the IS. The objective is not to be able to quantify something but to understand different occurrences from different points of view.

Therefore this part of the work sets itself apart from the positivism theory which has the goal of formulating universal laws and normally follows hypothesis testing as a method. Positivism aims to present factual knowledge that is universal [**89**]. In this situation one adopts an interpretive view which is in its core the understanding of a complex social environment involving qualitative methods by a researcher, it is the interpretation of the view a given individual has on a situation [**90**]. The interpretive view is particularly relevant for this research because as Walsham [**91**] states interpretive views on IS research are "aimed at producing an understanding of the context of the information system, and the process whereby the information system influences and is influenced by the context".

For the interview type used, the broad nature of the issues advised against a rigid interview protocol as that would limit the interviewee's ability to expose his thoughts freely and would limit the information obtained from the said interview. Therefore it was decided that a semi-structure interview would be the best interview protocol to use for this situation as is the type of interview which usually features in qualitative type researches. A semi-structure interview as the name suggests is a combination of structured and unstructured interviews where the interviewer has a small set of predetermined questions or a set of topics to go over and explore with the interviewee. Normally the predetermined questions are accompanied by *why* or *how* questions [**92**] which may stimulate the interviewee to give more personalized and detailed information instead of a default and standardized answer. It gives the opportunity to the interviewer to explore topics that otherwise would remain obscure.

The interviews were designed to take about 1 hour each and due to the sensibility of some information were not recorded. Notes were taken along the interview by the researcher. This is an option that offers a poorer account of the statements but the possible bias due to being recorded would be more detrimental to the quality of the research as some information might not be given or omitted by the interviewee due

to fear of some type of backlash. Therefore this was considered the best course of action to take. The interview topics and scripts are discussed in Section 3.6.3.

3.6.2. Key Players

To take the most out of the interviews, the interviewees needed to be key players with key functions in the university that interacted with the IS regularly to be able to understand the social context present around the IS and the general feeling towards it. Certain criteria had to be defined in order to create a key player profile and choose the right candidates. Therefore the key players have been identified as those individuals working at Iscte that cumulatively:

- Are in a central node within the network of professional relations in the IS/IT system.
- Have a position that allows them to have an overview of the system while also performing oversight functions.
- Have decision making power.

Following these criteria, the key players identified who possess such attributes are:

- The director of the academic services.
- The director of SIIC.
- The coordinator of GDSI.
- The vice-rector with oversight of the quality and information systems.

3.6.3. Interview Samples

The goal of the interviews was to get the identified key players perspective and opinions on the context surrounding the information systems both technological and social. To every interviewee the same first question would always be asked, "What are your thoughts on the information systems at Iscte?", with the interviewee encouraged to explain further with "Why", "How" or "Who" type questions. Prompted with this question the interviewees would normally focus more on the technological part which led to the second question to be focused more on the social context, "How would you describe the interaction people-people and people-systems in the university inside the information systems context?". To wrap up the interview a final question would be asked which would be "If any, what things, processes or systems could be improved and changed?". With these 3 questions one would hope to be able to get and understand the perspective from the key players on the information systems and correlate the information taken from each perspective and the Zachman Framework to form meaningful analysis and conclusions.

To sum up the planned script lined up as following:

(1) "What are your thoughts on the information systems at Iscte?";
(2) "How would you describe the interaction people-people and people-systems in the university inside the information systems context?";
(3) "If any, what things, processes or systems could be improved and changed?".

As mentioned in Section 3.6.1 the interviews were not recorded due to some information being sensible and a possible bias of it being recorded being detrimental to the whole interview process. Therefore the interviews described in the next subsections do not contain direct quotes and are instead listed in topics/ideas as to not misquote any interviewee or lose meaning in translation.

Director of the academic services

The director of the academic services manages the team which ensures the normal operations of activities related to the teaching in the university, both from the student and teacher perspective and liaising with the university technical and administrative support units in order to ensure all the necessary support to teachers and the efficient and effective operation of the schools and departments. Therefore they are a

central node which has an input/output relation with the information systems while dealing frequently with other stakeholders being the first ones in the "line of fire" if something goes wrong.

This idea can somewhat be verified as it was the interview which took longer and where the interviewee was more eager to participate and help in the project, however this might come down to a personality trait and this assessment being incorrect. The interview described by question can be found below.

Question 1 answers:

- Some system don't communicate between each other;
- Fenix (central academic system) isn't user friendly;
- Translations in the systems are poorly done or nonexistent;
- Service system is archaic;
- The Portal is done to be consumed by the people inside the university;
- On-demand functionality development without strategy and planning;
- Doesn't feel it can trust the systems due to access control not being done properly;
- Some systems are half-developed and others are heavily delayed;
- *Ad hoc* development which creates errors in other systems which disrupt other processes.

Question 2 answers:

- Interaction with the student is done manually in many situations;
- GEPQ doesn't have an interactive role in the process design and support but does too much policing;
- Some student requests leave the services and are "walking around" as the processes are not optimized which leads to bad interactions with students ;
- The Student Association have been on request for meetings with the academic services to discuss improvements to the systems;
- There seems to be no well-defined roles, everybody tries to reply to everything;
- GDSI misses development deadlines as they are always occupied with other projects;
- There are hardly any meetings between services;
- We have planning and action plans, but simultaneously lots of actions are "short-notice and on demand";

Question 3 answers:

- Improve the information displayed in the portal/fenix;
- Training people in the systems;
- It is necessary to identify points of vulnerability. Strategic and continuous improvement meetings;
- Services should do an examination of what tasks it does, the processes it needs and communications with other offices and from there do a needs assessment;
- Definition of priorities based on mission and resources;
- Development has to be done together with the target services;
- Iscte needs to work on processes, functional mapping, dematerialization and automation, in a strategic way, with the participation of all parties (involve services), but with the support of project managers for design and implementation.

Director of SIIC

As stated before, SIIC have as an objective to implement, integrate, provide, optimize and maintain the technological infrastructures of the university and therefore have an important role in the relationship between systems and people and and deal with it on a daily basis. However they don't get much say in the planning, design and development of the systems as it is not their competence.

Question 1 answers:

- The systems are design to make the university function but result of a job of giving punctual answers to little things and are never thought of in a holistic way as there is a lack of strategic vision;
- no one thinks about systems critically;
- There is a too centric view about Fenix which leaves the rest a bit put aside.

Question 2 answers:

- SIIC don't have much communication with other services;
- Planning or project-related actions take a long time;
- Other decision-makers take too long to decide and each meeting is scheduled between very long intervals;
- There is a heavy lack of human resources which leads to planning failure.

Question 3 answers:

- All the parties should come together and discuss planning and vision as decisions are transmitted but are not discussed with all the stakeholders;
- Better definition of responsibilities and accountability;
- There needs to be a person/team who designs the systems, thinks about them strategically and holistically.

Coordinator of GDSI

GDSI who have as a mission to develop and mantain the Iscte information systems are the most pivotal service when it comes to the technological side of information systems and therefore its director is a very important key player for this research.

Question 1 answers:

- Fenix is a bigger product than it should be as it have and does more features than the ones supposed to;
- It is an old system and the visual aspect is very hard to change;
- GDSI doesn't design the procedures, only execute them;
- Changes in different rules and procedures raise many other problems;
- GDSI only performs maintenance and new functionality design in the system they develop in-house and not on ones outsourced or with an acquired license.

Question 2 answers:

- GDSI doesn't deal alot with other services outside the scope of requirements gathering for developing a new system or functionality as meetings to improve planning for example;
- There is a heavy lack of resources which leads to at least 80% of planning failing as team members are diverted to emergencies;
- Dean's office assigns different priorities to things mid-project which leads to half developed features/systems.

Question 3 answers:

- Better planning in order to achieve goals;
- Hire new team members.

Vice-Rector with oversight of the quality and information systems

The Vice-Rector with oversight of the quality and information systems is the communication link between the dean's office and SIIC and GDSI who are under his oversight. Ultimately he is top decider when it comes to the information systems and the one with more power to promote any change.

Question 1 answers:

- Systems are old with several problems of aging code.

Question 2 answers:

- It is difficult to implement fluxes and/or procedures because there are several last-minute requests and unforeseen exceptions;
- Technicians were reluctant to receive expensive training courses due to the fact it would forbid them to leave the institution for several years depending on the price of the courses;
- Between SIIC and GDSI there are still some grey areas when it comes to responsibilities;
- Difficulty in hiring skilled technicians due to low market availability and not being able to compete with the salaries of the private sector;
- Hiring services of external programmers by the hour is expensive, but a pilot project is being tested.

Question 3 answers:

- Progressively systems are being renovated;
- The rules of permanence in the institution are being reviewed and an amortization policy of the course price has been implemented;
- The help of human resources specialties is being used to try to improve the recruitment of skilled technicians;
- The competences between SIIC and GDSI are being organized differently;
- Trying to improve the phase of system design with more in depth specifications combined with more strict rules in place.

CHAPTER 4

Analysis and discussion of results

4.1. Zachman Framework

Enterprise Architecture is a path not a destination [**18**] and therefore isn't something that can be used once and discarded as previously stated in Section 1.1. It also isn't a magic wand [**52**] that will fix any problem that one may encounter being a tool to think. Especially Zachman Framework which is called a framework but would be better classified as a taxonomy as it doesn't prescribe any methodology and as such it may be hard to classify any benefits given from it especially as mentioned in Section 2.4 most of them are not easily quantified.

For this research, the Zachman Framework gave us an holistic view of the university organization from both the social and technological viewpoints which was something that was missing in Iscte according to SIIC director, as people in the university tend to pay attention to the here and now, overlooking the future and the picture as a whole. It is exactly as Rocha and Santos [**52**] described EAFs, as "tools to think". One believes this is especially true for Zachman as it stimulates one to dive deeper into the EA path considering ZF as an introduction to the discipline. In this research it stimulated the participants to explore this area more and hopefully take a step back to understand the holistic view and think more critically. As a finished product the ZF has yet to have more practical value than the one explained above but one hopes to introduce it more and more into talks and meetings and branch the EA discipline talks out of SIIC only and disseminate it through the rest of the services and schools. As stated before in Section 2.5 trying to start an EA endeavour for the whole university right at the start would be like "trying to boil the ocean" [**75**] and as such this was considered the first step into introducing the discipline into the university which has seen a rise of popularity in the higher education sector in the rest of the world. Iscte as one of the most important universities in Portugal cannot be left behind, although many EA efforts are already being done especially by the GEPQ. However those same efforts seem to be disconnected from the rest of the university and have the goal to be used in external audits rather than actually bettering the university architecture.

Nonetheless travelling back to the first phrase of this section, EA is a path and not a destination, is a key motto to understand many of the benefits brought by ZF to the university. Considering the completion of the ZF as the destination or at least as a pit stop most of the value gained was on the way to the completion of it. Making the Zachman Framework allowed for much valuable information that was lost or scattered around to be condensed into one space or one model. Models that will be used in the daily life of the university and will make some tasks easier as for example the RACI matrices or the inventory model. It was also possible to uncover and verify some dysfunctions which sometimes might be overlooked as the problem runs deep but shows itself as "skin problems" but is actually a "metabolic" issue.

While having the meetings with GEPQ stated in Section 3.5.8 which served to check the fidelity from the models produced it was said they couldn't verify any technological information regarding the information systems as they didn't have any knowledge over it. This means that any planning regarding the systems is being done at an operational level and not at a strategic level. This introduces a huge amount of bias when it comes to planning the systems as the designer and the builder are the same group of people (SIIC and GDSI) and plan according to their own agendas with a lack of financial and

strategical knowledge or vision that would allow for the alignment with the business and strategic side of the university to be correct. This problem is reflected and propagated into many other small issues creating a snowball effect.

SIIC and GDSI plan and execute the systems without strategic and financial input and therefore do it without an holistic vision and with a lack of information which is crucial to perform such task. This issue carries into another problem found while doing the RACI matrices which was previously identified by the SIIC director that is the lack of clarity regarding responsibilities between SIIC and GDSI which creates a "push to the side" mentality regarding who does what and accountability issues. Since systems are not defined and planned at a strategic level but at an operational one each service plans the things they have in mind to be better, introducing bias into the planning of the systems and therefore the responsibilities are not clear between who is actually accountable for what. A plain example of this which can be verified in the RACI matrix is that SIIC is actually responsible for the Blackboard, which is the e-learning system in place at the university which one could argue it should be under GDSI wing since it is an information system.

Other systems suffer from the same problem being in a grey area and these are all symptoms of the lack of planning or strategic guidance. A brief conversation with the SIIC director while doing a model for the "Time" column of the matrix also revealed that to create this planning there is no information about the budget available, only after the planning phase one does know if there is the necessary budget available to execute it, which makes the task of managing the planning phase much harder. This only reinforces the idea that the planning of the systems is being done at the wrong level. This doesn't mean that they shouldn't have any input into it, but is recommended to be done by another team that should be responsible for the design of the university architecture with the help and input of SIIC and GDSI.

It becomes clear that the Zachman Framework had value to the university in several areas and will hopefully help fix some existent issues, however the framework can only do so much as to help spot any dysfunctions or misalignment. Only the stakeholders and key players have the power to actually solve them. It is also expected that as long as EA practices keep being used at the university and as the architecture becomes more mature these issues would be easier to fix.

In order for the Zachman Framework not to turn out into a burden it is vital to streamline the maintenance process of the *wiki* and the and models/information updates. Therefore, in the future, the process of making such models should be as autonomous as possible connecting the *wiki* to different sources of information. Responsibilities regarding the *wiki* should also be clearly defined otherwise the platform will get lost in time as it will be slowly set aside.

4.2. Interviews

As stated in Section 3.6.1 an interpretative approach was used as the relationship between people and systems are not quantifiable and only possible to evaluate through the subjective interpretation of the context that was presented to the researcher as the type of data is not regular and easily subjective.

Several interviews had to be made and not only one or two so the researcher was able to check that potential issues were not local and biased due to getting information only on one perspective but that they were systemic and could be verified across the board when piecing the different perspectives together. Despite that, statements that can't be verified by other perspectives shouldn't be set aside and ignored. They can also portrait symptoms of a deeper issue as was also seen in the Zachman Framework.

Reading the answers provided by the key players it is easy to understand that many issues can be spotted that are common and appear in every perspective. It is possible to classify the issues into three big categories:

- Planning
- Communication
- Resources

All the key players had issues with the planning, mainly because it seems to exist a lack of strategic guidance and vision. The director of the academic services stated that lots of actions were on "short-noticed and on demand" as it was felt the planning phase lacked vision and that the strategic line to follow wasn't clear. The director of SIIC said that the planning related actions take a long time and that planning normally fails as there is a heavy lack of resources matching what was said by the coordinator of GDSI which said that at least 80% of the planning failed as the team had few resources and had to divert the efforts to emergencies. The Vice-Rector doesn't mention planning explicitly but some of the statements provided could be symptoms of the lack of planning as the difficulty to implement fluxes and/or procedures, the grey areas of responsibilities that are verified between SIIC and GDSI or the absence of system renovations.

The lack of planning is then felt heavily in the systems as they seem to be developed *ad hoc* as stated by the director of the academic services and aren't carefully planned or any accountability for the future is made. This view is supported by the director of SIIC which says the systems are not the result of critical thinking or careful planning but of small additions to respond to the "here and now" situations that might arise. This is verified in the answers given by the coordinator of GDSI as it is their responsibility to develop the systems and if they fail on their planning, the systems will suffer as a result of it.

The resources and planning are heavily intertwined as the lack of resources can lead not only to failed planning but bad planning of the use of said resources can also lead to planning failure. Nonetheless there seems to be a serious lack of human resources in both GDSI and SIIC as both can't complete their respective planning due to the teams being small and can't deal with all the workload at hand. This issue is severely aggravated by, as stated by the Vice-Rector, not being able to hire more skilled technicians while being also unable to provide attractive training courses to the existent team members.

Good communication between teams and stakeholders could help dial down some of these issues but it is not an area which sees a lot of investment or special concern. The consensus between the interviewees is that meaningful communication between people outside the same service is as good as non-existent. This doesn't mean there aren't any meetings scheduled, the key players attend plenty of meetings. However those meetings lack planning and objectivity which makes the meeting lose purpose as no significant conclusions or actions are reached. Without good communication, hardly one is able to do a successful planning. A snowball is then created that streams down eventually impacting the systems and their functioning. All of these issues are connected to each other and combined are a "deadly cocktail" for any architecture as robust as it may be.

Another matter that is not encapsulated into these 3 categories but most likely derives from it is the lack of well defined roles and process following as some interviewees mention. The director of the academic services mentions that people don't quite know their roles inside the university and this behaviour is also displayed between SIIC and GDSI with both the Vice-Rector and SIIC director acknowledging that the roles and responsibilities between the two services are blurred. This leads to workers not following the processes they are supposed too. This governance problem comes from the snowball that is formed by the other issues as the lack of planning and communication leads to this uncertainty of what one is actually doing.

As uncovered as well during the Zachman Framework completion phase, there seems to be a gap in GEPQ spotted here. As mention in Section 3.5.1 the GEPQ has as its competencies to define the organizational, structure, responsibilities, processes, objectives and indicators that integrate the Integrated Quality Assurance System of the Institute. Therefore, these responsibilities and processes issues should be detected by them and consequently a course of action to fix it developed but they seem to have no active part in these matters. As the director of academic services says, GEPQ doesn't have an interactive role in the process design and support and does instead a job of policing for audits. GDSI and SIIC share the same opinion as they feel it doesn't have as much of an active role as it should.

However the first step to fix any issue is to recognize its existence and therefore the first step is taken as this research spots some, but more important than that is that the key players themselves acknowledge many issues and make meaningful suggestions. Both the directors of SIIC and the academic services seem to embrace the wider view and call for more communication and detailed planning. The academic services director makes several remarks in this direction saying that is necessary to identify points of vulnerability, detailed planning by each service and communicate with each other in strategic and continuous improvement meetings. A vision that is shared by the SIIC director who also suggests that all the parties should come together to discuss planning. A very important suggestion is also made that there is a need to have a team designing the systems and thinking about them holistically, as mentioned in Section 4.1 the design of the system should be done at a strategic level and not operational with the Vice-Rector touching on this idea by calling that improvements to the system design phase should be made. The coordinator of GDSI and the Vice-Rector offer more direct suggestions that would fix specific issues but at the end of the day may not have a great impact in the *status quo*. However they are meaningful suggestions which have the potential to improve many aspects of the university and as such shouldn't be discarded as they have value and one should still try to implement them.

4.3. Recommendations

There isn't a magical solution that would fix the architectural issues presented in this research and solve the issues that are then reflected in the information systems. Nevertheless, there are several steps that the university could take in order to achieve the desired architectural state. Having a well defined architecture in place with well established processes is costly and may deplete many of the already scarce resources but one can argue that the inefficiency (unproductive use of time and money) that is verified in the *status quo* is actually more expensive at the end of the day than the attempt at developing a established architecture.

The problem seems to be more social-cultural related than actually technological. The technological side has its issues but it is reflecting the problems that exist outside of its realm as they are the actual cause of misalignment between the systems and the actual mission goal. Systems cannot be built to predict so many exceptions and events that the lack of well defined processes creates. The "pains" felt in the systems are a snowball that starts with the inadequate planning of the university services. As mentioned in Section 4.2 specific fixes in the systems like making a given system more user friendly as suggested by the director of the academic services would only get you so far and would probably only mask the real issues for a time. A counterargument to this idea would be as expressed by some key players that some systems are old and archaic with aging code and therefore there is a problem with the systems specifically. To refute this argument one argues that the systems being old is a symptom of the lack of planning to renovate them and of the *ad hoc* mentality installed. Consequently there is nothing innately wrong with the systems as the same technology would function better if it was encompassed by another social context. Therefore to try to fix some of the issues regarding governance and the coordinating mechanisms present at the university three possible scenarios are established:

- Scenario 1: *Status quo* maintenance (incremental changes at a micro level in processes, responsibilities and planning);
- Scenario 2: Incremental structural change, reallocation of functions and responsibilities while maintaining the organic structure;
- Scenario 3: Radical change, restructuring of the organic structure.

Scenario 1 is the course of action that would implicate the least drastic change but the one which would consume less resources and might be effective as a short-term solution but eventually a bigger change would be necessary if the aim was to fix most of the existent problems. Scenario 3 is the most radical option that one would be able to choose and could be way too drastic as a change of the dimensions suggested by the third scenario may create even more disarray in the university and an experienced and expensive enterprise architecture team would be needed to be able to sustain a transition of this magnitude. Considering the lack of resources currently felt at the university this option doesn't feel feasible while maintaining the daily activities operational. Scenario 2 seems to be the most grounded of the alternatives presented and perhaps the best course of action. Seeing that it guarantees the most amount of potential fixes to the issues while maintaining a sustainable cost. It would allow for the university to keep practicing Enterprise Architecture approaches and to create a successful university architecture that would enable the organization to be as efficient as possible with the resources available. Nevertheless, there are specific actions that this research would recommend the university to do regardless of the path chosen by key players and stakeholders with them being:

- Creation of an architecture team which would overview and oversight the information systems architecture and that would design it at a strategic level;
- Better communication between services (strategic and continuous improvement meetings as suggested by the director of the academic services);
- A more active role from the GEPQ near the services as to help create better processes and improve planning across the board;
- Do not concentrate the IS and IT decisions on the Vice-Rector as the decisions shouldn't be centralized in one individual as it may create bias;
- Restructure SIIC and GDSI responsibilities inside the scope of the IS as to make it clear the roles each service has, and to guarantee no accountability issues;
- Offer better and more attractive career development programs to workers;
- Be able to provide more attractive job and career opportunities in SIIC and GDSI.

This list presents several actions to take but one should not be limited to it and ought to have a holistic view of the university which the Zachman Framework may help and think critically of the current state of the university. Understanding what are the reasons why the current *status quo* is in place is a good start point to any Enterprise Architecture endeavour as one needs to understand the context first to act on it. Therefore and as stated previously, the *wiki* needs to be maintained and updated in order to stay relevant. Clear responsibilities should be defined so the Atlas project doesn't become another grey area that will be set aside. One argues that a team compromising of members from SIIC, GDSI and the architecture team should all have clear responsibilities over different aspects of the *wiki*. SIIC being responsible to provide with the platform hardware, GDSI should have responsibilities over developing a possible automation for the model updating phase and perform maintenance while the architecture team should have control over the sources of information that are used in the models.

CHAPTER 5

Conclusions and Future Work

5.1. Conclusions

The Enterprise Architecture (EA) discipline has been around since the eighties but is fairly new to the higher education sector. Universities operate in many similar ways to any other enterprise and therefore depend on a strong and stable architecture to function and achieve their mission goals. Much of that needed stability comes from the alignment between business and information systems. Inside the EA scope there are several frameworks and practices to help one achieve the desired state.

The use of the Zachman Framework in this work combined with the interviews with key players from Iscte allowed this research to identify several issues. The issues found are mainly inserted in the topics of planning, communication and resources. These problems found at an organizational and governance level are then felt and reflected in the systems as they are a product of the social-cultural context lived at Iscte. Based on the circumstances at Iscte one was then able to suggest several scenarios and solutions that might fix some of the issues presented in this thesis.

A *wiki* style platform named Atlas was also developed to host the Zachman Framework. The key players when dealing with the university architecture are now able to interact with the framework and get a blueprint of what the current architectural state of the university is. Having this vision easily accessible and concentrated in one platform will help not only the decision making but to stimulate the discussion between stakeholders for possible changes and improvements. This platform is a pilot test as it is something new that wasn't seen in other publications or researches.

Another goal of this research was also to be able to answer the 5 research questions that started this work to study the viability of Enterprise Architecture inside the higher education sector. Those questions are now answered below.

- Is there any form of Enterprise Architecture in place in Iscte?

After this research one can conclude there are several forms of Enterprise Architecture being displayed in Iscte. Although they are not necessarily being applied consciously and the intent is not to bring the discipline into the university but to apply things that are innate to an organization for its necessary functioning.

- Which Enterprise Architecture practices or frameworks are being used in Iscte?

As far as this work was able to ascertain, there is no specific framework being used at Iscte and as stated there are several practices being applied that are innate to an organization and usually feature in project management. They are mostly used in an *ad hoc* form as there isn't apparently a detailed plan to use them. For example several forms of Enterprise Modelling can be seen featured in the GEPQ Quality Manual for the university. The manual serves itself as a form of Enterprise Architecture as it explains and exhibits part of the university organization, processes and motivations.

- Which Enterprise Architecture Frameworks and practices should be used for this research?

The answers for this question mainly come from the literature review one performed as the lack of field experience in the area makes it impossible to have the knowledge necessary for such a choice. In spite of that one took what was learned through the literature review and the context where this research is inserted in to create a set of premises which defined a criteria to choose a framework. Based on those

criteria and the level of maturity in Enterprise Architecture the university displayed one opted for the Zachman Framework and to perform a set of interviews that would complement some aspects that the framework chosen didn't cover.

- How does one measure the benefits of the practice of Enterprise Architecture at Iscte?

It was seen in the literature review that measuring and finding the benefits of the practice of EA is not always easy or obvious. Especially at a short-term after using it as is the case of this research. One hopes and is positive that this research will eventually bring benefits to the university. The documentation produced and the recommendations that came out of this research can certainly bring benefits even if not considered hard benefits that one can quantify. Most of the benefits one is expecting to see are intangible and strategic that won't be felt instantaneously. However it is possible to measure them by doing future researches and understanding if the points brought out by this work had any positive effect in Iscte. There is also a point to be made that the results and conclusions that this work is able to reach are already a benefit to Iscte in itself as it helps the university to prepare for the future.

- If any dysfunctions or problems were detected, how can one solve them?

There were several issues detected by this research. Mainly about the lack of planning and well defined responsibilities which then creates a snowball that ends up reflected in the systems. The systems are being planned at an operational level which creates bias as the designer and the builder are the same entity. With the responsibilities between SIIC and GDSI being blurred there is a lack of accountability when it comes to the information systems. However, the lack of well defined planning is felt across the board and one could say it's systemic, as sometimes an *ad hoc* mentality reigns supreme. A serious issue found is the lack of ability to hire new staff members for SIIC and GDSI as Iscte is not able to compete with the salaries of the private sector. Adding to this workers are reluctant to receive training courses as that would bind them to the institution and make them unable to leave for some years depending on the price of the courses.

The recommendations to solve the issues detected feature:

- Creation of an architecture team which would overview and oversight the information systems architecture and that would design it at a strategic level;
- Better communication between services (strategic and continuous improvement meetings as suggested by the director of the academic services);
- A more active role from the GEPQ near the services as to help create better processes and improve planning across the board;
- Do not concentrate the IS and IT decisions on the Vice-Rector as the decisions shouldn't be centralized in one individual as it may create bias;
- Restructure SIIC and GDSI responsibilities inside the scope of the IS as to make it clear the roles each service has, and to guarantee no accountability issues;
- Offer better and more attractive career development programs to workers;
- Be able to provide more attractive job and career opportunities in SIIC and GDSI.

Nonetheless, to solve them the university has to be proactive in tackling these issues as they will only pile up and be progressively harder to rectify. It is necessary to act on them as soon as possible.

Following the DSR methodology this work used, it is possible to consider the artifact, the Zachman Framework and the interviews, a success as it allowed for the problem to be tackled and explored. Therefore one doesn't see the need to do another iteration of this specific research as more value could be extracted in exploring different paths. This thesis along side with the article that came from this research serves the purpose of completing the last step of DSRM, which is the communication of the results.

5.2. Limitations

As with every research, this work also suffers from some limitations. As this work was proposed by SIIC which served as an entry point to the organizational/business side of the university the researcher's view could be biased in some points as some views might be skewed due to one being embedded into the SIIC reality and context. The sheer size of the university also poses as a limitation as it is hard, could even be said impossible, to understand the whole context and factor every stakeholder perspective or view into this work. Therefore a choice had to be made to choose certain key players in the detriment of others at the risk of missing some things that would also be beneficial for this work.

As a work that has to deal with an organization and stakeholders which is not only dependent on the researcher and his work, one has to accept that is counting on the good faith and goodwill of the people involved. It is necessary to trust the information provided by stakeholders as sometimes there are no procedures possible to check the information's authenticity. The researcher runs the risk of the information given by stakeholders omitting some important details that the stakeholder may think that it would make the organization/stakeholder look bad before its peers.

5.3. Future Work

Just as stated multiple times through this research, the Enterprise Architecture endeavor is not a one-time utilization product. It is a continuous process that an organization needs to do through its life cycle. Abandoning it now would only be counterproductive and the work already started in the area would be wasted. Therefore one encourages Iscte to keep trailing the Enterprise Architecture path as it would only bring benefits for the university and would set Iscte apart from its local counterparts.

For Atlas, the *wiki* platform, it is recommended in order to expand its life cycle for automation processes to be designed and developed. As it would only be necessary to change the information in one source and no time would be spent in updating the models. The *wiki* by itself would get the information from the source and update the models. This would be a key aspect for the continuous and successful use of the Zachman Framework at Iscte.

As far as future researches go, following up on the work this research explores, there re many options and paths one could follow. It would be interesting for the university and the EA discipline to understand the benefits this work brought to Iscte in a medium-long term scenario and if any of the recommendations done were followed and their actual impact on the organization operations. It would also be compelling to understand if any other frameworks and practices can be used to help Iscte and the higher education sector in general to achieve the desired state which would make the mission fulfilment possible. In addition to that compare those results with the ones achieved by this research.

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Appendices

Appendix A

BookStack vs. Confluence vs. DokuWiki vs. MediaWiki vs. Tiki Wiki CMS Groupware

GENERAL FEATURES	BOOKSTACK	CONFLUENCE	DOKUWIKI
Version	v21.05.2	5.2	2020-07-29 "Hogfather"
Last Release Date	2021-06-12 (2 months ago)	2013-08-12 (8 years ago)	2020-07-19 (1 year ago)
Last Update here	2021-06-24 (2 months ago)	2013-08-22 (8 years ago)	2021-08-09 (30 days ago)
Author	Dan Brown	Atlassian	Andreas Gohr
URL	bookstackapp.com	atlassian.com/software/confluence	dokuwiki.org
Free and Open Source	✓ Yes	✗ No	✓ Yes
License	MIT	Commercial + Free personal/open source project/community use	GPL 2
Programming Language	PHP	Java	PHP
Data Storage	Database	Database	Files
License Cost/ Fee	0	starting at US $10 installed (unlimited wikis)	0
Development status	Mature	Mature	Mature
Intended Audience	Small to mid-size groups and businesses	Enterprise + Technical Teams	personal, small to medium compa

vs. Wiki.js vs. XWiki

MEDIAWIKI	TIKI WIKI CMS GROUPWARE	WIKI.JS	XWIKI
1.32.2	22.1, 21.3 LTS, 18.8 LTS	2.0.12	13.7
2019-06-05 (2 years ago)	2021-02-02 (7 months ago)	2019-11-22 (1 year ago)	2021-08-30 (9 days ago)
2019-06-21 (2 years ago)	2021-05-20 (3 months ago)	2021-08-09 (30 days ago)	2021-09-01 (7 days ago)
Magnus Manske, Brion Vibber, Lee Daniel Crocker, Tim Starling, Erik Möller, and others.	Tiki Software Community Association	Nicolas Giard	XWiki Development Team
mediawiki.org	tiki.org	wiki.js.org	xwiki.org
✓ Yes	✓ Yes	✓ Yes	✓ Yes
GPL	LGPL	AGPL-v3	LGPL + Free hosting on http://myxwiki.org for individuals/non profit
PHP	PHP	Javascript	Java
Database	Database	Database, Files, other, RCS	Database, RCS
0	0	0	0
Mature	Mature	Mature	Mature
anies End Users/Desktop, Education	Needing not just a robust wiki, but a full-featured CMS/Groupware with a bug tracker, discussion forums, blogs, etc.	Everyone	Enterprise, Workgroups, Developers

FIGURE 20. Excerpt from the *WikiMatrix*[**82**] comparison as of 8th September 2021.

Appendix B

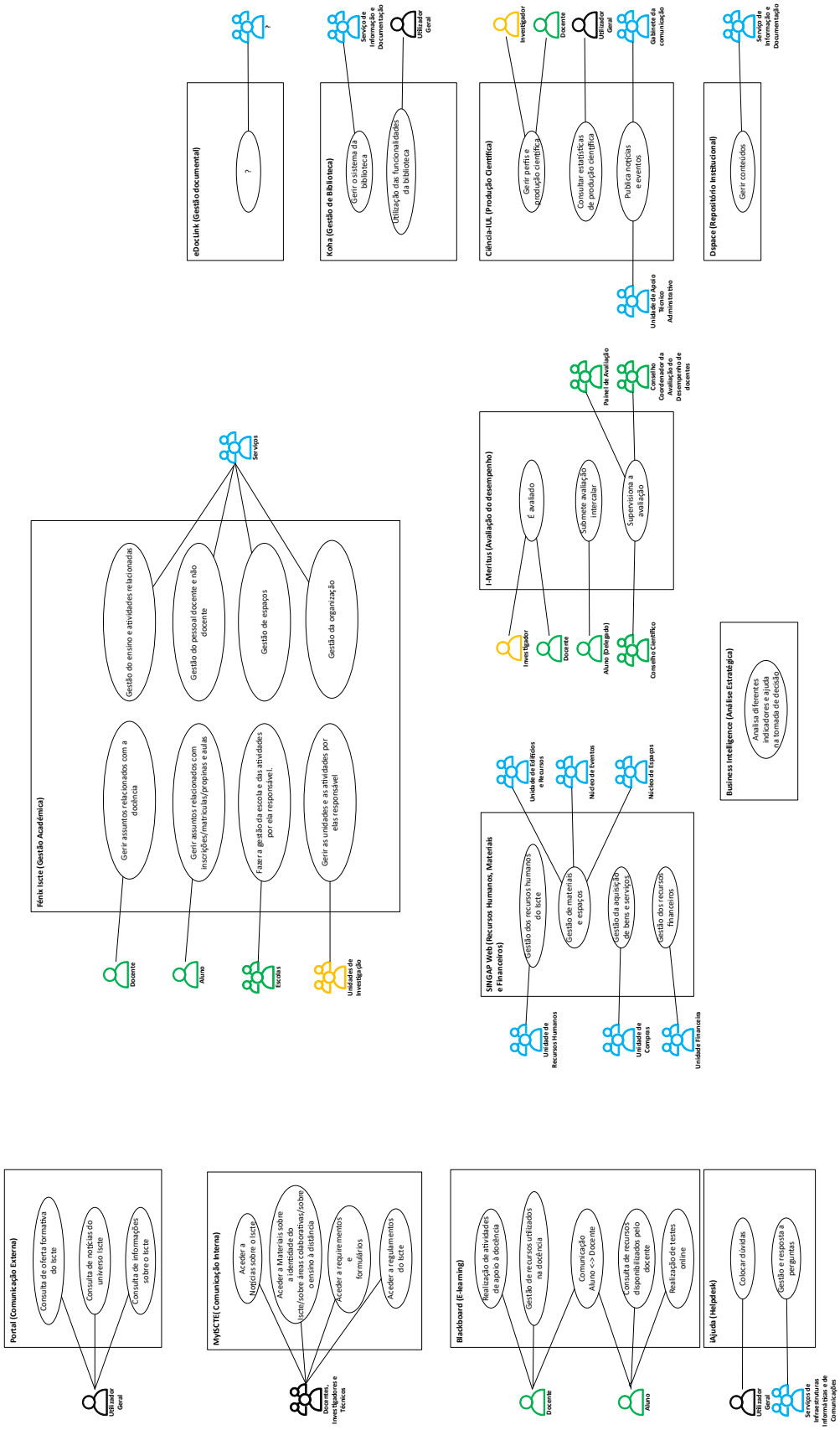

FIGURE 21. UML use case diagram for the *Designer* row..

Appendix C

Sistemas e Responsabilidades	GDSI		SIIC				Outros serviços Iscte
	Fénix	Projectos	URCS	NAU	EATIEC	ESI	Biblioteca
Fénix	R/A						
Blackboard			R	R/A			
Singap		R					
Ciência-IUL		R/A					
I-Meritus		R/A					
MyISCTE		R/A					
Portal		R/A					
iAjuda			R/A	C	C		
eDocLink				R/A			
Dspace							R/A
Koha							R/A
Qualidade		R/A					
Gestor de Identidades			R/A	C			

FIGURE 22. *Designer* view RACI matrix in the *Who* column.