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Comparing Enterprise Architecture Frameworks – A Case Study at the Estonian Rescue Board

Master's Thesis (30 ECTS)

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Abstract:

Every organisation has strategic goals it wants to achieve, and if it does not have an architecture combining all different elements such as business processes, enabling information systems, data flows and platforms, it will not be sure which investments will lead to achieving which objectives. Since there has not been any research like this performed for Estonian Government Organisations, the Estonian Rescue Board is taken as an example for conducting a case study. A systematic literature review is performed, for identifying Enterprise Architecture Frameworks, criteria for performing a comparative analysis of the framework as well as for the further evaluation at the Estonian Rescue Board. The identified final papers are analysed in order to answer the Research Questions (RQ). This helped to identify seven Enterprise Architecture Frameworks, which were evaluated and left only three frameworks for further implementation: The Open Group Architecture Framework (TOGAF), The Federal Enterprise Architecture Framework (FEAF), Service-Oriented Architecture (SOA). In the case study, the selected frameworks are modelled, showing 2 or 3 services in details, with further evaluation and discussion of them during the meeting at the Rescue Board, following the criteria, which are described in the literature review. Case study and on-site meeting at the Rescue Board set two main things to be the most vital while developing Enterprise Architecture Framework in the organisation: organising architecture into views that are subsets of the organisation information architecture and understanding how the goals in the organisation are supported. This can be a good backbone for further developing Enterprise Architecture in the Rescue Board, and other Estonian Government Organisations in general.

Keywords:

Enterprise Architecture, Enterprise Architecture Frameworks, Estonian Government Agency, literature review, case study, criteria, evaluation, comparison

CERCS: P170 Computer science, numerical analysis, systems, control

Ettevõtte arhitektuuri raamistike võrdlus – juhtumiuuring Eesti Päästeametis

Lühikokkuvõte:

Igal organisatsioonil on strateegilised eesmärgid, mida ta soovib saavutada. Ilma tervikliku arhitektuurita, mis kombineerib kõik erinevad elemendid - äriprotsessid, infosüsteemid, andmevood ja platvormid -, ei saa olla kindel, kas või kuidas viivad investeeringud eemärkide täitmisele. Kuna ühegi Eesti riigiasutuse kohta ei ole teadaolevalt selleteemalist uurimust tehtud, valiti selles magistritöös juhtumiuuringu näiteks Päästeamet. Magistritöös antakse esmalt süstemaatiline ülevaade erialasest kirjandusest eesmärgiga leida sobivad organisatsiooni arhitektuuri raamistikud ning kriteeriumid raamistike võrdleva analüüsi läbiviimiseks ja edasiseks hindamiseks Päästeameti näitel. Valitud allikate põhjal vastatakse uurimisküsimustele. See aitas tuvastada seitse ettevõtte arhitektuuri raamistikku, mida hinnati ja jättis alles kolm raamistikku edasiseks rakendamiseks: The Open Group Architecture Framework (TOGAF), The Federal Enterprise Architecture Framework (FEAF), Service-Oriented Architecture (SOA). Seejärel modelleeritakse juhtumiuuringus erinevaid raamistikke kasutades detailselt 2-3 teenust ning viiakse kirjanduse ülevaates kirjeldatud kriteeriumite abil läbi hindamine ja arutelu Päästeameti töötajatega. Juhtumiuuring ja kohapealne kohtumine päästeametis seadsid ettevõtte organisatsioonide arendamiseks organisatsiooni arhitektuuri raamistikud jaoks kõige olulisemad kaks peamist asjaolu: organiseerida arhitektuur seisukohtadesse, mis on organisatsiooni infoküsimuste struktuuri alamhulk ja mõista, kuidas organisatsiooni eesmärgid on toetatud. Töö tulemus on heaks aluseks organisatsiooni arhitektuuri edasisele arendamisele Päästeametis ja teistes Eesti riigiasutustes.

Võtmesõnad:

Ettevõtlusarhitektuur, ettevõtlusarhitektuur, Eesti riigiasutus, juhtumiuuring, kirjanduse ülevaade, kriteeriumid, hindamine, võrdlus

CERCS: P170 Arvutiteadus, arvutusmeetodid, süsteemid, juhtimine (automaatjuhtimisteooria)

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List of Abbreviations

The table below describes the meaning of the abbreviations used in the thesis.

Abbreviation	Meaning
ERB	The Estonian Rescue Board
EA	Enterprise Architecture
EAF	Enterprise Architecture Framework
GEA	Government Enterprise Architecture
TOGAF	The Open Group Architecture Framework version 8.1
ADM	Architecture Development Method
FEAF	The Federal Enterprise Architecture Framework
CPM	Collaborative Planning Methodology
PRM	Performance Reference Model
BRM	Business Reference Model
DRM	Data Reference Model
ARM	Application Reference Model
IRM	Infrastructure Reference Model
SRM	Security Reference Model
DoDAF	The Department of Defence Architecture Framework
DoD	Department of Defence
MODAF	The British Ministry of Defence Architecture Framework
NAF	The NATO Architecture Framework
SOA	Service-Oriented Architecture
ESB	Enterprise Service Bus
WSDL	Web Services Description Language

GEA	Government Enterprise Architecture
SDLC	Software Development Lifecycle
BPMN	Business Process Model and Notation
SIM	Siseministeerium (Ministry of Interior)
PKPO	Pääste- ja Kriisireguleerimispoliitika Osakond (Rescue Work and Crisis Management Department)
TSO	Teabeseireosakond (Information Monitoring Department)
IHO	Infohaldusosakond (Information Management Department)
CTIF	International Association of Fire and Rescue Services
FEU	Federation of the European Union Fire Officer Associations
ICT	Information and Communication Technology

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1 Introduction

For the past years in Estonia, there has been a lot of discussions about an inadequacy of a systematic and process-based approach to the development and management of public services, increasing the quality of provided services in the organisations such as the Social Insurance Board, the Police and Border Guard Board, the Rescue Board. All of the mentioned public sector organisations are currently in a state of reorganising and describing their structure, processes and customer-focused orientation. Research initiated by the Ministry of Economic Affairs and Communications and the Government Office, made by PricewaterhouseCoopers (PwC), aimed to create a consistent classification for managing public services provided by all national and local governmental institutions. Following this, the Estonian Rescue Board (ERB) identified and described 31 main, as well as 31 support services. 62 mentioned services have the process hierarchy with more than 200 sub-processes listed. An example of the ERB structure is provided in Appendix 1 [1].

The development of Estonian IT Interoperability Framework architecture is service-oriented. For that, a data transfer layer called X-Road (so-called common service area) was developed and is currently in use. It is considered among the best practices at the international level. Estonia is one of the first countries, which has had a national interoperability for several years already. Today, this requires only a few days or, in some cases, only a few hours, and limited budgets (on average from $ 1,000 to $ 10,000) to develop [2]. Moreover, it is required from Estonian Government Agencies to share the data they have, in order to make e-services better, the number of which is currently equal to approximately 25,000. It is worth mentioning, that even though X-Road is used at the ERB, IT development and maintenance is not a part of the organisation. An IT-related work is outsourced to a separate organisation. Therefore, the need for developing Enterprise Architecture (EA) has arisen. EA and different Enterprise Architecture Frameworks (EAF) organise and design different "views" that make sense and ease to understand the whole structure of the organisation by various stakeholders. The primary objective of Interoperability Framework is to ensure that public information systems are citizen-centric and service-based. The Estonian IT Interoperability Framework uses three perspectives [2]:

- Organisational Interoperability – the ability to provide services to other agencies or their clients, which is ensured by legislation and general agreements
- Technical interoperability – is based on interoperability of infrastructure and software, which requires standard data exchange protocols, software development, necessary for managing data connections
- Semantic interoperability – the ability of different organisations to understand exchange information in the same way

For the future research, two research questions presented below were formulated, which will help to get an understanding of how Estonian Government Agencies can select and evaluate EAF, taking the ERB as an example.

RQ1: Which EA frameworks are relevant for evaluation for an Estonian Government Agency?

RQ2: Which criteria are important for selecting an EA framework at the Estonian Government Agency?

1.1 Objectives

Three stages are vital in implementing EA at every organisation. **Modelling "as-is" architecture,** which provides a view of current goals, processes and resources. In the current architecture, the organisation and its IT assets are shown. In many cases, the current structure is a starting point. **EA plan** shows the transition plan from "as-is" to "to-be" architecture. The development plan illustrates how the target structure will be implemented in the organisation. While developing it, it is easy to understand if there are resources and time to realise the vision of the organisation. The transition plan is a basis for planning resources, determining the timing of the launch for projects, monitoring these projects. **Modelling "to-be" architecture,** which provides a view of future goals, processes and resources, that are based on the mission, vision and strategy of the organisation. In the case of the ERB "as-is" architecture will be modelled.

Just having a look at the structure of the organisation and processes described in the text, makes it difficult to estimate how current business objectives can be reached using IT, how IT functions should be altered with changing of the organisation, etc. However, together with results to be performed, directions of the organisation's development, key projects, and initiatives, to achieve by 2025, the ERB has formulated Strategic Courses of Action, which includes five main points [3]:

1. Continuing transformation into a preventive population protection organisation.
2. Expanding partnership with all related parties, such as employees, volunteers, science and education institutions, local community leaders, etc.
3. Modernising technologies and adoption of more to improve the effectiveness of prevention and rescue efforts.
4. Data analysis and fact-based long-term planning.
5. Improving organisational capacity.

The primary objective of the thesis is to find the criteria, which will help government agencies to select the most suitable EA framework for them before they start doing all the modelling process. This can be accomplished with the following steps: conducting the literature review for identifying different EA frameworks and assessing their suitability; taking a few examples as "test case", creating a shortlist of EAFs that will meet needs of the ERB most; modelling a part of "as-is" architecture using the chosen EAF; getting feedback and evaluation from the ERB employees; analysing based on the Rescue Board strategy, finalising and advising the final criteria for selecting EAF.

1.2 The Estonian Rescue Board

The Estonian Rescue Board is a governmental institution under the jurisdiction of the Ministry of the Interior, which has the leading role in planning preparedness for emergencies and the operational management of Regional Rescue Centres. As each of the government organisations or private companies, ERB has their mission, values, and vision, which are the following:

Mission: We prevent accidents, save lives, property, and the environment [3].

Values:

- Helpfulness – we notice and assist people in need of help.
- Courage: we have the courage to decide, act and take responsibility.
- Trust: we trust, and we are trusted [3].

Vision: Together we have reduced accidents and losses to the level of the Nordic countries [3].

In 2013, based on the mission, values, and vision, the ERB completed a strategy for ten years (2015 – 2025). The next step after already setting strategic goals was facing the challenge of aligning all the processes at the ERB, information systems and data flows, for the purpose of efficient execution of the strategy. In Table 1, some of the baseline figures for the year 2013, as well as objectives and strategic choices for 2025 are provided [3]. The Rescue Board is striving to achieve the level of safety indicators common to the Nordic countries within the next eight years (as of 2017). In general, achieving a vision means that in the future there will be fewer accidents and less damage, people who use the services will be satisfied, the awareness of preventive actions will be raised and will become more wide-spread. However, for this, the resources that are available need to be allocated more efficiently.

Objective	2013 level	By 2025
The number of fatalities in accidents is reduced		
In fires	47	< 12
In water-related accidents	56	< 20
In detonations of explosives	0	0
In chemical accidents	0	0
The number of rescue events is reduced	20 195	< 15 500
The number of fires in buildings is reduced	1627	< 1300
The number of fires in residential buildings is reduced	892	< 700
The number of environmental accidents and the amount of environmental damage declines. The number of forest and wildfires is reduced	1275	< 500
Property damage caused by building fires is reduced	13 575 000 €	<10 000 000 €
People feel safe in Estonia. The trustworthiness rating of the Rescue Board is high	95%	> 95%

Table 1: Impact of ERB to society [3]

2 Literature Review

In this part, the steps how literature review was conducted, the relevant scientific articles were found, and the information from them was extracted, is described. Literature review was conducted in order to identify EA frameworks and gather evaluation criteria. The aim of this part is not to find every EA existing and all its variations but focusing on the main ones applied today in the world. The first part of the literature review will focus on identifying EA frameworks in order to answer RQ1, while the aim of the second part is to answer RQ regarding criteria for selecting the right EAF.

2.1 The Method of Literature Review

The Literature Review is a method of evaluating and interpreting all types of research relevant to a particular research topic or subject area. Systematic reviews tend to provide an assessment of the research topic using a reliable methodology. The main guideline for Literature Review [4] is based on existing guidelines of Keele University and University of Durham. The guidelines cover three stages of a systematic literature review: planning a review, conducting and submitting a review. However, the guidelines do not consider the impact of research questions on the search and do not indicate the steps that are necessary for implementation [5].

Systematic reviews begin with the definition of the review protocol, which determines the research question and is based on a clearly defined search strategy. For systematic reviews, clear inclusion and exclusion criteria are required in order to evaluate each potential primary study. Before starting a systematic review, it is necessary to confirm the need for it and carry on the most important pre-revision activity, which is definition of research question or questions. The review protocol should also have an independent evaluation process. The choice of research is a multistage process. Initially, the selection criteria should be interpreted, so if a study identified by electronic and manual searches cannot be clearly excluded based on the name and abstract, a full copy should be obtained. The next step tends to be the application of inclusion/exclusion criteria based on practical questions such as: language, article, authors, publication date, etc. [5].

2.2 Finding Relevant Researches

In order to get familiar with the available literature, ACM Digital Library, SpringerLink, IEEE Xplore were used for search. The key phrases used were ("Enterprise Architecture" OR "Enterprise Architecture" OR "Enterprise Architecture Framework" OR "EA" OR "EAF") AND (“evaluation” OR “implementation” OR “developing” OR “analysis”). More precise queries are listed in Appendix 2, and articles published in year 2000 or later with a full text available online for free were checked. Despite the fact that a lot of results were got, most of them turned out to be irrelevant. The search in ACM Digital Library resulted in 2 203 articles, Springer Link gave 307, while IEEE Xplore – 1581. Reading the title of the papers, approximately half of them were excluded as duplicates. For example, in ACM Digital Library nearly two-third were talking about object oriented programming, testing, networks, which made them clearly out of scope. This left only 23 articles for ACM Digital Library; for IEEE Xplore – 3; for SpringerLink – 8. Further, the abstract and when needed the introduction to the work was read, excluding the articles that were less than 4 pages, and including those that

talked about actual EA implemented in any government or private organisation with a full text available online.

2.3 Researches selected

Using the exclusion and inclusion criteria, mentioned in Part 2.1, left the following results: ACM Digital Library – 15 articles, among which only 2 turned out to be relevant [6] [7]; IEEE Xplore – 3 works [8] [9] [10]; Springer Link – 3 articles [11] [12] [13]. [6] discusses the process of making management decisions in the Service-Oriented Architecture (SOA) with an emphasis on the decision to implement it, its impact on the cost and flexibility, as well as the impact of environmental and organizational conditions. In [7], ArchiMate, an approach and a design tool for developing EA is described, showing the advantages of using it, such as decreasing the complexity of the process by helping the developer to see the alternatives. In [11] model-based development using class diagrams, use case diagrams, activity diagrams is described, while [13] focuses on SOA and SOA roadmap, which is required for successful adoption of the architecture

All the articles gave an understanding of what EA is, helped to identify some EAF [10] and set the additional keywords for finding more information about them. For searching by the keywords mentioned above Google Search was used, as there is the information available on the organisations' websites that initially developed some of the frameworks, where the first 20 links were taken and read. The keywords were the following: "Zachman Framework" [14] [15][16], "Open Group Architecture Framework", "TOGAF" [17] [18], "Federal Enterprise Architecture Framework", "FEAF" [19] [20] [21], "The Department of Defense Architecture Framework", "DoDAF" [22], The British Ministry of Defence Architecture Framework", "MODAF" [23] [24] [25][26] [27], "The NATO Architecture Framework", "NAF" [28] [29] [30] [31], "Service-Oriented Architecture", "SOA" [9] [32] [33] [34]. The full list of articles is presented in Appendix 3. The result of the analysis of the materials will be presented in Part 3.

2.4 Finding Evaluation Criteria

As a second step for conducting literature review, a bibliographic database Scopus was used with the keywords specified in Figure 1. This search gave 105 results, among which 86 were related to Subject area "Computer Science" and going through titles left 44 articles that were relevant to the search criteria. After reading an abstract, half of the articles were deleted from the list as they were not focused on EA or EAF, some other were excluded as those that were less than 4 pages or didn't have the full text available for free, which left 11 articles listed in Appendix 4 as a result.

```
Search:  (TITLE-ABS-KEY("enterprise architecture" OR "enterprise architecture framework") AND
         TITLE-ABS-KEY("choose" OR "evaluate" OR "select")AND TITLE-ABS-KEY("company" OR
         "organisation" OR "organization" OR "government")) AND ( LIMIT-TO ( SUBJAREA,"COMP" ) )
```

Figure 1: Keywords used for Scopus search

2.5 Evaluation Criteria selected

All the selected articles whether analyse different EAF [35], [36], [37], or provide different schemes for selection [38], [39], or evaluation of the frameworks [40], [41], [42], [43], [44]. In [35] EA is proposed to a large Finnish local government organisation in the city of Koulova with 90 000 citizens, in order to improve the interaction between the government business needs and IT part of the organisation. Although the authors suggest adapting Government Enterprise Architecture (GEA), no actual implementation was mentioned, which makes it difficult to evaluate or draw any conclusions. In [36] the use of EA models in analysing the maintainability of the system in a particular organisation, with a help of the metamodel were used as an example to illustrate how they can help in decision-making situations, is done. [37] proposes a model for evaluation of EAF usability, which includes five viewpoints: Business, Data, Application, Technology and Enterprise. This approach is rather unique and can be considered for the future modelling or evaluating of the EAF at the Rescue board. Article [38] focuses on EAF usages and related to them perspectives and aspects. Perspectives are comparison criteria and aspects are the criteria attributes. The research proposes Enterprise Architecture Framework selection scheme that is focused on usages and implements it for selecting the best EAF for each usage that consists of 4 steps and will be analysed further. In [39] the author claims that for successful EAF selection all stakeholders have to agree on common evaluation criteria and methods, as well as develop transferable, predictable and repeatable collaboration process for the evaluation. [40] describes which requirements the currently existing EAF should meet to develop, describe and keep up EA, such as meta model, procedure model, modelling technique, role and specification documents. A main result of the evaluation is that no framework meets the listed requirements. In [41] the authors propose a set of metrics for evaluating the degree of alignment between the goals in strategic level and information system. [42] proposes five types of evaluation elements, such as business architecture, data architecture, application architecture, technology architecture, communication and deliverables. However, no clear conclusion after the evaluation was made by authors.

3 An overview of EA and its frameworks

In this part, the overall analysis of EA and its frameworks is presented. As it was found there are plenty of researchers with description and analysis of EA, a few of them are about implementing EA at University [17], Danish Municipalities [45], Finnish [46] and Norwegian Companies [15], E-government [43]. No study that focuses on EA in Estonian public-sector institutions or Estonian companies was found. However, Ernst & Young in cooperation with the Ministry of Economic Affairs and Communications and the Information System Authority released a handbook "Avaliku sektori äriprotsessid. Protsessianalüüsi käsiraamat" ("Business Processes in Public Sector. Process Analysis Manual"), which provides a process control and process management methodology, based on the world's best practices, that is suitable for use in the Estonian public sector. Process-based management makes organisations more transparent, allowing the development of an effective performance measurement system and improve the cost and resource tracking capability [47].

As was already mentioned in Part 2.3, the frameworks identified for future analysis are the following: The Zachman Framework, The Open Group Architecture Framework, The Federal Enterprise Architecture Framework, The Department Of Defence Architecture Framework, The British Ministry of Defence Architecture Framework, The NATO Architecture Framework and Service-Oriented Architecture.

3.1 Enterprise Architecture

The Open Group states that "Enterprise Architecture is about understanding all of the different elements that do the business and how those factors are related to each other" [48]. The US, however, defines EA as a strategic base that integrates strategic goals, business requirements and technology solutions. [49]. Schekkerman sees EA as "a management program as well as a documentation method that together can give an integrated view of an enterprise's strategies, business services, information flows, and resources" [19]. Nonetheless, most researchers agree that EA started from Zachman and his originally designed "The Zachman Framework for Enterprise Architectures" (Zachman framework). This framework shows how the information systems fit into the organisation by asking six questions – what, how, where, who, when and why [14]. EA detects all the components in the organisation and is a facilitator for aligning IT and business goals that need to include business related issues such as organisational goals, business processes, performance. If the organisation lacks such an alignment, then it is more challenging for them to adapt to changes in business strategy [20]. For better understanding of what is EA, the visualisation shown in Figure 2, which consists of 4 main organisational levels, is commonly used [48] [49] [19] [16]. **Business layer** presents strategic goals that will drive IT solutions, business roles, business functions, business processes and service flows, business information objects. **Data architecture** shows data that must be collected, organised and later distributed. **Application layer** describes people and systems that are in the organisation, applications, software components and enterprise services. **Technology layer** presents technical infrastructure that is composing the systems, network unit.

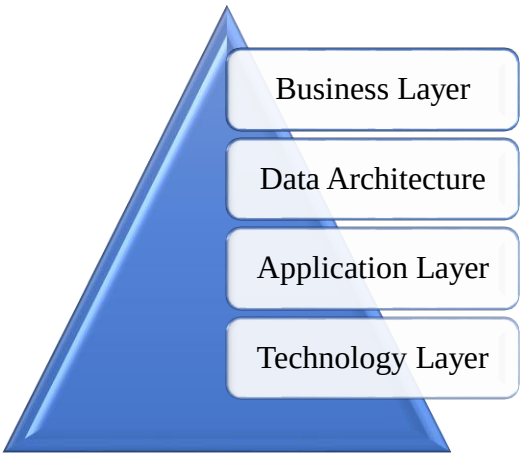

Figure 2: Layers of Enterprise Architecture [50]

Each of the levels describes either as-is model that already exists or to-be that will exist in the future. As well as this, it is important to remember that all levels are related to each other. For example, the IT system is modelled in the application level as an application that provides services, while in the technology level it is a set of software components that make it possible for services at the application level to work. For creating and future usage of EA, EA frameworks are needed. Nowadays, there are more than a hundred EA frameworks that are divided into defence industry, government, open-source, proprietary frameworks, etc.

3.2 The Zachman Framework

The Zachman Framework is usually considered to be the first EAF that was established and proposed by John Zachman [14]. This framework is a structure for helping the management to organise and classify the detailed representation of an enterprise, which represents in a visual way the interaction between the roles in the process. Moreover, it defines owner, designer and builder of the process, as well as setting the component, the way it works, the location where it is situated, the person who is responsible, the team which does the work and why it matters [15]. Zachman Framework, on the one hand, is shown as a planning tool, which can be helpful for enterprises in making better choices, finding the issues in the context of the business and seeing the alternative options and solutions (Figure 3). On the other hand, it is just a tool for planning and better executing EA development, as it does not focus on the strategy or governance mechanisms. When moving across the table horizontally (for example, from left to right) the different descriptions of the system are shown from the the point of view of the same player. When going through the table vertically (for example, from top to bottom), only one aspect is considered, but the player is changed from the perspective of which this element is considered. Columns give the answers to 6 questions:

- What? – data that needs to be understood and worked with.
- How? – function or how the process of changing the aim of the enterprise into a more detailed description of its operations.
- Where? – network or where the business activities are taking place or will be distributed in the future.

- Who? – people who are involved in the business processes and into implementing the new architecture.
- When? – time and effects of time on the organisation.
- Why? – motivation and formulating the business goals and strategies [14].

Firstly, in Zachman's, each architectural artefact must be only in one cell. The location of a particular artefact must not be undefined, and the architecture is considered complete only if all the cells are filled. Secondly, a cell is considered to be full if it contains artefacts that determine the system for a particular player in a specific aspect. If all cells are filled with objects, this gives enough information to adequately describe the system from each interested stakeholder's point of view and at any possible angle. Thirdly, in Zachman table, the cells in the columns are linked to each other. For example, in the data column of the table, from the point of view of the business owner, the data represents information about the firm, while for the database administrator, the data shows rows and columns in the database. Even though Zachman Framework in most of the cases is considered as EAF, it is rather an ontology rather than a methodology.

Figure 3: The Zachman Framework for Enterprise Architecture [16]

3.3 The Open Group Architecture Framework (TOGAF)

TOGAF is an architectural framework, which in comparison to The Zachman Framework, gives an approach to designing, planning and implementing of EA and is provided by The Open Group free of charge. While TOGAF consists of three main elements: Architecture Development Method (ADM), Enterprise Continuum and Resource Base, ADM is considered as the key component of this framework [43]. Description of TOGAF includes seven parts [18].

Introduction – contains a high-level description of the key concepts of EA in general and TOGAF in particular. **ADM** – is an essential part of TOGAF, which describes a step-by-step method for developing EA. **ADM Guidelines and Techniques** – include a detailed description of the rules and techniques that are used in ADM. **Architecture Content Framework** – describes the approach to the description of EA. It contains a metamodel of architectural artefacts, the structure and description of them. **Enterprise Continuum & Tools** – describe the method for categorising and storing the results of core activities in the organisation. **TOGAF Reference Models** – gives a description of the reference models that can be used in the architectural projects. **Architecture Capability Framework** – an approach to organising the architectural practice in the organisation.

ADM (Figure 3) is a core part of TOGAF and is more than the methodology that uses a step-by-step approach for developing EA. The result of ADM is organisation of concepts, rather than approach for architecting the structure that will help the organisation to solve its problems. The Enterprise Continuum primarily supports the ADM and is a virtual repository where all the information connected to the architecture is stored, as well as the Resource Base – documents, guides and templates. Moreover, ADM process is iterative, cyclic and consists of 8 phases which are shown in Figure 4. Throughout the ADM cycle, the permanent validations of the results against the set expectations have to be done. As to TOGAF, it starts with a preliminary phase, and go all the way from stage A to stage H. Nevertheless, it is possible to return to one of the phases for refinement and more detailed elaboration.

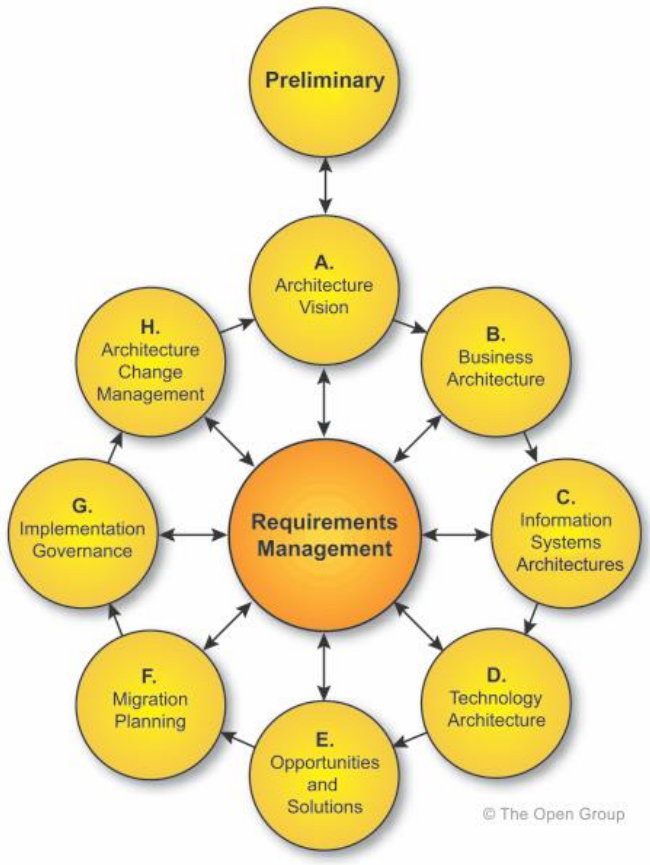

Figure 4: TOGAF ADM [51]

3.4 The Federal Enterprise Architecture Framework (FEAF)

FEAF was developed by the United States Federal Chief Information Officers Council and is used for promoting shared development for similar US Federal processes, exchange information within governmental and federal agencies [43]. The Federal Government of the United States has more than 300 organisational units of different sizes, scales and means, which include departments, administrations, bureaus, commissions, agencies and councils. These organisations use more than 2.6 million people and spend more than 3.4 trillion dollars per year for the performance of their functions. They often provide services, which are directed to client groups, including civil, industrial, academic, non-profit organisations and the government agancies [49]. FEAF is based on Zachman framework, but refers only to the first three columns there (using slightly different column names) and focuses on the top three rows. FEAF consists of six reference models [49] [19]: **Performance Reference Model (PRM)** – is used for measuring the performance of initial IT investments and estimating how they contribute to identifying opportunities that can be improved; **Business Reference Model (BRM)** – is used for organising, constructing in a hierarchical way and describing day-to-day business operations in the government; **Data Reference Model (DRM)** – describes the interactions and data exchanges between the government and ordinary citizens; **Technical Reference Model (TRM)** – is used for categorising the standards and technologies, supporting and delivering service components; **Infrastructure Reference Model (IRM)** – is used for supporting the hardware that provides functionality; **Security Reference Model (SRM)** – is used as a common language, as well as a methodology, for describing security and privacy regarding business goals in various organisations. A comprehensive description of FEA methodology should include the points, shown in Figure 5.

- The point of view where the architecture of the enterprise will be considered.
- A set of reference models describing different perspectives on the structure of the organisation (the six models listed above).
- The process of creating EA.
- The process of transition from the old paradigm (before the creation of the organisation's architecture) to the new one (after its inception).
- Taxonomy for classifying assets that fall within the scope of the enterprise's architecture.
- The technique, allowing to estimate success of EA use for increasing the business value.

The primary method for modelling FEAF is the Collaborative Planning Methodology (CPM) that is a simple, repeatable process that consists of an integrated multidisciplinary analysis, the result of which produces the recommendations developed together with stakeholders, planners and implementers [21]. The CPM is structured in a way that allows to use, reuse and guide planners in determining whether other organisations previously addressed such needs and whether they can use their business models, experiences, and work products. The methodology also helps planners to support management and stakeholders, as they make decisions regarding the directions, which are appropriate for the mission, investment and implementation. Finally, and perhaps most importantly, the methodology provides planners with guidance in their support of measuring the actual performance changes that were the result of the

recommendations, and in turn, the use of these results in the future planning activities. The more detailed description of the five steps of the CPM is as follows [21]:

1. Definition and verification – identifying and assessing what needs to be achieved, understanding the primary drivers of change, identifying, approving and prioritising the operational realities of the mission and objectives with management, stakeholders and executive staff.
2. Research and use – identifying external organisations and service providers that may have already completed or are currently facing similar needs, analyse their experience and results to determine whether they can be applied.
3. Definition and Planning – developing a plan, which defines what will be done, when it will be done, how much it will cost, how to measure success and what significant risks should be considered to meet the needs identified in Step 1. Also, it includes a timetable that indicates what benefits will be achieved, when they can be expected, and how they will be measured.
4. Invest and Execute – making investment decisions and implementing the changes defined in the integrated plan. At this stage, many groups participate, but it is important to note that these groups will have to work as a coordinated and joint team to achieve the primary goal of this step.
5. Execution and Measurement – managing and measuring the performance of the work by specific indicators.

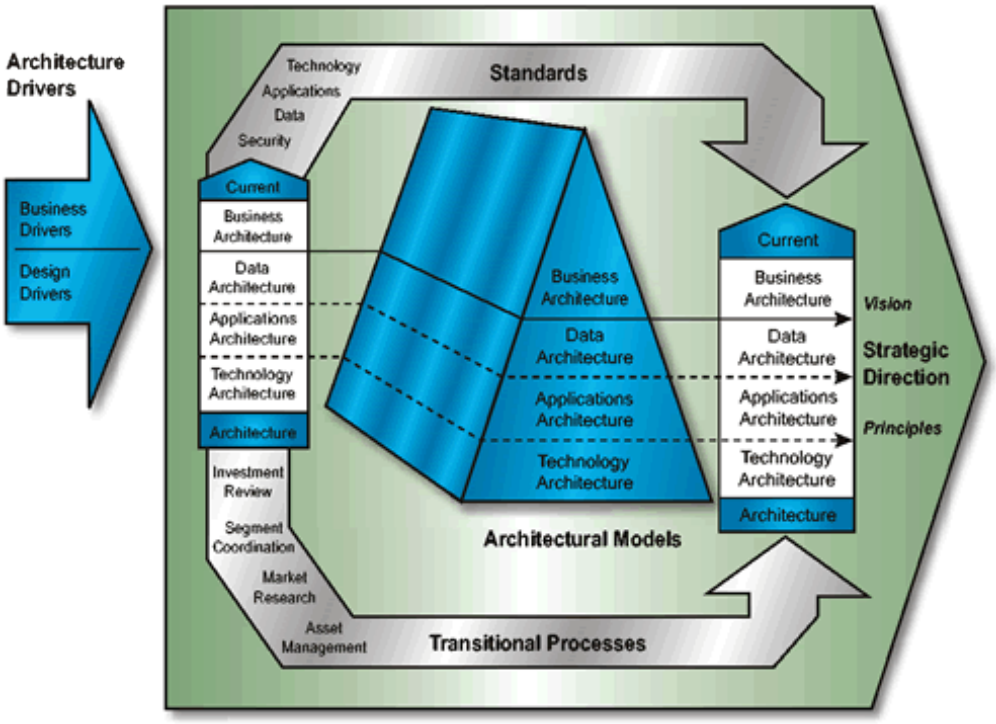

Figure 5: The whole structure of FEAF [52]

3.5 The Department of Defence Architecture Framework (DoDAF)

DoDAF focuses on architectural data, rather than on architectural artefacts, identifying and specifying the information. A model that is displayed as a diagram, narrative text, table, dashboard or other representation is used as a template for organising and displaying data in a format that corresponds to the person, making the decision. DoDAF specification consists of four volumes [22] [53].

Volume 1 – Introduction, Overview and Concepts – the concepts of the Department of Defence (DoD) architecture are presented, and general recommendations on the development are given. This volume explains the role of the architecture in the first processes of DoD, the key concepts of the structure are defined, which contain overview and vision of DoDAF, structure overview, introduction to the DoDAF meta-model and description of key DoD Viewpoints. Key DoD Viewpoints can be seen in Figure 6.

Volume 2 – Architectural Data and Models – describes DoDAF meta-model, data groups meta-model, perspectives and standard DoDAF models. The DoDAF meta-model defines the types of things that can be modelled and the relationships between these things. Target audience: architects, program managers, system engineers, capability analysts, testers and other users with a technical orientation.

Volume 3 – DoDAF Meta Model Ontology Foundation and Physical Exchange Specification **–** describes the physical layer format for the exchange of DoDAF compliant architectural data, which helps transferring information between interested parties using different ways. Target audience: developers, analytics.

Volume 4 – DoDAF Journal **–** is the informative volume of DoDAF. It contains a description of best practices, lessons learned, background documents and other information that complements the three normative of the DoDAF. As well as this, DoDAF describes three main types of architecture that contribute to the DoD architecture [22]: **Enterprise level reference structure** – provides information about a particular subject area, which directs and limits instances of several architectures and solutions. It consists of 5 elements: strategic purpose – defines the goals and objectives of the architecture; principles – rules, cultures and values that govern technical positions and patterns; technical positions – manuals and standards based on specific principles that should be implemented as a part of the solution; templates – a representation of the generalised architecture, such as viewpoints, graphic and text models, diagrams, etc., which show the relationship between elements and artifacts; vocabulary – terms and definitions that are used in the architecture and are related to the design and solutions. **Component enterprise architecture** – a description of mission-specific services and capabilities within the component, which displays the relationship between all elements of the DoD. **Solution architecture** – describes the system or other resources that are used in the organisation to achieve its mission.

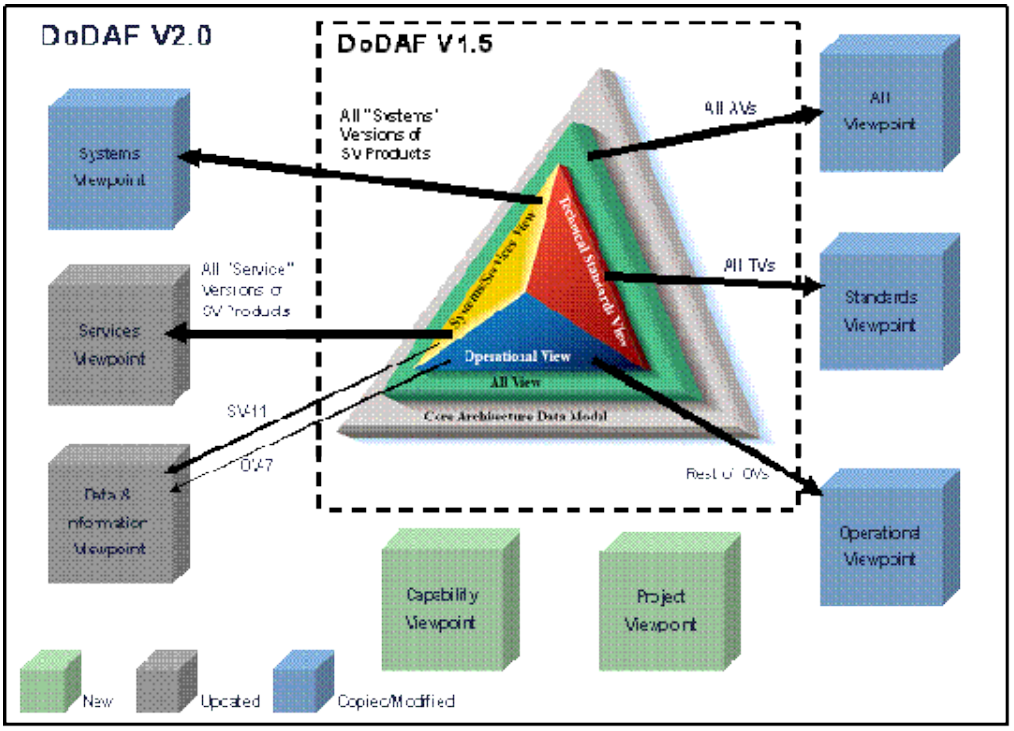

Figure 6: DoDAF V2.0 Viewpoints [54]

3.6 The British Ministry of Defence Architecture Framework (MODAF)

MODAF is the architecture framework for describing, analysing and effective managing of defence enterprises, which, to a large extent, is based on DoDAF [55]. MODAF describes enterprises through conceptual models. Complex problems of the business are divided into components, which are described at the highest level in MODAF meta-model, the information presented in the views. Although the meta-model is a generalised model of any enterprise, each of the components must be created with specific standards for a particular organisation. Since the primary architectural data is stored in computer tools or repositories, it is important that data warehouses and modelling tools use common modelling standards so that they can be shared or reused [23]. MODAF maintains compatibility with exact DoDAF views to facilitate the exchange of information with the US, for example, when conducting an international interaction analysis. However, MODAF has supplemented DoDAF with two new points of view that better support defence processes and life cycles. MODAF consists of six templates (called "Views") that are pictured in Figure 7 [24] [25]. Views are used to query the data model, visualise the architecture components and their dependencies; and to represent real perspectives of the structure of the enterprise. **All Views (AV)** – provide the summary of the architecture; **Strategic View (StV)** – defines the goals of the business and the resources that can be used in order to achieve these. **Operational View (OV)** – presents the activities, functions that are required to conduct business and operational activities. **Service-Oriented View (SOV)** – describes the services, required to support the tasks and activities described in the Operational View. **System View (SV)** – explains what happens when the Operational and Service Oriented Views are implemented and, thereby, define the solution. **Technical View (TV)** – contains standards, rules, policy and guidance that apply to aspects of the architecture. **Acquisition**

View (AcV) – describes what is needed and how much time it will take for delievering it. Description for some of the MODAF views is provided in Figure 6 [26].

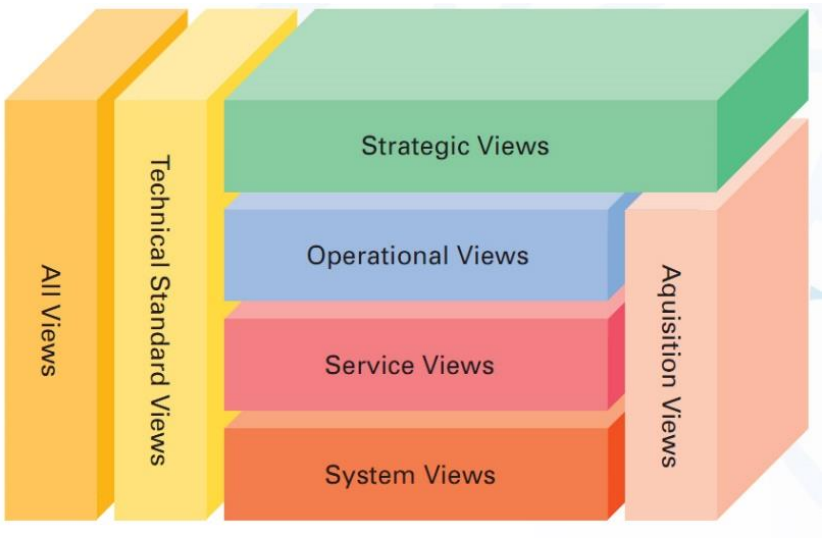

Figure 7: MODAF views [56]

View Category	View Number	View Name	View Description
All Views	AV-2	Integrated Dictionary Defines	Describes the taxonomy elements used by the architecture
Strategic	StV-1	Capability Vision	Outlines the vision for a capability area over a particular time frame
Operational	OV-1a	Operational Concept Graphic	Graphical or textual description of operational concept
System	SV-7	Systems Performance Parameters Matrix	Performance characteristics
Technical	TV-1	Technical Standards Profile	Listing of standards that apply to all the views in a given architecture
Acquisition	AcV-2	System of System Acquisition Programmes	An overview of the complete acquisition programme

Table 2: List of some MODAF views [27]

MODAF provides a structural model of how essential elements of the organisation are related. However, it does not directly model the resulting behaviour, it only captures and determines some dynamic attributes of the system, for an in-depth evaluation of the required executable models to observe the simulated action. Such a simulation cannot be built without defining an architectural model in the first place.

3.7 The NATO Architecture Framework (NAF)

Since NATO does not have its forces – the military power depends on the member states, so they need to understand what opportunities can be given to each country to get the optimal military effect. NAF is one of the standards for developing EA, which defines: methodology, viewpoints, stakeholder viewpoints and meta-model [28]. In NAF everything that delivers the result can be seen as a service that plays a fundamental role. The capabilities of each country are modelled as services, and the maximum effect is achieved through the right organisation of these services. For example, the services will be available to the operations planners, to get information about what is happening. Currently, NAF v3.0 is in use, and v4.0 documentation is under development with not much information available. The NAF was delivered from DoDAF, and for now, MODAF and NAF are similar, but not completely aligned. It is expected, that NAF v4.0 will include adapted MODAF Documentation as well NAF v3.x [29]. In NAF v3.0 seven views are available [30]. **NATO All View (NAV)** – captures general aspects related to all seven views, defines the scope and context of the architecture, includes the deadlines, the interrelated conditions, such as techniques, procedures, goals and visions, scenarios, etc., that make up the context for it. **NATO Capability View (NCV)** – fixes the main elements of NATO strategic vision and concepts, explores NATO capabilities, provides detailed information on the dependencies between military capabilities, the possibility of creating more coherent and efficient trade-offs that will be implemented. **NATO Programme View (NPV)** – describes the relationship between the needs for NATO capabilities, various programs and projects, contains program details and conditions for their interaction with NATO operational and financial systems. **NATO Operational View (NOV)** – describes tasks and activities, operational elements and exchange of information that is necessary for the implementation of the NATO mission, determines the types of data exchange, the frequency of it, any activities that support analysis and transfer of the information. **NATO Technical Systems View (NSV)** – a set of graphic and text products describing systems and relationships that provide or accept the functions of NATO. NSV connects system resources with NOV. **NATO Service-Oriented View (NSOV)** – provides a description of the services required to grant an access to the operational area, as described in the NOV and pays particular attention to the identification and description of services. **NATO Technical View (NTV)** – ensures that the system meets a particular set of operational requirements. Also, NTV provides the introduction of technical systems, which is based on technical specifications and include a collection of technical standards, implementation conventions, rules and criteria. Each of the views is divided into subviews, which describes the main aim, objects and components to be used, relationships within the particular view to the other subviews [57].

3.8 Service-Oriented Architecture (SOA)

SOA is the most widely used architecture, with a potential for creating mission-critical, modular, adaptive and enterprise applications [9]. SOA appears as the implementation of a service platform consisting of many services that can be combined into different solutions and scenarios, as determined by business needs. This capability to integrate and recombine services is what provides the closer relationship between business and IT, as well as flexibility to address new situations. The role of the SOA services platform is to provide a foundation for

delivering essential business services in a flexible and easy to compose view. The need for this has led to the creation of SOA, through which composite applications can be set up, modified and removed dynamically using services, abstracted from existing applications and data, presented by the platform or external sources [32].

From a business point of view, SOA can be expressed as a set of flexible services and processes that the organisation wants to expose. In this case, these same services can be recombined and supplemented to support changes in business requirements and models over time. From the technical point of view, SOA defines software regarding discrete services, which are implemented using components that can be called upon for performing a particular business task. Figure 8 shows a representation of the architecture with the description of each layer below [33].

1. Scope – describes what area of the enterprise is this architecture for.
2. Operational systems layer – consists of existing custom applications, including object-oriented system implementations, as well as applications for business intelligence. A complex, multi-tiered architecture of SOA can use existing systems and integrate them using service-oriented integration methods.
3. Enterprise components layer – is responsible for implementing the functionality and maintaining the quality of open services. These unique components are managed, regulated and financed at the organisation or department level. This layer typically uses application servers for component implementation, workload management, high availability and load balancing.
4. Services layer – describes the services that the organisation chooses to finance and exhibit. This level also provides a mechanism for using enterprise-scale components, components specific to business units, and in some cases components for specific projects, and allocates a subset of their interfaces in the form of service descriptions. Thus, the enterprise components provide the implementation of the service at runtime, using the functionality provided by their interfaces.
5. Business process and composition layer – defines the structures of the services exhibited on Layer 3. Services are combined into a stream and thus act together as one application. These applications support specific use cases and business processes.
6. Access or presentation layer – although this level, as a rule, goes beyond the discussions around SOA, it gradually becomes more relevant, it can be thought of as a future layer, which is needed to be considered.
7. Integration layer – allows integrating services by implementing a set of capabilities such as intelligent routeing, protocol mediation, and other conversion mechanisms, often described as Enterprise Service Busses (ESB). The Web Services Description Language (WSDL), on the other hand, specifies a binding that refers to the location where the service is provided. On the contrary, ESB provides a location-independent mechanism for integration.

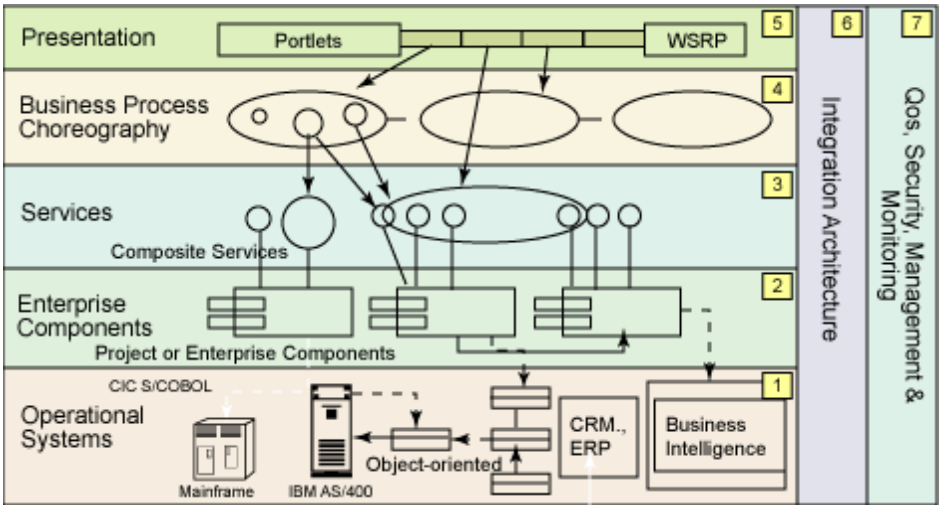

Figure 8: The layers of SOA [58]

3.9 Discussion

As no such analysis was not done neither in the ERB nor any Estonian Government Institution, the first step for finding the criteria was to check if there are any related works that have done this before. For a general understanding of EAF that has been implemented in the governments all around the world, "enterprise architecture in government" was used in Google Search and 50 first pages were checked. The most widely used EAF turned out to be TOGAF (Switzerland, South Korea, South Africa), FEAF (The United States, Australia, Singapore), Zachman Framework is used in Denmark, while in Finland the Governmental Framework is a combination of TOGAF and FEAF. The popularity of usage of EAF is shown in Table 3.

Name of Framework	**How common it is** [10]	**References**
Zachman Framework	25%	[15], [14], [16]
TOGAF	11%	[43], [18], [51]
FEAF	9%	[49], [19], [21], [52]
DoDAF	11%	[53], [22], [54]
MODAF	N/A	[55], [23], [24], [25], [26], [56], [27]
NAF	N/A	[28], [29], [30], [57]
SOA	N/A	[9], [32], [33], [58]

Table 3: Overview of the EAF analysed

While the literature review was conducted, some of EAF were decided to be excluded from the further comparison. Since both DoDAF and MODAF took TOGAF as a basis for further development, and were specifically designed for the US Department of Defence and the UK Ministry of Defence consequently, to support their military operations. As was mentioned in

Part 3.2.1 Zachman Framework just helps to organise concepts in a particular view without telling what to do with them, therefore cannot be considered as the EAF. A part of Zachman Framework is used by FEAF, first 3 columns to be more precise. Thus, the following frameworks were chosen for further comparison – TOGAF, FEAF, NAF, SOA.

In [59] five frameworks are compared – Zachman, DoDAF, FEAF, TEAF, TOGAF – using three different comparison criteria – by Views/Perspectives, by Abstractions, by Software Development Lifecycle (SDLC) Phases. According to the author "*Zachman framework appears to be the most comprehensive framework of those studied. It uses some viewpoints related to the different aspects. Most frameworks only represent a small number of viewpoints and aspects"* [59]. In another article [60] there was no comparison of EAF, but implementation assessment criteria were presented instead, which might be helpful in the future after EA is developed. Article [43] focuses on the evaluation of EAF for e-government focusing on improved interoperability and integration, reduced costs, improved change and risk management, assessment of business-IT alignment. It will be taken as a reference example for formulating requirements for evaluation the frameworks for the ERB.

3.9.1 Evaluation regarding qualitative requirements

In this section five requirements were taken for the assessment: **Organisational Interoperability** – deals with the harmonisation of business processes and information technologies, which covers both inter- and intra- organisational boundaries. **Common infrastructure and interoperability** – provides an accurate value for exchanging information; the ability of organisations to share information and knowledge within and across organisational boundaries. The underlying foundation for effective interoperability comes from standardised common infrastructure – in case of the ERB, it is X-Road. **Technical Interoperability** – refers to technological aspects of connecting computer systems to share information or use functionality – ERB systems connected to X-Road. **Agility** – ability of the organisation to manage changes, which is an essential characteristic for the survival of businesses that are forced to work in dynamic conditions, where changes are permanent. **Reusability** – refers to skills that are both business reference models and services. Reusable modules reduce the time and cost of implementation, increase the likelihood of modifications when a change in implementation is required. Table 4 presents a comparison of the characteristics given above. These estimates are subjective and were based on the conducted literature review, a personal understanding of EA and needs of the ERB. The following assessment scaling was used: 0 – does not support (the criteria cannot be implemented in EAF), 1 – partially supports (the criteria can be applied to some extent), 2 – fully supports (the criteria can be entirely carried out in EAF)

Criteria	TOGAF	FEAF	NAF	SOA
Organisational Interoperability	2	2	2	1
Common infrastructure and interoperability	1	1	1	1

Technical Interoperability	1	2	1	1
Agility	2	1	1	2
Reusability	1	2	0	2
Total	**7**	**8**	**5**	**7**

Table 4: Evaluation of the frameworks according to qualitative requirements

3.9.2 Evaluation regarding development requirements

Here, six requirements were taken for the evaluation: **Effort required to develop and maintain** – the complexity of the modelling tools and methods adopted within the context of EAF – the easier to model and later support the architecture, the better. **Service Orientation** – applying a performance paradigm about what secures the implementation of sections on operational capabilities for individual tasks. **Evaluation and Governance** – the framework should allow assessing the effectiveness and maturity of various agents when using EA or the management process to ensure that IT organisations' investments are closely related to business objectives. **Reference Models** – allow to describe everything using one language. **Documentation** – in case the policy and stakeholders are always changing, the documentation on the development of EA is important and needs to be taken into account for the dissemination of knowledge and the exchange of experience. **Cost effectiveness** – whether the framework is free or requires some additional money investments. Table 5 shows a comparison of the five frameworks by selected development criteria. The same scaling as in Part 4.1 was used for evaluation: 0 – does not support, 1 – partially supports, 2 – fully supports.

Criteria	TOGAF	FEAF	NAF	SOA
Effort required to develop and maintain	3	2	2	2
Service Orientation	2	2	2	3
Evaluation and Governance	2	3	1	3
Reference Models	2	3	3	2
Documentation	2	3	1	1
Cost effectiveness	3	3	3	3
Total	**14**	**16**	**12**	**14**

Table 5: Evaluation of the frameworks according to development requirements

3.10 Summary

In this part, the results of comparative analysis of the EAF will be presented. Based on the qualitative and development requirements comparison, the final overall evaluation of the frameworks is shown in Table 6, based on which the following three frameworks were chosen for further analysis and implementation: TOGAF, FEAF and SOA. Each structure for each criteria was evaluated, and FEAF turned out to have the highest score, it might be the best

architecture that can be adopted by the Rescue Board since it meets most of the criteria. TOGAF has had convergent results as well. TOGAF has been adopted by many governments and has many advantages, especially its mature architectural process, and its integration with the dominant ArchiMate language. Regarding SOA, it is not as widely used as TOGAF and FEAF but has a plenty of advantages, such as business-focused development, reusability, flexibility, platform independence. However, none of the corporate architectures is complete, they have strengths and weaknesses, and they complement each other.

Requirement	TOGAF	FEAF	NAF	SOA
Qualitative	7	8	5	7
Development	14	16	12	14
Total	**21**	**24**	**17**	**21**

Table 6: Overall evaluation of the frameworks

4 Case Study

In this part, the Case Study with implementation of different EAF will be conducted. The outcome is going to be a visual or textual representation of the frameworks, as well as the evaluation conducted at the ERB.

4.1 Case Study Methodology

A case study is an investigation, which uses qualitative research methods. There are many types of case studies, which can be done. For example, explanatory – answers a question that tries to explain the proposed changes in real actions that are too complicated for experimental strategies; exploratory – is used to study situations in which the evaluated case does not have a clear set of results; descriptive – is used to describe the phenomenon and the actual context in which it occurred; multiple case study – allows the researcher to investigate differences within and between cases with the goal to repeat the results for all cases; instrumental – is used to achieve anything other than an understanding of a particular situation, which gives an idea of the problem or helps to clarify the theory; collective – is similar to multiple case study [61] [62]. For planning the further case study the descriptive type will be used, illustrating different approaches for developing EA and how they will be used [63]. All in all, the case study should answer research questions, formulated in Part 1.

RQ1: Which EA frameworks are relevant for evaluation for an Estonian Government Agency?

RQ2: Which criteria are important for selecting an EA framework at the Estonian Government Agency?

The process of designing and conducting case study research is usually the same as for other researches, including the following steps: plan – identifying stakeholders, information that is needed, documents that will be reviewed to get it; collect data – investigate all relevant documents, conduct interviews for gathering data if needed; analyse data – summarise all the information that was found; evaluate/disseminate results – get a feedback [64]. In the ERB the case study was planned as follows:

1. Case study implementation: model three different solutions; clearly, explain what are the differences and similarities between them. The idea was to include processes from different areas of the organisation (finance is a support function, fire safety is a core process directly related to strategic activities, management information / risk assessment is a management function)
2. Get the evaluation and feedback on the work done; choose one solution that will be implemented; precisely express the reasons for choosing it.
3. Present all steps in textual and visual format; mention challenges that were on the way.

4.2 Case Study Implementation

EA can be represented as a hierarchy of architectures. Strategic architecture describes the whole organisation. It is focused on the organisation's strategy, where business processes, investments, data, systems, technologies, principles and priorities are defined, common IT services are created for the whole organisation. The next level is segment architecture – the architecture of the direction of the organisation, the program of projects or a separate unit,

which describes the specific characteristics and requirements of a particular unit. Segment architecture should have the same structure and common services as the strategic architecture. The third level is the architecture of the solution, which is used for implementing new or refining the existing parts of IT solutions. It considers both – common requirements for the organisation and specific needs identified at the level of segment architecture.

However, when designing the architecture, it is not necessary, to begin with, developing of a strategic architecture [65] [66]. Thus, two main approaches are used: “top-down” (Figure 9) – the most common approach and “bottom-up”. “Top-down” approach has many advantages, such as: ease of understanding the general vector of the organisation’s development; general rules and approaches that are defined at the organisation’s level, and then broadcasted to the level of segments and solutions; general information systems and technical services are created for the organisation, which will be re-used at the level of segments and solutions. On the contrary, "bottom-up" approach, goes from the architecture of specific design solutions to strategic architecture. This approach allows to get a value from the methods of EA more quickly. For implementation in the ERB, “top-down” approach was chosen, because initially all services will be modelled, going into more details for some processes selected.

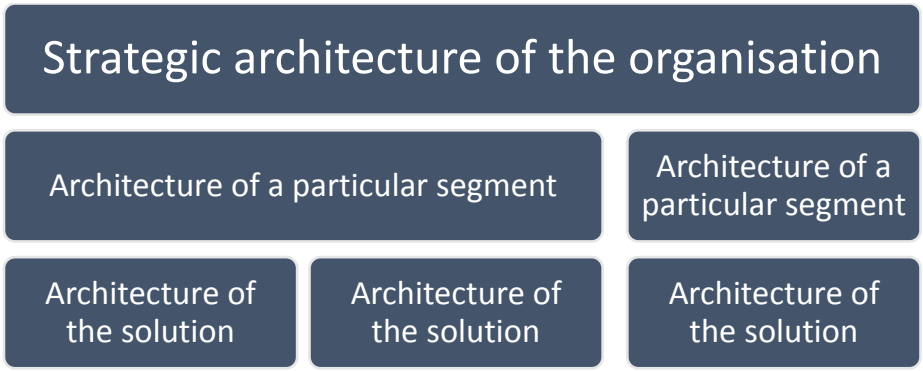

Figure 9: Three levels of EA

For modelling EA, a visual modelling and design tool Archi, was chosen, following three reasons: it is cross-platform, open source and free [67]. Archi uses ArchiMate as a modelling language, which is an open and independent EA standard that supports the description, analysis, visualisation of architecture within and across business domains. ArchiMate is one of the open standards hosted by The Open Group and is fully aligned with TOGAF changes [17]. However, the main disadvantage of Archi tool is that it does not support Business Process Model and Notation (BPMN) language, which makes process modelling not as clear as it is. One more reason, for choosing Archi was that the ERB has already decided to develop EA using Sparx Systems Enterprise Architect, which supports ArchiMate as one of the modelling languages.

4.2.1 TOGAF

The first framework to implement was TOGAF, as an approach that allows building the entire architectural process – from starting practice to results using a complete set of tools for creating and developing architectural practices. Since both, TOGAF and ArchiMate are the standards of The Open Group and have their specifications, they can be used separately, independently

of each other, or together with other standards. On the other hand, there are significant advantages in the joint use of TOGAF and ArchiMate. The language allows creating individual models, including those corresponding to TOGAF representations, and models that combine different domains of architecture.

EA was developed applying TOGAF 9.1 standard as a reference framework and using ArchiMate as the modelling language, which work well together and is compatible and complementary for EA development, even despite the difference in terms and definitions between the two standards. As can be seen from Figure 10, all layers correspond to the phases of ADM: **Motivation Layer** – Preliminary Phase; Requirements Management Phase, Phase A: Architecture Vision, Phase H: Architecture Change Management; **Business Layer** – Phase B: Business Architecture; **Application Layer** – Phase C: Information Systems Architecture; **Technology Layer** – Phase D: Technology Architecture; **Implementation and Migration** – Phase E: Opportunities and Solutions, Phase F: Migration Planning, Phase G: Implementation Governance.

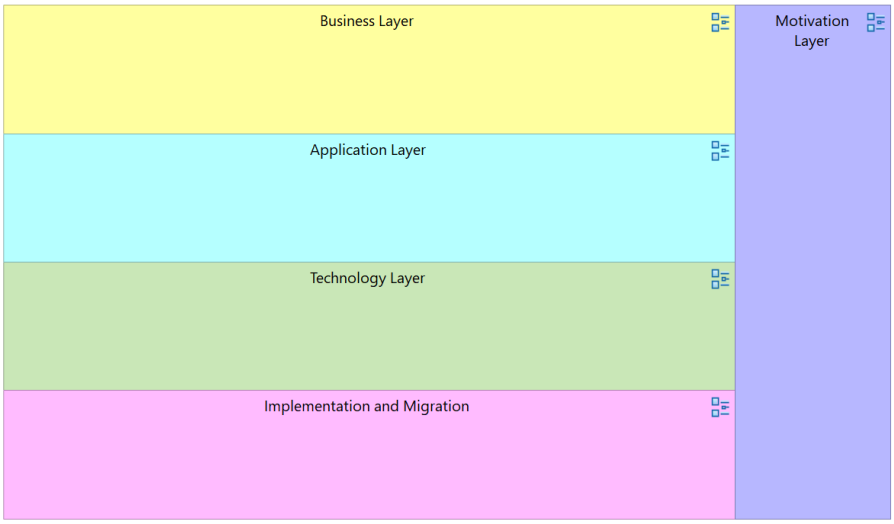

Figure 10: TOGAF ADM mapping using Archimate 2.1 Language

In TOGAF ADM requirements management is the central process, which is supported by ArchiMate through motivational concepts (Appendix 5), such as goal, principle and demand. It discusses the method of harmonising the architecture of enterprises with the context described by motivational elements. Stakeholders represent groups, individuals or companies that influence, direct or restrict an enterprise. Drivers represent internal or external factors that affect the plans and objectives. Understanding the strengths and weaknesses, opportunities and threats to these drivers will help to guide them to solve these problems. Requirements management is the primary activity in the process of designing and managing architectures by enterprises. Goals, which affect the management of changes, need to be transformed into requirements for the architecture of the organisation. **Motivation Layer** for the current situation at the Rescue Board is shown in Appendix 5 and represents how goals of the organisation are driven and what are the requirements for achieving them.

Business Layer of TOGAF pictures actors, functions and processes existing in the organisation. The main objective of this layer is to interpret the baseline business architecture,

describe the strategy, organisational process and information of the business goals and strategy. Based on the information from the Rescue Board, business layer architecture was developed and presented in Figure 11, Figure 12, Figure 13 and Figure 14 in more details. As can be seen from Appendix 6, business layer shows all actors, functions and processes that exist at the Rescue Board. For example, from Figure 11, can be seen that the Financial Department, located in Tallinn, is under the supervision of Deputy Director General of Administration, who is supervised by the Director General. The Financial Administration role of the Department includes two processes – Bookkeeping and Budgeting. Figure 12 presents the current Budgeting Process, which consists of the following processes: Compiling the Budget in Details, Changes in the Budget, Financial Planning, Budgeting Methodology for the Management. Figure 13 shows the baseline process for Self-Inspection Report Processing at the Fire Safety Supervision Department, while Figure 14 pictures Management Information Service at the Strategy Department.

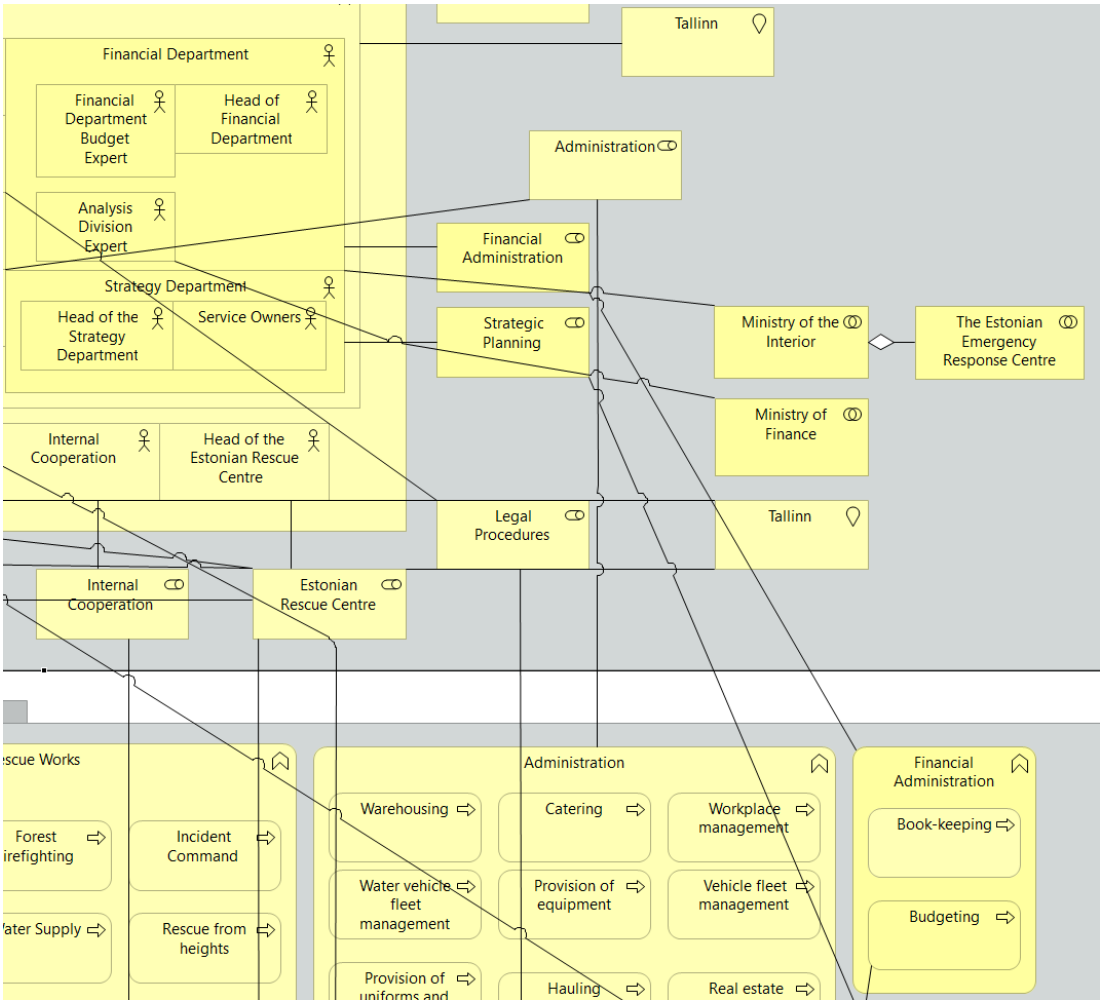

Figure 11: Financial Department Actor and Budgeting Business Function at the ERB.

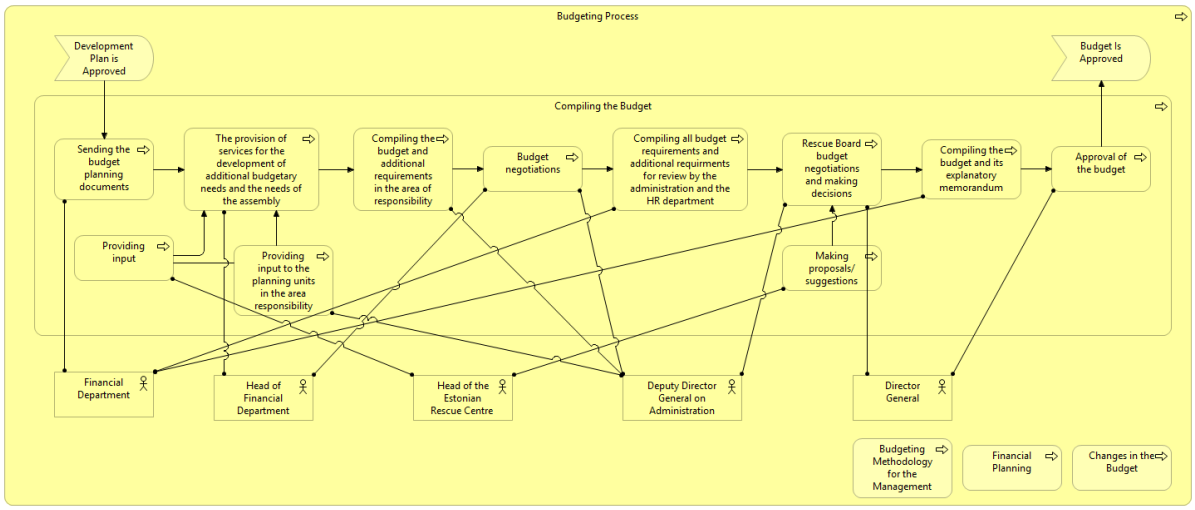

Figure 12: Compiling the Budget Business Process at the Financial Department at the ERB

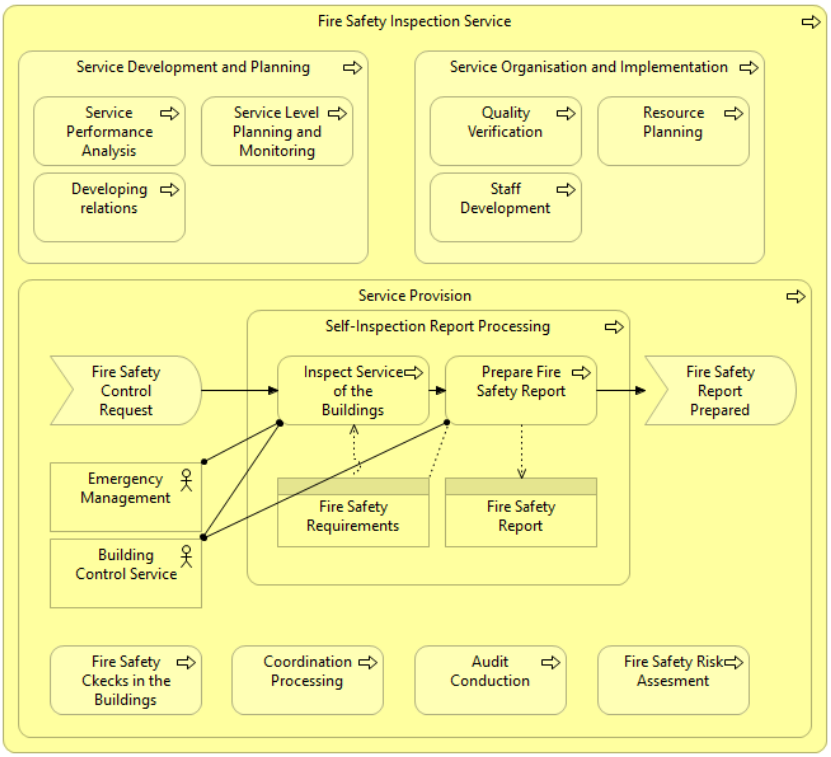

Figure 13: Self-Inspection Report Processing at the Fire Safety Department at the ERB

In the future, for the validation of target EA, the Gap Analysis could be used, which is a matrix of business architecture building blocks for the baseline architecture at the vertical axes and the target architecture at the horizontal. It helps to identify services and functions that were accidentally forgotten, intentionally deleted or not released.

Application Layer of ArchiMate combines the architecture of applications and data in the presentation of their concepts, representing the elements of the particular system that helps to implement the business-level concepts and explain how the concepts of the business layer are deployed. Appendix 7 pictures the core applications for the chosen processes.

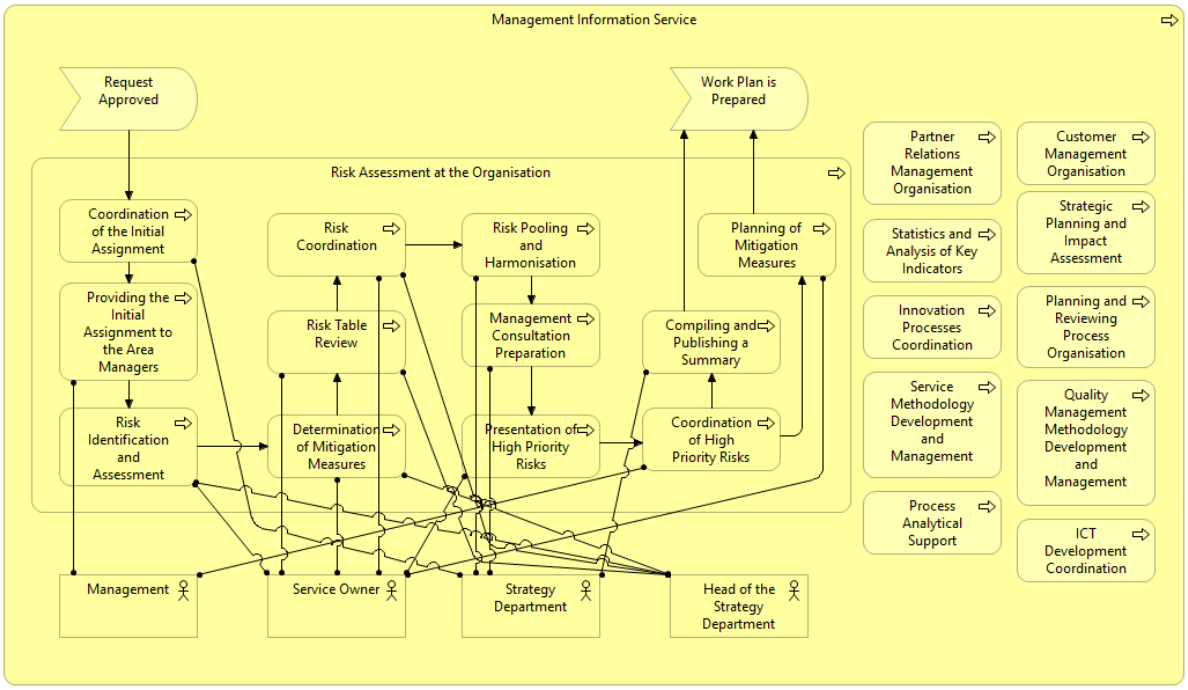

Figure 14: Management Information Service at the Strategy Department at the ERB

Technology Layer describes the device-level elements at the technology level. The descriptive elements of this level are disclosed by IT systems that support the application layer, and in some cases also specific elements of the business layer. While the application layer represents the components of the application, the technology layer shows which hardware systems contain these components and what are the relationships between them. Figure 15 shows the current technologies used at the Rescue Board.

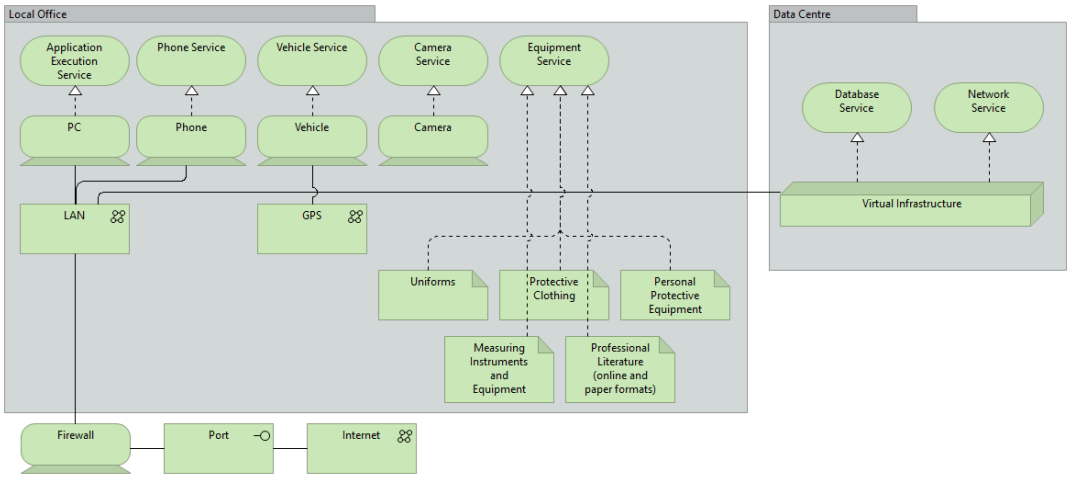

Figure 15: Technology Layer at the ERB

Implementation and Migration Layer supports a temporary transitional state with a concept called a plateau. The gap is the difference between the two plates, for example, the baseline and target architecture. The visualisation of gaps in the diagram in practice shows that they can be very effective for stakeholders. The whole TOGAF baseline architecture with all layers connected is presented in Appendix 8.

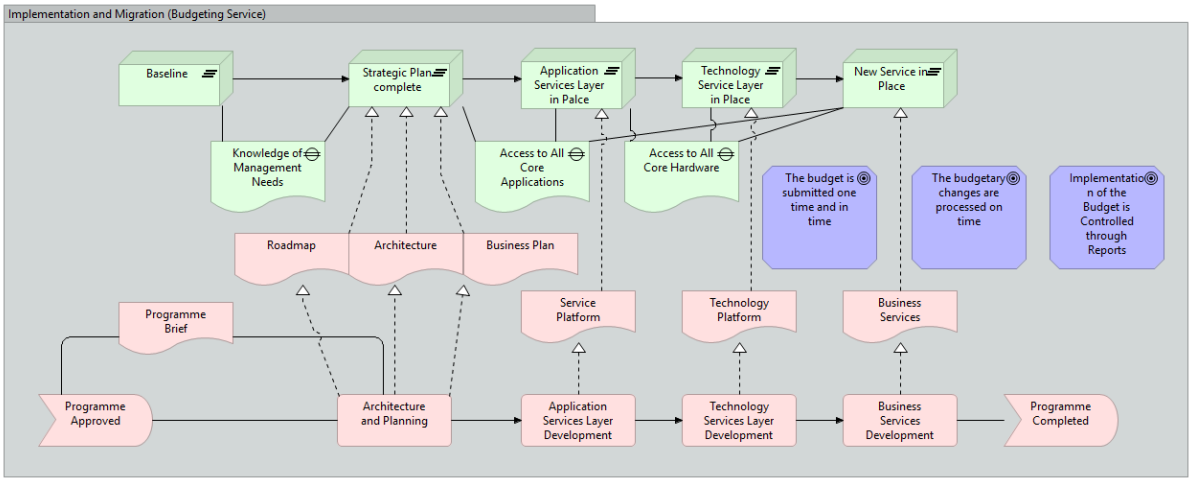

Figure 16: Implementation of EA at the Safety Supervision Department at the ERB

4.2.2 FEAF

The second implemented Framework was FEAF. The US Federal Government realised it on 29th January 2013 an extensive guideline [68] which was taken as the fundamental reference for modelling EA. In contrast to TOGAF and ADM phase, FEAF has six main reference models, which were already mentioned in Part 3.4. The reference model provides a standardised classification of strategic, business, technological models and information. In **PRM**: goals – allow to group investments and activities through the general structure; measurement area – describes the way in which the activities are supported; measurement category – any category that can be applied to any purpose. Appendix 9 presents PRM for the Financial Department and the Fire Safety Supervision Department of the ERB, based on goals, stated in service cards. As can be seen from Appendix 9, all goals that need to be achieved are measured by different areas and categories in those areas. However, the more detailed description should be provided for each of the measurement categories. In this case, EA stakeholders can see how the current services are realised and what can be improved for services to be at the aimed level. The example of this is shown in Figure 17, where the Measurement Category "Schedule" has a requirement that it should be done "not later than 30/11 of each year" (the date is an assumption) for achieving Planning Budgeting goals for the Budgeting Service.

BRM supports structural analysis and reporting in the presentation of the sub-structure of business services for a common expert. BRM describes the organisation through a taxonomy of shared missions and support areas, and not through a single organisational view. Thus, BRM facilitates intra- and inter-agency cooperation. Two main things presented are: business function – describes what the Rescue Board is doing, while business process – outlines how the processes are done at the organisation in more details (Appendix 10).

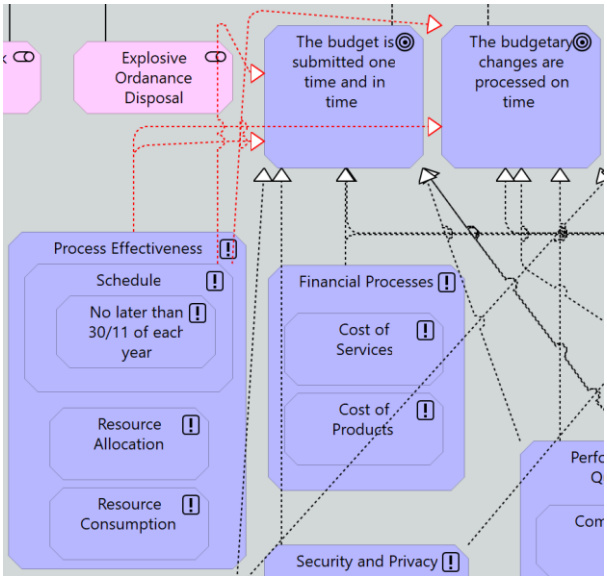

Figure 17: Measurement Category requirement for the goals related to Budgeting Service

DRM is designed to provide a flexible overall framework for the efficient exchange of information within the framework, empowerment, reuse and support for semantic compatibility, while respecting the security, confidentiality and quality of the use of this information. DRM provides standard means by which data can be described, classified and separated. They are reflected in each of the three DRM standardisation areas: description of the data – representing data, thereby supporting its discovery and sharing); data context – a search that allows data to be obtained in accordance with taxonomies; data sharing – accessing and exchanging data. Unfortunately, for implementing DRM for the selected services, there was no information available, except that for the data exchange at the Rescue Board X-Road is used. Nonetheless, when there is more information and it needs to be described, Table 7 can be used as an example.

Data			
Domain	**Subject**	**Topic**	**Definition**
What kind of data it is	Which activities are supported by this data	Which sub-activities are supported by this data	Where and for what the data is used, what it describes or represents

Table 7: DRM Taxonomy Definitions

TRM classifies the standards and technologies associated with them and the application that supports and delivers the components and capabilities of the services. Appendix 11 pictures TRM for Compiling the Budget and Self-Inspection Report Processing Functions with all the applications which are in use. **IRM** supports structural analysis and reporting in the representation of the infrastructure of EA, classifies standards and technologies related to the network or cloud to support and deliver components, data, video, and mobile services. IRM also integrates corporate consulting and standardisation, software development and

maintenance. In Figure 18 the infrastructure components for the Financial and Fire Safety Supervision Department are presented. Since there wasn't enough information about the whole hardware used at the ERB, it was quite challenging to model a comprehensive IRM.

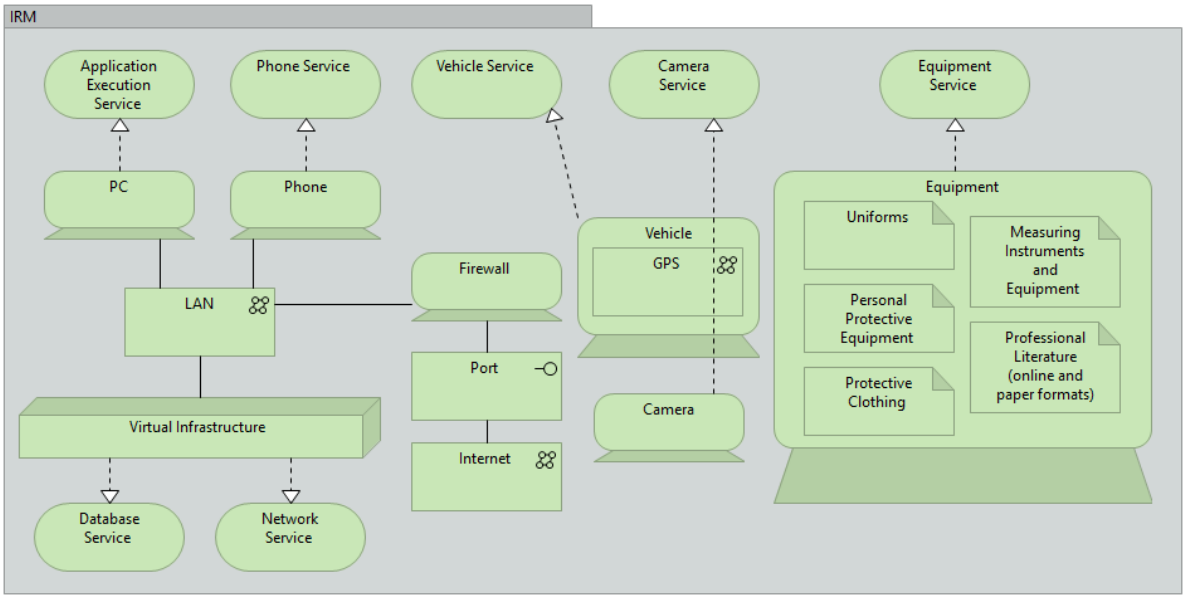

Figure 18: IRM Taxonomy Overview

SRM is a taxonomy for the development risk management elements in the architecture for addressing issues related to information security within and between systems, segments and departments. SRM develops a plan that helps organisations to integrate IT security and provides a mechanism for identifying security requirements, promotes the inclusion of security and privacy in business processes. The relationships between the models need to be shown for a better understanding of the whole Consolidated Reference Model (CRM), which can be found in Appendix 12.

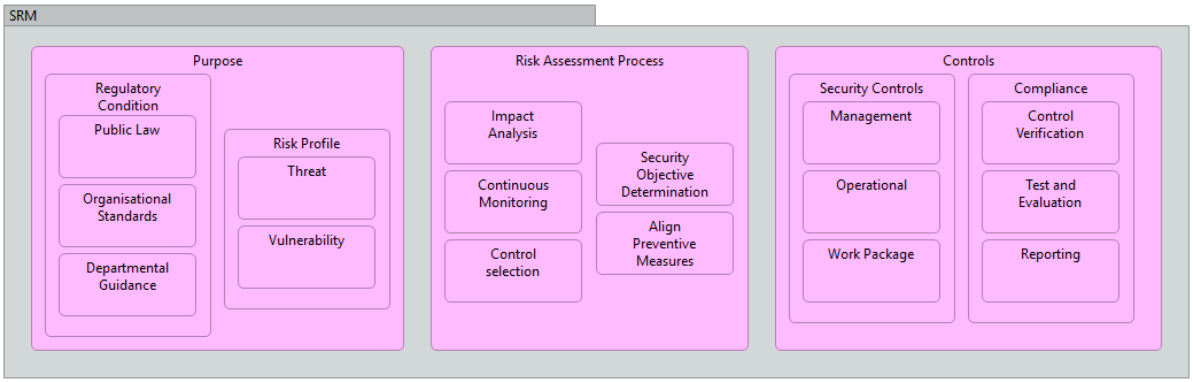

Figure 19: SRM Taxonomy Overview

4.2.3 SOA

There are various benefits of using SOA, such as that there is a real synchronisation between the perspective of the introduction of business and IT, well-formed service provides a single management system [69], etc., have been described. Two main reasons are considered vital for

SOA implementation [70]: the requirement to quickly respond to business needs, be agile, and the requirement to reuse the assets in big organisations. Both cases mentioned above are corresponding to the Rescue Board needs. Steps required for implementing SOA are shown in Figure 20 and described further [71]. SOA reference architecture – provides a general overview of what is service, how to identify it. Business architecture – defining the general business architecture, processes and their workflow. Service Identification – identifying a set of services in the context of an enterprise that supports the business architecture. Semantic Information Design – creating different data models which provide an understanding of general semantics of processes and service and is usually performed together with the identification of the service. Service Specification – selecting the appropriate services for realisation. Service Realisation – designing and implementing the services. Implementation of service-oriented solutions – building enterprise solutions with services, which are affected by application architecture. For starting to implement SOA having the full business, architecture is not required since this process is iterative and incremental; implementing the first set of services to support specific business goals is enough as there is always a possibility to update business architecture and services consequently.

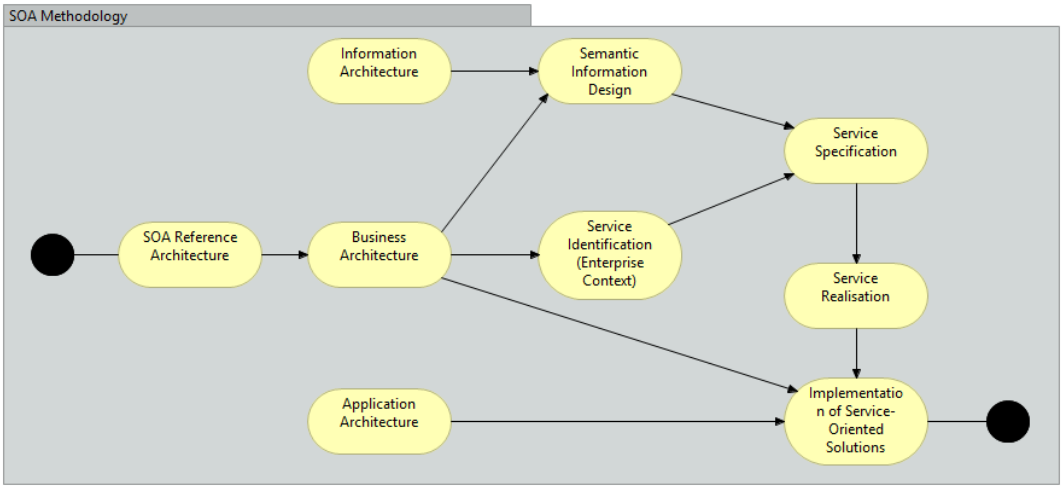

Figure 20: SOA Methodology

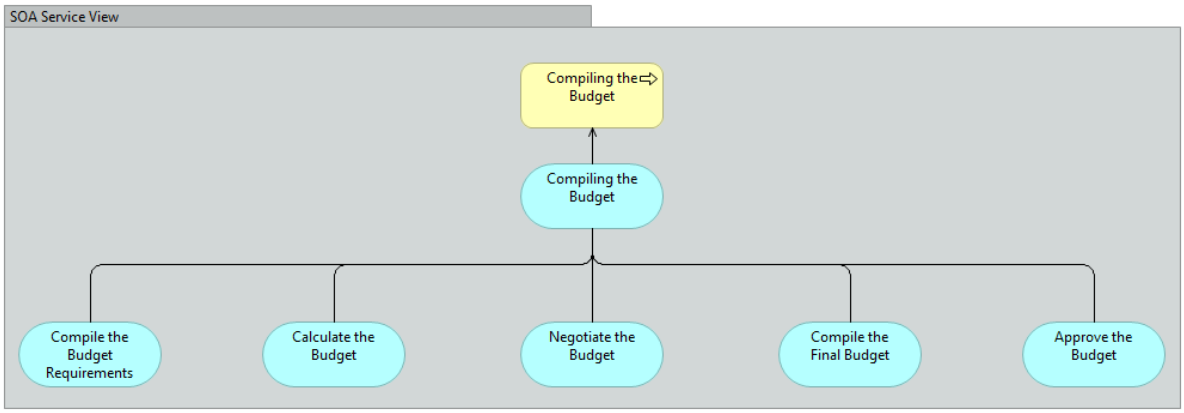

Figure 21: Suggested Services for Compiling the Budget Business Process

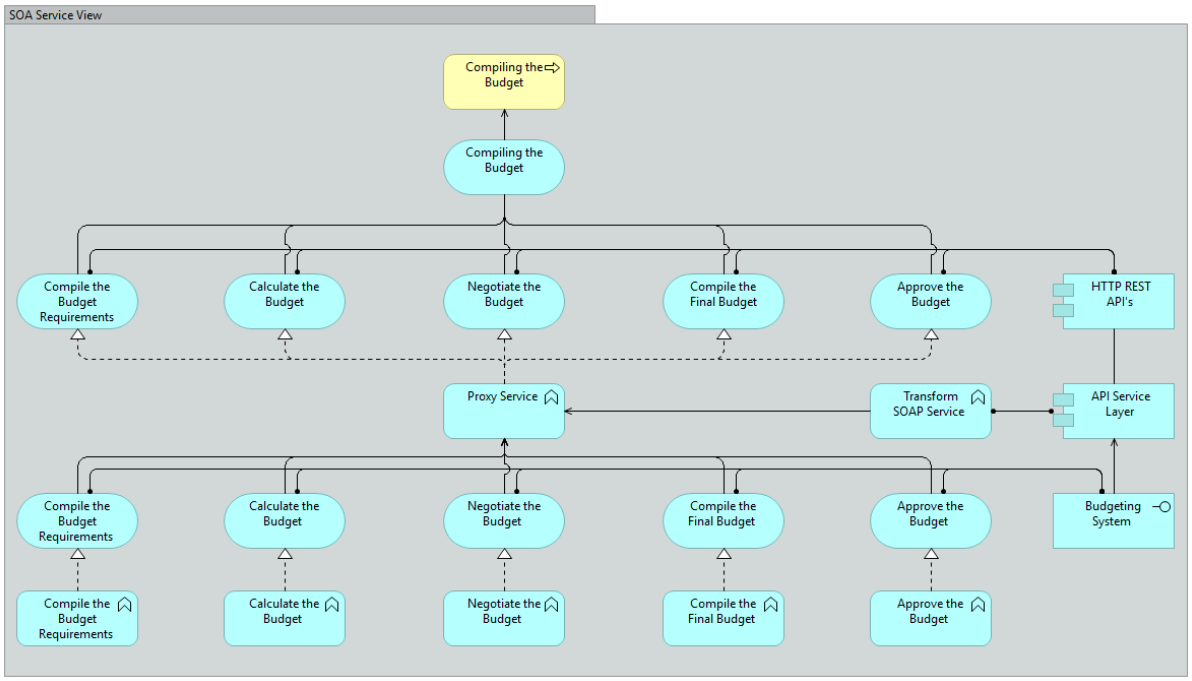

Figure 22: Suggested SOA Implementation for Compiling the Budget Business Process

Based on Compiling the Budget Business Process, a few services can be seen as Application Services: Calculate Budget, Change Budget, Submit Budget and Approve Budget (Figure 21). As interfaces are access points, and there can be many of them, it can be considered that some of the services can be implemented through the interfaces. Thus, Budgeting Service Interface can be seen in Figure 21 and Figure 22, which is assigned from four different functions. Interfaces are effective ways to show which functions are tied to which infrastructure. By aggregating all budgeting services under a single service, a simpler view of derived relationships is achieved (Appendix 13).

4.3 Evaluation and Discussion

In this part, the meeting at the ERB and its results will be described. The meeting brought together a group of experts, who are related to the future implementation of EA in the organisation. As the outcome of the meeting, the evaluation of the modelled EAFs will be done, showing which EAF is the most suitable for the needs of the ERB, from the employees' point of view. There were 6 participants invited, based on their experience and involvement in the topic of EAF evaluation, – ICT Development Adviser, Head of Development Department, Process Management Consultant, Quality and Customer Service Adviser, Statistics and Analytics Adviser, Strategy Adviser / BI Service Owner. However, Quality and Customer Service Adviser as well as Statistics and Analytics Adviser were not able to attend the on-site evaluation meeting.

For finding assessment criteria a small analysis was conducted. At first, there were 45 different evaluation criteria, divided in 5 groups, presented and shown in Appendix 14. The first set of evaluation criteria included those that are vital for modelling and representing EAF. The second set consisted of criteria for evaluating architecture repository tools or tools, the purpose of which is to create, store and provide access to architecture data for use in architecture models

or products. The third set focused on different ways of user customisation support. The fourth set of criteria included interoperability, computer systems or software to exchange and make use of information. The fifth set consisted of general characteristics, such as supporting various IT platforms, spell checking, supporting collaboration among team members. Some of those criteria were already used for EAF comparison in Part 3.9. Based on relevance to the case of the ERB, some groups were excluded, which left the following criteria:

1. Organising architecture into views that are subsets of the organisation information architecture.
2. Understanding how the organisation's goals are supported.
3. Illustrating the essential process flows / Visibility of the business processes and the information that they manage.
4. Extendibility and Customisation while integrating them with other systems, such as X-Road.
5. Creating, maintaining, and comparing different versions.
6. Scalability, for example to thousands of architectural elements and relationships, and multiple versions of the architecture.
7. Implementation / supporting of various standards (ISO, IEEE, etc.).
8. General understandability of the full model.
9. Ability to categorise information.
10. Understandability from different stakeholders' viewpoints.

During the meeting, firstly, a brief overview of the current situation at the ERB was done, as well as describing what is EA and its main goals. Secondly, general information about the models developed was given. For the sake of anonymity and any familiarity with the frameworks, they were given simple names as shown in Table 8. Lastly, Google Form with the 10 criteria, mentioned above was sent to all participants. Each criteria had 2 questions: How important is this criteria? Which of presented Models fulfils it best? (Figure 23). Since, the participants were not familiar with ArchiMate modelling language, notations that were used for modelling were described and explained as well.

For Question 1, the evaluation scale 1-7 was chosen, where 1 – not important at all and 7 – very important, as one of the most widely scales used, together with 1-5. While 1-5 allows to get a neutral response, scale 1-7 gives two levels between "not important" and neutral, offering higher degree of measurement precision. It is possible to provide an effective verbal label for each point on a scale containing more than 7 points, but doing so becomes more difficult as the number of scale points increases beyond that length [72]. Question 2 was decided to be closed, not open, because additional comments and suggestions were possible to gather during the discussion part.

EAF	Name	Description
TOGAF	Model 1	The most widely used and has been adopted by 80% of Global 50 companies, such as Honda, Coca Cola, Toyota, McDonald's.

		Also, is a backbone for the majority of other EAF that were developed.
FEAF	Model 2	Was developed by the Federal government of the United States and is designed to ease sharing of information and resources across federal agencies, reduce costs, and improve citizen services.
SOA	Model 3	Has a service as a key component, which are provided through a communication protocol over a network. A service is a discrete unit of functionality that can be accessed remotely and acted upon and updated independently, such as retrieving a credit card statement online.

Table 8: EAFs description used for the meeting

After filling in the questionaire (Figure 23), a general discussion was held, recorded and transcripted, with some of the questions mentioned below:

1. Do you think implementing sucha kind of architecture would be useful for the Rescue Board? Why?
2. What was easy for understanding in the presented models and what was difficult?
3. In how much details should the views be modelled? Subprocesses in details, more general
4. How and from where should the information, requirements for developing EA be gathered?
5. Which evaluation criteria can be added, removed, changed? How?

Overall, based on the discussion, it turned out that implementing one of the presented frameworks would be useful and the various parts of EA have been modelled already, but there has been no attempt in putting IT at the same picture with goals and proceses. Based on the models presented, it is very easy to see the connections between services and processes, which are important to have a better understanding of what affects what. For example, if there is a need to shut down an IT service, employees need to see what will be affected by this.

However, despite the fact that models were easy to understand in general, a lot of presented information, made it hard and time-consuming to validate for people who were not familiar with it before. Yet, everyone agreed that the model should be zoomable with a possibility to go into all details, even though it will take a lot of effort to maintain. One of the possible solutions can be, that depending on the functional area or number of people within a particular process, the process descriptions should get more detailed as it needs to be communicated to more people. For example, if there is, one or two people included in the process – a less detailed description can be done. However, the more people, the more detailed instructions should be given to each of them. In this case, picturing the process in a lot of details should be done.

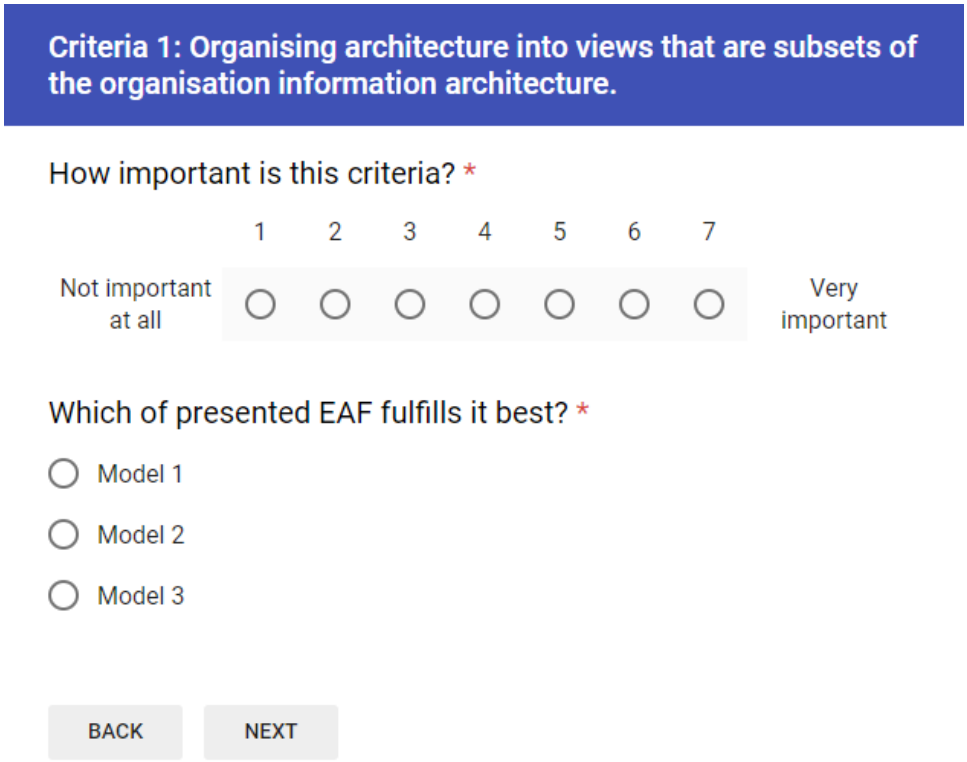

Figure 23: An example of the Assessment Criteria used for evaluation

The initial information for developing EAF, can be taken from the documentation that the ERB has already or Service Owners, who are responsible for the set of services. Depending on the functional area, some documentation is already very detailed. In case it is not, then people should be interviewed and once the process or service is modelled, they should be validated with the relevant service/process owner. Ideally, they should be part of the modelling process or even do it themselves. Last but not least, a very good point was made that the processes and/or services need to be connected with other organisations, which are the partners of the ERB, for example Ministry of the Interior, Emergency Response Centre, Ministry of the Interior's Information Technology and Development Center (Siseministeeriumi infotehnoloogia- ja arenduskeskus – SMIT). Essential business processes and the information that they manage for such organisations should be illustrated at some basic level, to make the general process flows easily understandable.

5 Results

In this part, the results of the thesis will be presented, describing which framework and why was chosen, future work that can be done in this topic and overall conclusion. As well as this, the general approach for selecting a framework, which can be used by any Estonian Government Organisations, will be described.

5.1 Selected Framework

Analysing the responses, collected during the meeting, made it possible to answer **RQ2:** Which criteria are important for selecting an EA framework at the Estonian Government Agency? It turned out that 6 out of 10 criteria, such as understanding of the processes, connections and different views, were relevant for the Rescue Board and important for every participant (Figure 24). Extensibility and customisation while integrating with X-Road as well as scalability, turned out to be not that vital, even though during the discussion part most of the participants agreed on how important is to make the models as detailed as possible. The least important criteria was the one regarding different standards. Two main things were agreed to be the most vital while developing EAF in the organisation:

1. Organising architecture into views that are subsets of the organisation information architecture.
2. Understanding how the organisation's goals are supported.

Apart from that, organisation's risks should be taken into account, and how they are connected with the goals. As well as this, people, resources, guidelines and relevant documents should be included into diagrams. However, quite a lot still depends on the software and on the interfaces (outputs) the software supports, which is used for modelling EAF, not only on EAF selected. People need to be familiar with the software that is used, to know what and how is done there. The main expectation of the ERB regarding EA was to use it as an impact assessment tool, so it is possible to see when the resources are changed how does this affect the results and goals. From all work done, it can be seen that their expectation was met to the extent of some processes being developed. All in all, the research was addressing some problems that needs to be solved. However, there are plenty of possibilities to make the research even more useful for a particular organisation. All feedback and comments, as well as steps that needs to be done for selecting frameworks, presented in the thesis can be used as a starting point for selecting EAF for the Estonian Government Agencies.

Answers to the second question at the meeting "Which of presented EAF fulfils it best?" gave nearly the same percentage to Model 1 and Model 3, TOGAF and SOA. Yet, the last question made it for TOGAF. Surprisingly, FEAF was not evaluated at a very high percentage. This might be due to the fact that FEAF is modelled using functions, not processes as TOGAF and SOA, making the model not easily understandable and the connections not clearly visible. Nevertheless, the results of the evaluation made and EAF chosen cannot be implemented without asking feedback from more employees of the Rescue Board or other government agencies that work closely with the ERB, as 4 people is not sufficient to make any statistical analysis

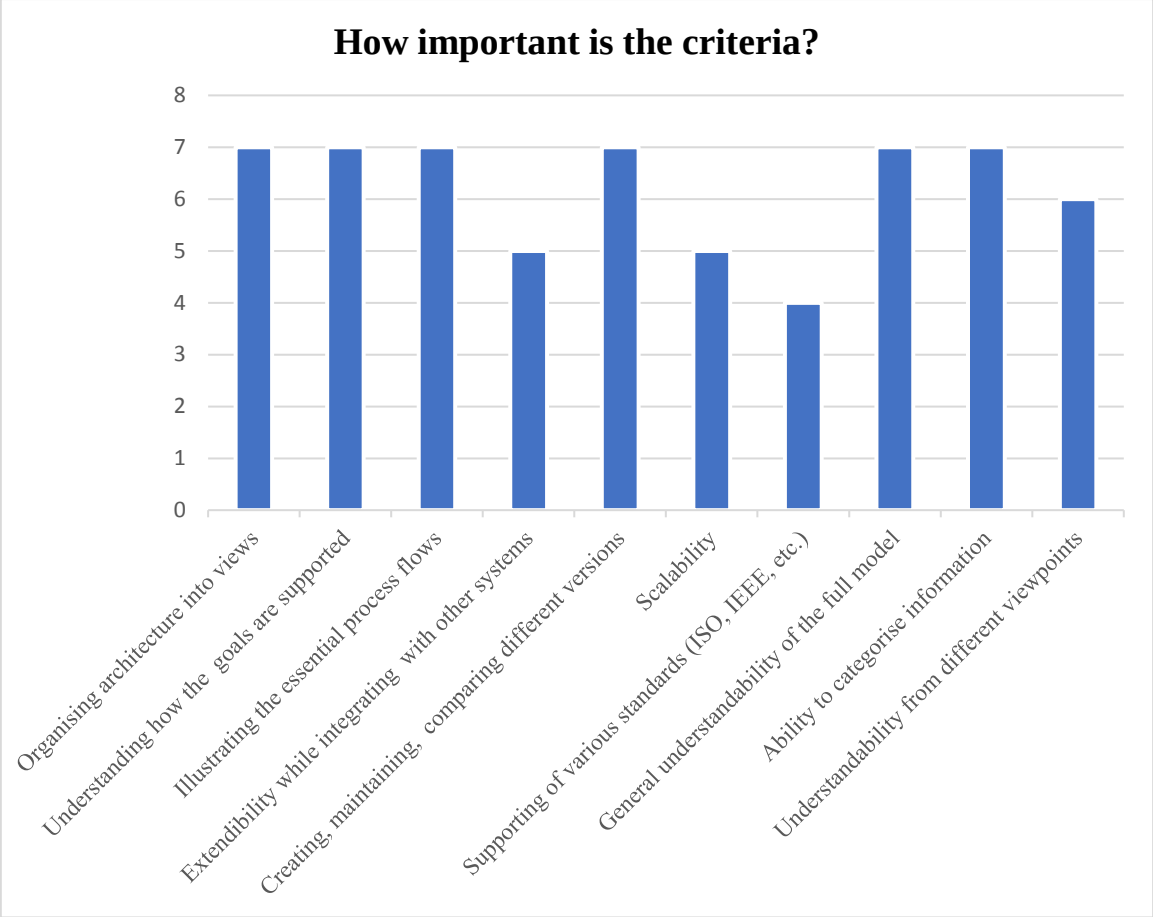

Figure 24: Criteria evaluation based on responses

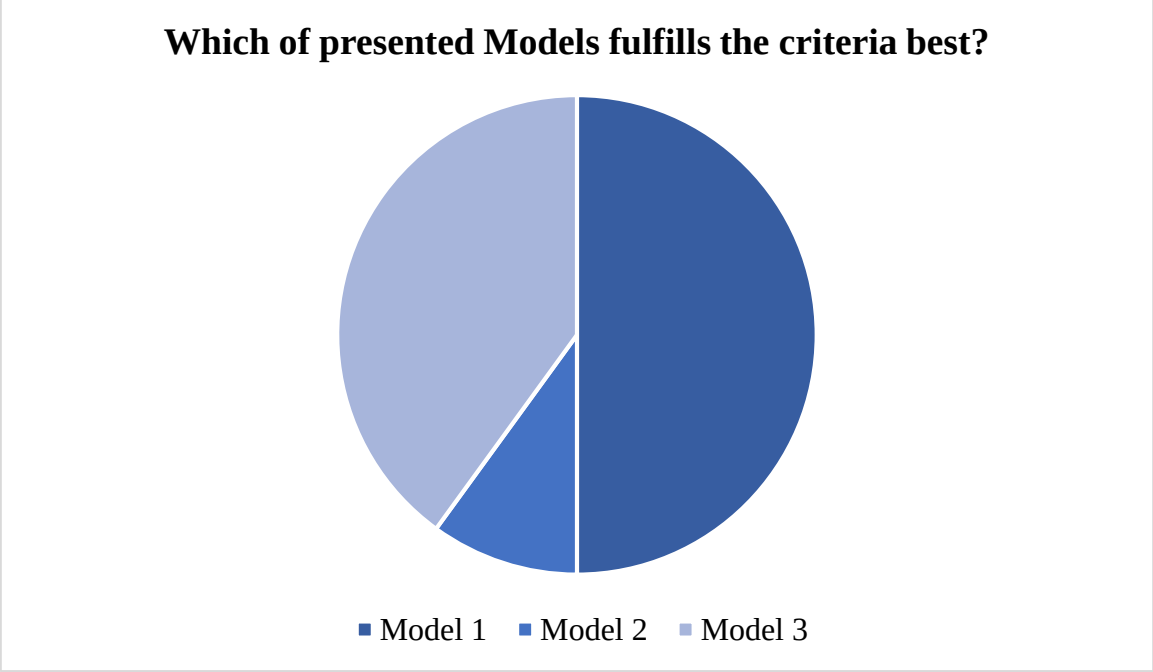

Figure 25: Models evaluation based on the responses

5.2 Threats to Validity

In scientific research, Internal Validity considers to what extent the casual conclusion based on the study is justified, which is determined by the degree to which the study minimizes a systematic error or bias. Main threats to internal validity are selection bias, attrition or mortality, history, maturation, instrumentation. On the contrary, External Validity is the extent to which it is justified to generalise results to other contexts. Main threats to External validity are situational/contextual factors, pre-test/post-test effects, hawthorne effects, experimenter effects [5].

In the conducted case study, both threats to Internal and External Validity were presented, such as selection bias, instrumentation and experimenter effects. Selection bias may have influenced the employees of the Rescue Board during the meeting, as they might have been only focused on the processes related to their department, not paying much attention to the other ones. There is also a possibility that some relevant papers were excluded or were not found during the literature review phase, which is instrumentation. Experimenter effects to some extent depended on the researcher, who could have mistaken in some parts. Moreover, as a threat to External Validity, population validity can be related, as the number of participants wasn't representative enough.

5.3 Conclusion

In this thesis, a literature review and a case study were conducted in order to answer two research questions regarding relevant EA frameworks in the Estonian Rescue Board, as an example of Estonian Government Agency, as well as the importance of parameters and criteria that should be used for EAF evaluations.

In the literature review part, 34 relevant works were found, using ACM Digital Library, SpringerLink, IEEE Xplore. Among them only 8 gave an understanding of what EA is, helped to identify some EAF and set the additional keywords for finding more information about the frameworks. The second part of the literature review gave 44 articles, after analysing which there were 11 articles left that either analysed different EAF or provided different schemes for selection or evaluation of the frameworks. Finally, the frameworks described in the first part of the literature review were compared and evaluated based on qualitative and development requirements. The result of the evaluation left three EAF, which were implemented and analysed in the next parts of the thesis.

Following the literature review, a case study was conducted illustrating different approaches for implementing EAF and how it will be used as well as answering the research questions. In this part steps of modelling the selected frameworks and the tool used for this were described. Moreover, all EAF were visually represented, first, by different layers (motivation, business, application, technology) and later as a whole architecture. Even though three frameworks had quite a lot in common, when it came to modelling, the meeting at the Rescue Board, which was the second part of case study, revealed that for people who were not familiar with EA and notations used for modelling, a lot of things might have been unclear. During the meeting itself, attendees got familiar with the frameworks modelled, based on which the answers to two questions regarding evaluating criteria for selecting EAF were given. The final part of case

study was going through all responses, and discussion, which was held after the evaluation, and analysing which criteria are more important, which are less, and why.

After case study was finished, it was possible to give the answers to the research questions. It turned out that most of the criteria given for the evaluation were important. Yet, some of them could have been altered for better understanding among non-IT people. Taking into account the possible threats to internal and external validity, the results of the analysis could have been slightly different, if some of the criteria were better formulated and the number of participants in the meeting was higher.

As a future work and before developing any of EAF, more people should be asked to assess different models. One of the organisations could be Riigi Infosüsteemi Amet (Information System Authority), which is responsible for Data Exchange Layer X-Road as well as the general architecture of the government information system, of which most of the ERB systems are an integral part [73]. The way for presentation can be also changed. For example, showing one by one how EAFs are represented using different notations, or some process and its connections. If it is possible to compare the visual representations of some service or part of the organisation, it will be easier to understand and evaluate, especially for people without an IT background. As well as this, some of the criteria can be changed or adjusted according to the specific process or part of the diagram that will be evaluated. Based on feedback from sufficient amount of people, statistical analysis can be performed and based on the results, EAF can be developed.

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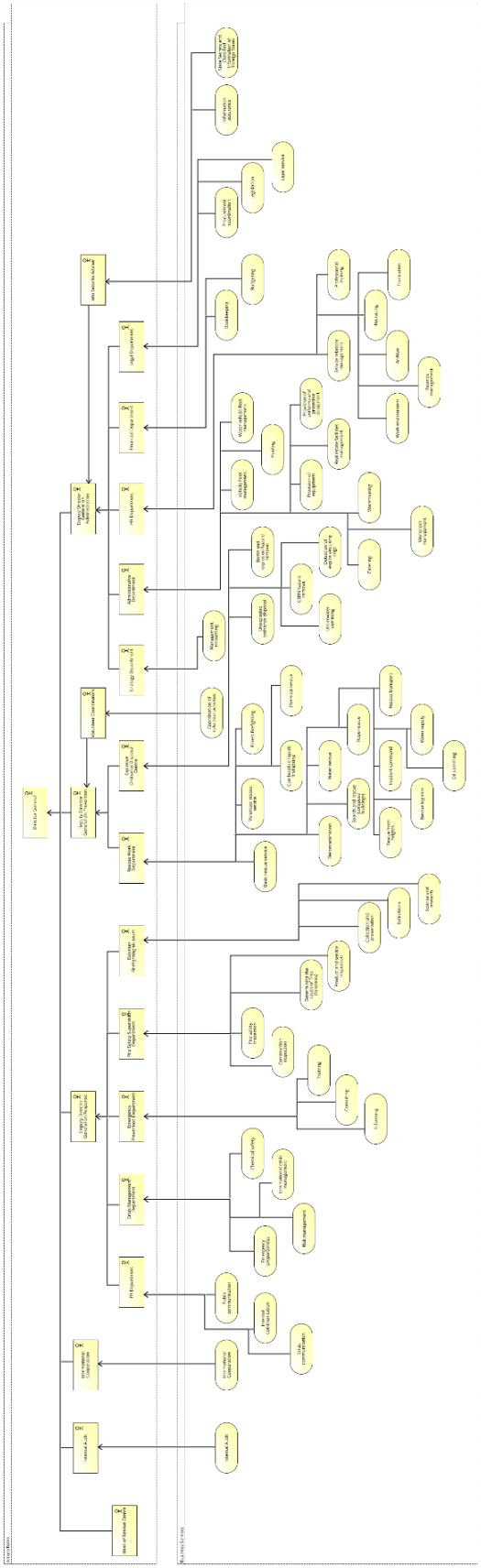
Appendix 1: A detailed organisational structure of the ERB



Appendix 2: Queries used for search

ACM Digital Library

Search Result Count: 2,203

"query": { (Enterprise Architecture, EA, EAF, Enterprise Architecture Framework analysis, developing, implementation, evaluation }) AND keywords.author.keyword:(Enterprise Architecture, EA, EAF, Enterprise Architecture Framework analysis, developing, implementation, evaluation) }

"filter": {"publicationYear":{ "gte":2000 }}, {owners.owner=HOSTED},

{allPubGroups.allPubGroup=Periodical, resources.ft.resourceFormat=PDF}

Springer Link

Search Result Count: 307

("Enterprise Architecture*" OR " Enterprise Architecture Framework*" OR "EA*" OR "EAF*") AND (evaluation* OR implementation OR developing OR analysis*)

within English Computer Science Software Engineering/Programming and Operating Systems Article 2000 - 2017

IEEE Xplore

Search Result Count: 581

(("Document Title":"Enterprise Architecture" OR " Enterprise Architecture Framework" OR "Architecture Methodologies" OR "EA" OR "EAF")) AND "Author Keywords":"Enterprise Architecture" OR " Enterprise Architecture Framework" OR "Architecture Methodologies" OR "EA" OR "EAF"))

and refined by Content Type: Journals & Magazines; Year: 2000-2017

Appendix 3: List of articles after the literature review for EA frameworks

Number	Title	Authors	Year	Reference
1	"The Impact of SOA Implementation on IT-Business Alignment"	J. A. E. Choi, D. L. Nazareth, and H. K. Jain	2013	[6]
2	"ArchMatE : From Architectural Styles to Object-Oriented Models through Exploratory Tool Support"	J. A. D. Pace, B. Tandil, B. Aires, and M. R. Campo	2005	[7]
3	"Frameworks for Enterprise Architecture"	H. Shah and M. El Kourdi	2007	[8]
4	"Cloud Enterprise Architecture for Smarter Enterprises"	Pethuru Raj Chelliah	2014	[9]
5	"Real Options in Enterprise Architecture : A Holistic Mapping of Mechanisms and Types for Uncertainty Management"	T. Mikaelian, D. J. Nightingale, D. H. Rhodes, and D. E. Hastings	2011	[10]
6	"What can we learn from enterprise architecture models ? An experiment comparing models and documents for capability development"	U. Franke, M. Cohen, and J. Sigholm	2016	[11]
7	"From enterprise architecture to business models and back"	M. E. Iacob, L. O. Meertens, H. Jonkers, D. A. C. Quartel, L. J. M. Nieuwenhuis, and M. J. Van Sinderen	2014	[12]
8	"Exploring the main building blocks of SOA method : SOA maturity model perspective"	S. Pulparambil, Y. Baghdadi, and M. Al-badawi	2017	[13]
9	"John Zachman'S Concise Definition of the Zachman Framework™"	John A. Zachman	2008	[14]
10	"The use of Enterprise Architecture , IT Strategy and IT Governance at StatoilHydro"	C. L. Parmo	2009	[15]

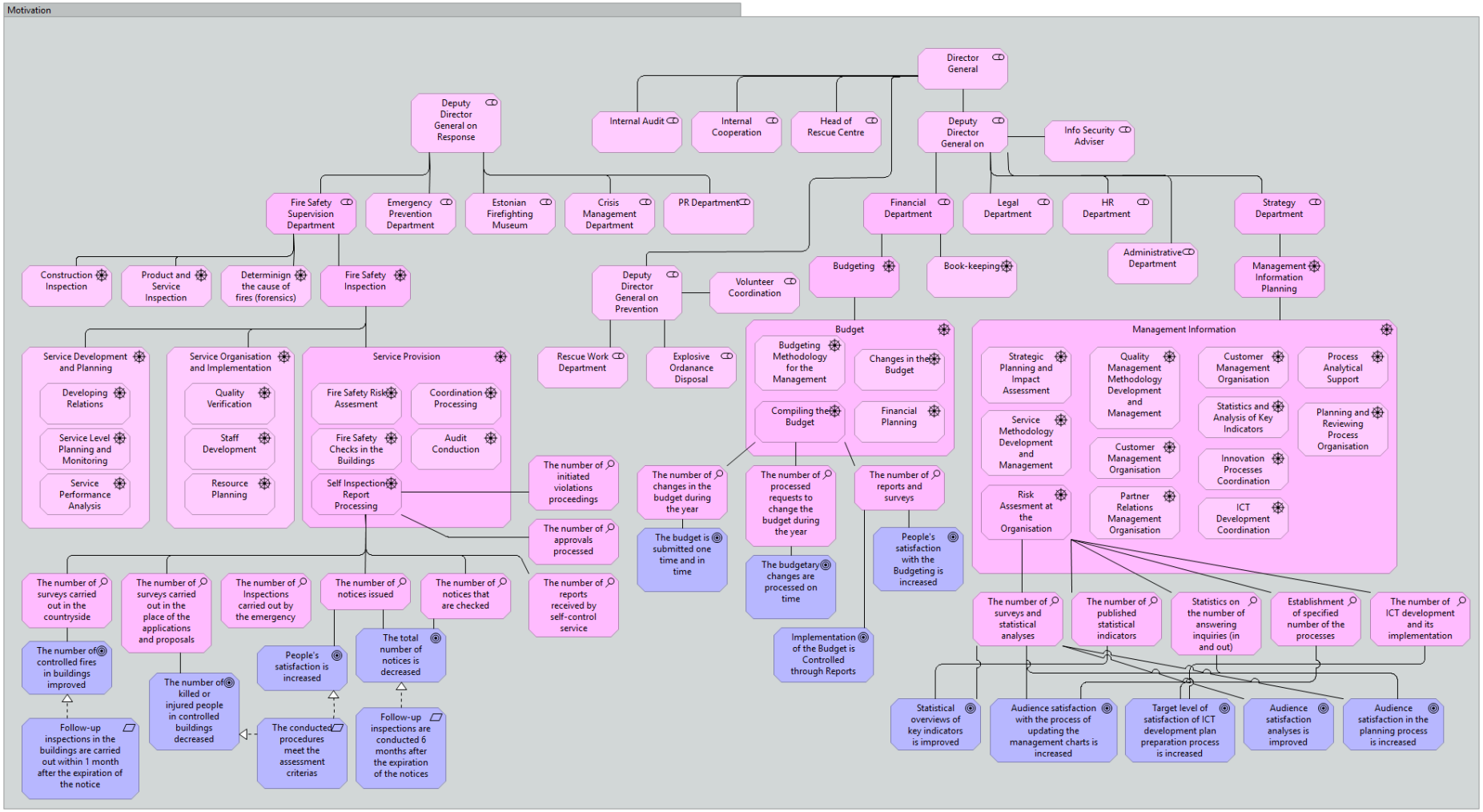
11	“Enterprise Architecture in University”	A. Ramadhan	2014	[17]
12	“TOGAF 9.1”	[Online]. Available: http://pubs.opengroup.org/architecture/togaf9-doc/arch/	2017	[18]
13	“How to Survive in the Jungle of Enterprise Architecture Frameworks: Creating Or Choosing an Enterprise Architecture Framework”	J. Schekkerman	2004	[19]
14	“Creating a Strategic IT Architecture Competency: Learning in Stages”	J. W. Ross	2003	[20]
15	“Basics of the Federal Enterprise Architecture Framework”	[Online]. Available: http://innovategov.org/2015/04/08/basics-of-the-federal-enterprise-architecture-framework/	2017	[21]
16	“DoD Architecture Framework Volume I: Overview and Concepts Manager’s Guide”	N/A	2015	[22]
17	“The Human View Handbook The Human View Handbook for MODAF: — Second Issue — The Human View Handbook Part 2: Technical Description”	Anne Bruseberg	2010	[23]
18	“IBM Knowledge Center - MODAF overview”	[Online]. Available: https://www.ibm.com/support/knowledgecenter/	2017	[24]
19	“MODAF- Ministry of Defence Architecture Framework”	[Online]. Available: https://www.slideshare.net/AaronVarrone/modaf	2017	[25]
20	“MINISTRY OF DEFENCE MOD Architectural Framework Technical Handbook”	N/A	2005	[26]
21	“A part of BMT in Defence TOGAF TO MODAF MAPPING”	N/A	2010	[27]

22	“NATO Architecture Framework v4.0 Documentation (draft)”	[Online]. Available: http://nafdocs.org/	2017	[28]
23	“An Update on the Convergence of MOD and NATO Architecture Frameworks”	Patrick Gorman, Kees van Haperen, Ian Bailey	2014	[29]
24	“Nato Architecture Framework (NAF) - 3 - Views - Training Material”	[Online]. Available: https://training-course-material.com/training/	2017	[30]
25	“Benefits and Challenges of Architecture Frameworks Benefits and Challenges of Architecture Frameworks”	D. Ota, M. Gerz	N/A	[31]
26	“Service-Oriented Architecture in Services Computing”	Springer Berlin Heidelberg	2007	[32]
27	“Service-oriented modeling and architecture How to identify, specify, and realize services for your SOA”	A. Arsanjani	2005	[33]
28	“Service-oriented architecture : concepts, technology, and design”	T. Erl	2005	[34]

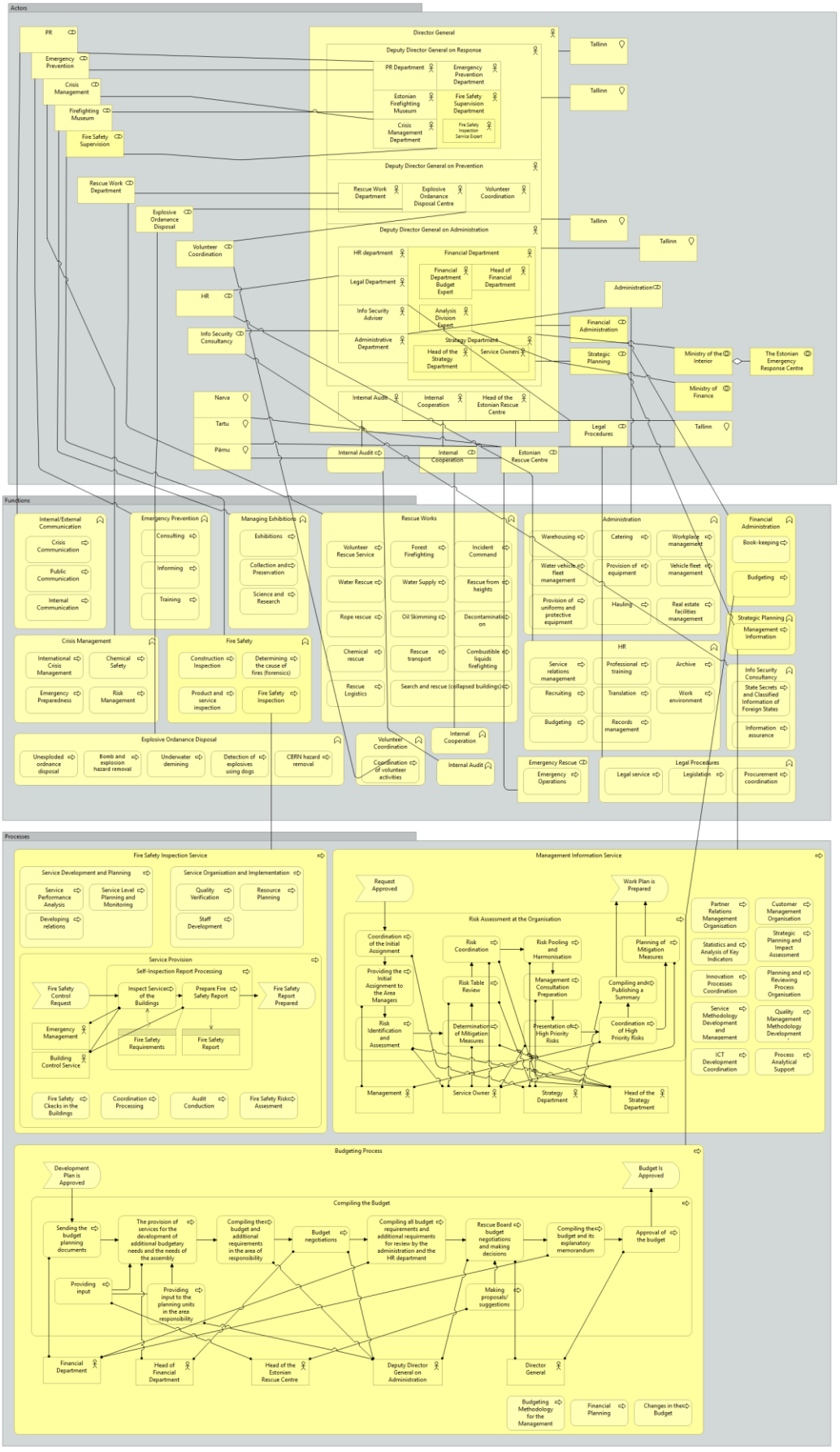
Appendix 4: List of articles after the literature review for Comparative Analysis of EA frameworks

Number	Title	Authorss	Year	Reference
1	"Analysing system maintainability using "Enterprise Architecture Models"	Lagerström, R.	2007	[36]
2	"A model to assess: The usability of enterprise architecture frameworks"	Bijarchian, A., Ali, R.	2013	[37]
3	"State of the art of the maturity models to an evaluation of the enterprise architecture"	Lakhrouit, J., Baina, K.	2013	[42]
4	"Strategic business and IT alignment: Representation and evaluation"	Doumi, K., Baïna, S., Baïna, K.	2013	[41]
5	"An evaluation of enterprise architecture frameworks for E-government"	Mohamed, M.A., Galal-Edeen, G.H., Hassan, H.A., Hasanien, E.E.	2012	[43]
6	"Enterprise architecture descriptions for enhancing local government transformation and coherency management case study"	Valtonen, K., Mäntynen, S., Leppänen, M., Pulkkinen, M.	2011	[35]
7	"A scheme for systematically selecting an enterprise architecture framework"	Odongo, A.O., Kang, S., Ko, I.-Y.	2010	[38]
8	"A method for application evaluations in context of enterprise architecture"	Addicks, J.S., Appelrath, H.-J.	2010	[44]
9	"Collaboration engineering approach to enterprise architecture design evaluation and selection"	Nakakawa, A.	2008	[39]
10	"Evaluation of current architecture frameworks"	Leist, S., Zellner, G.	2006	[40]

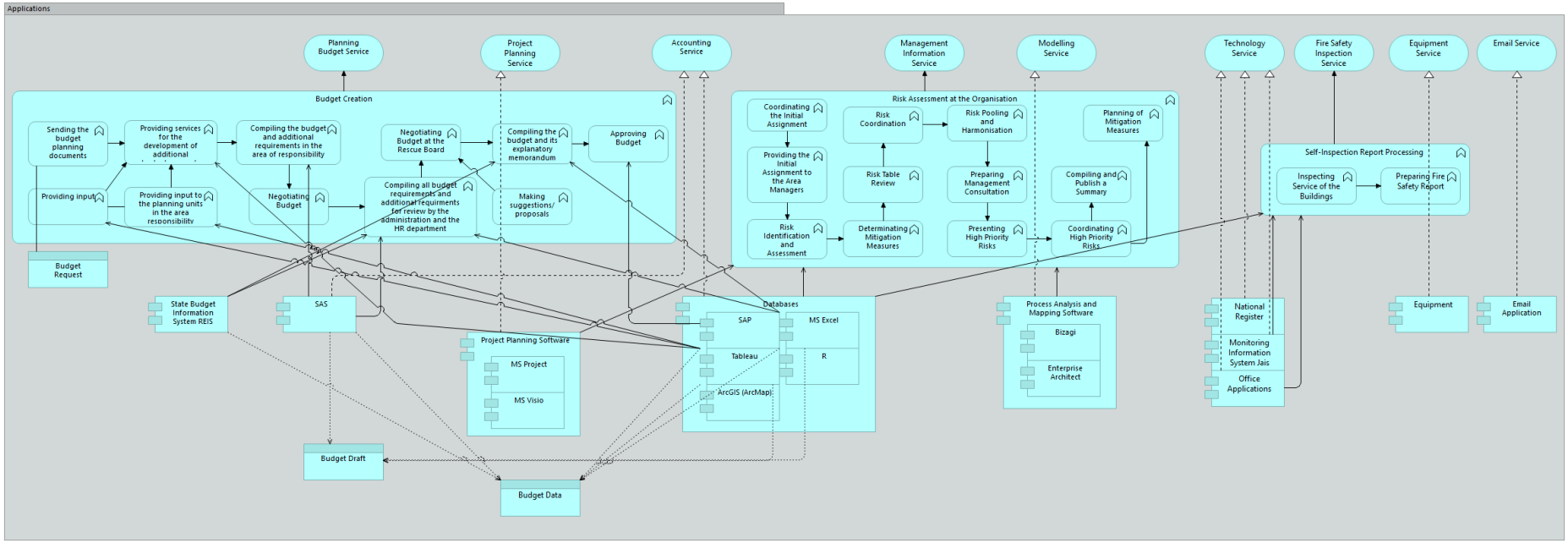
Appendix 5: TOGAF Motivation Layer



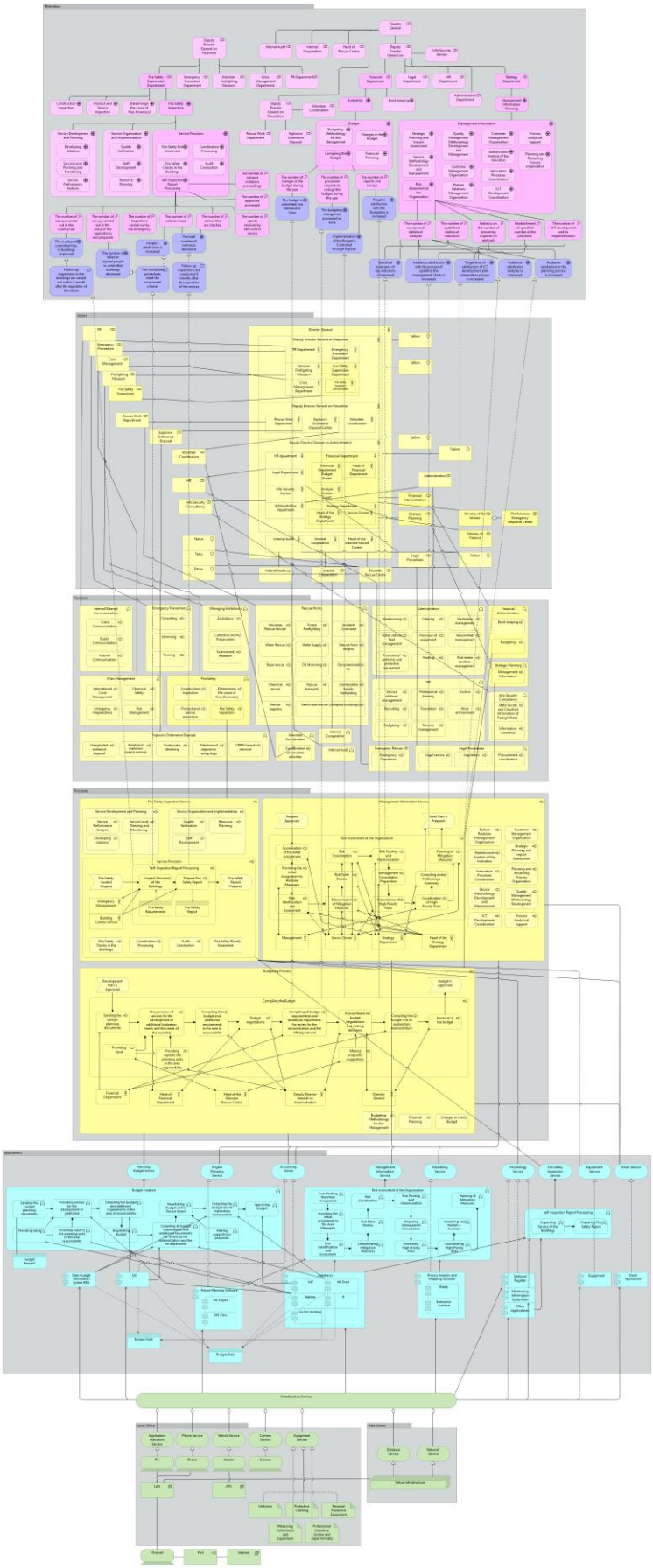
Appendix 6: TOGAF Business Layer



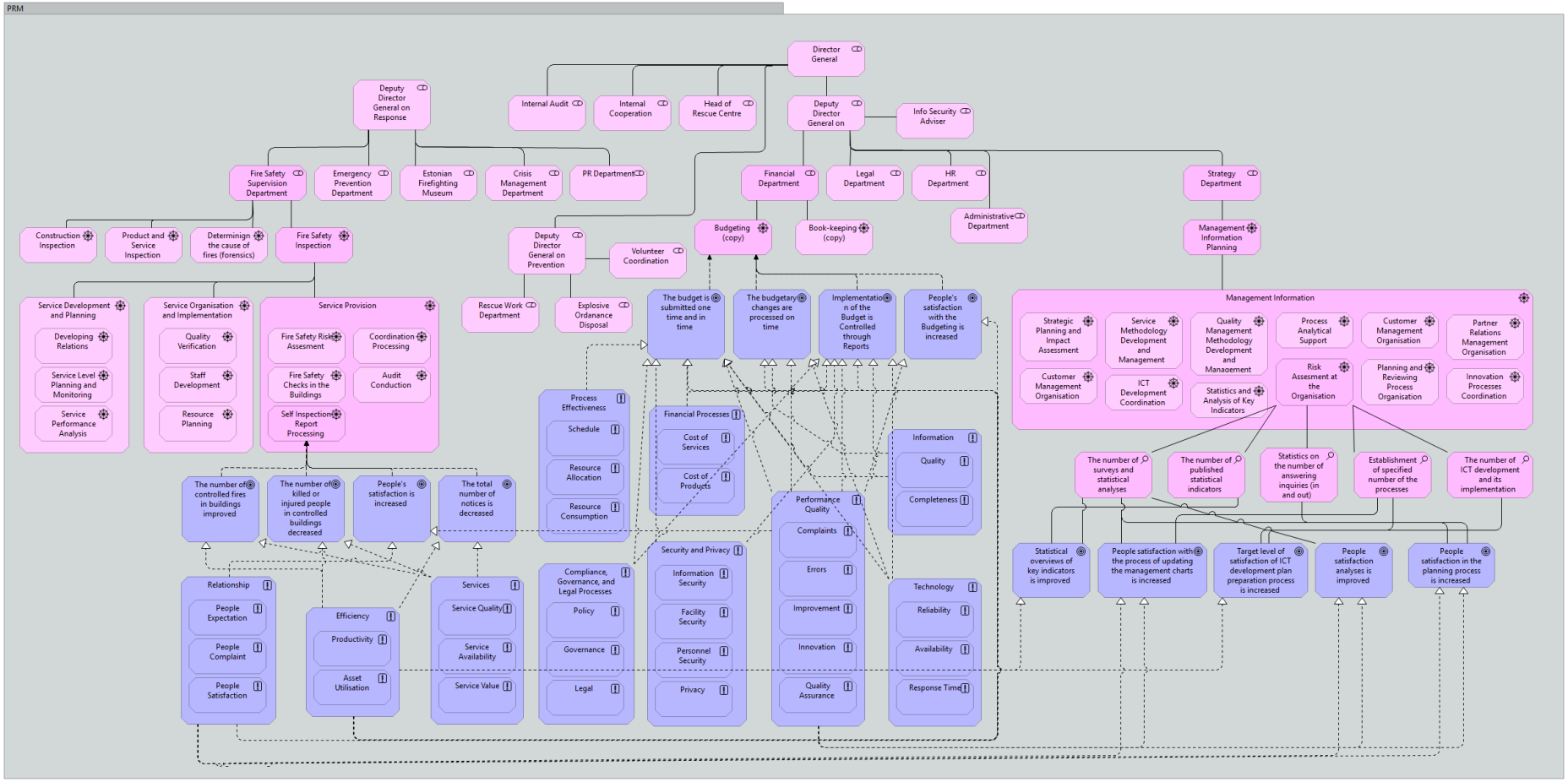
Appendix 7: TOGAF Application Layer



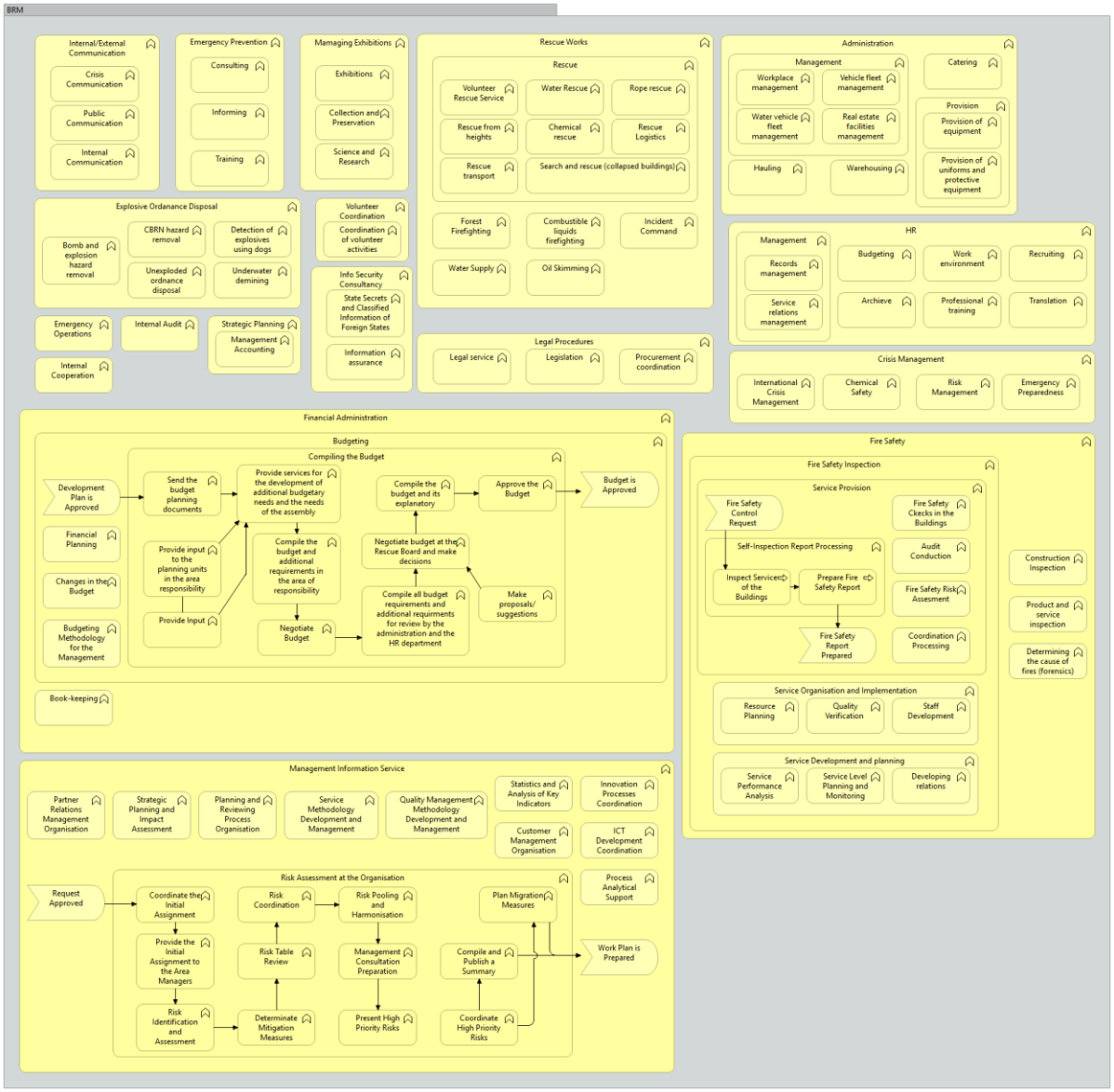
Appendix 8: TOGAF Baseline Architecture



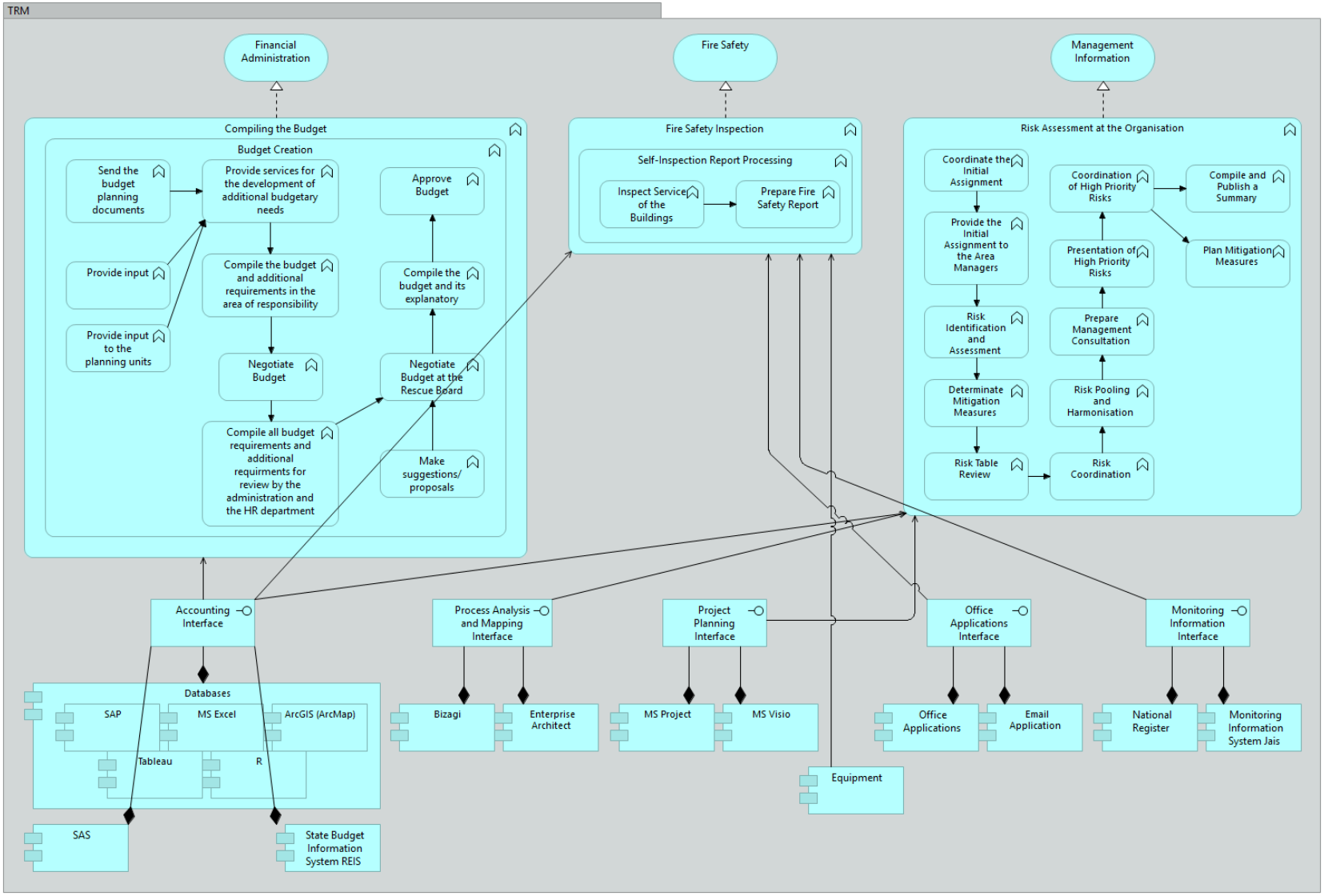
Appendix 9: FEAF PRM



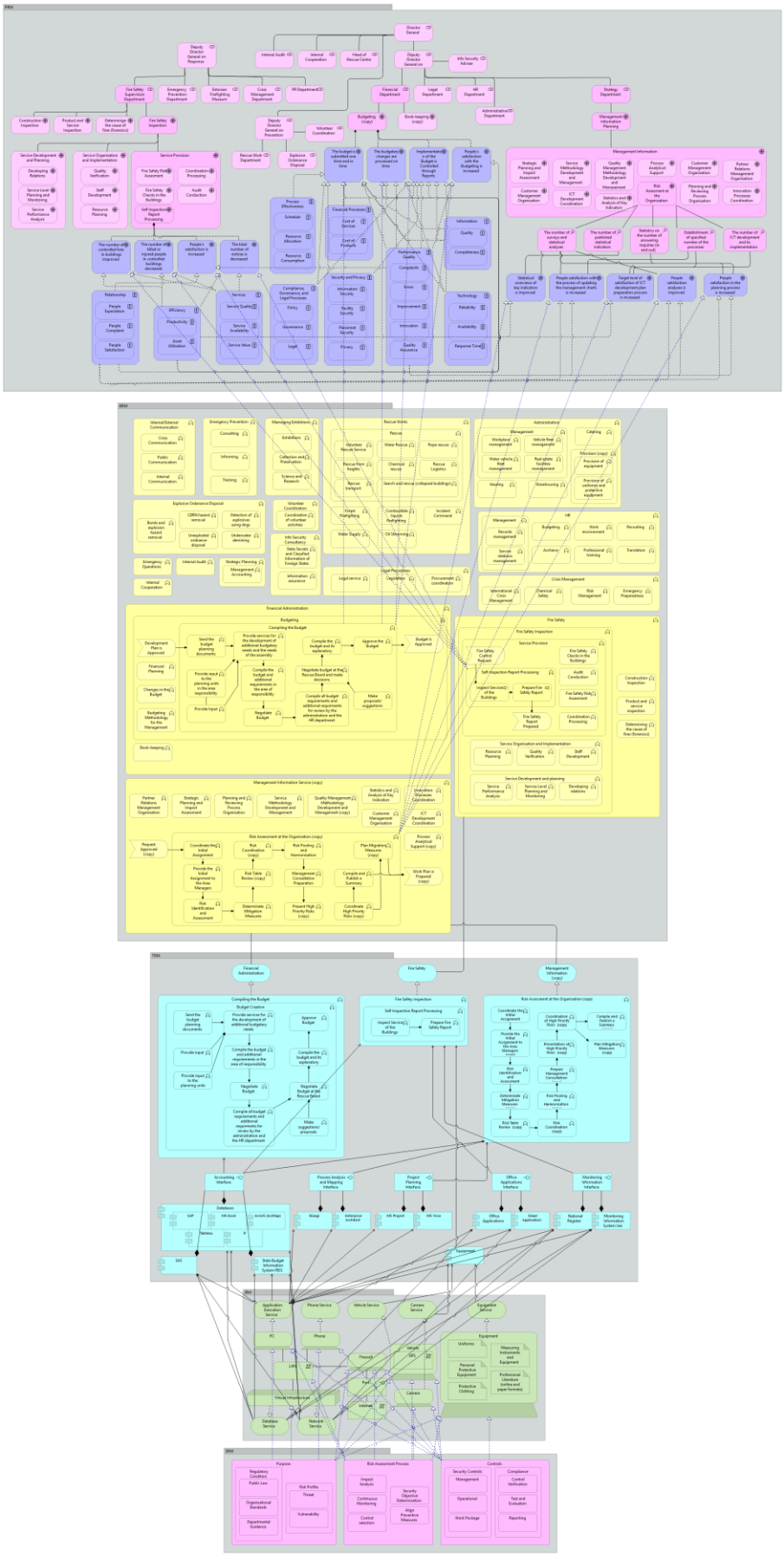
Appendix 10: FEAF BRM



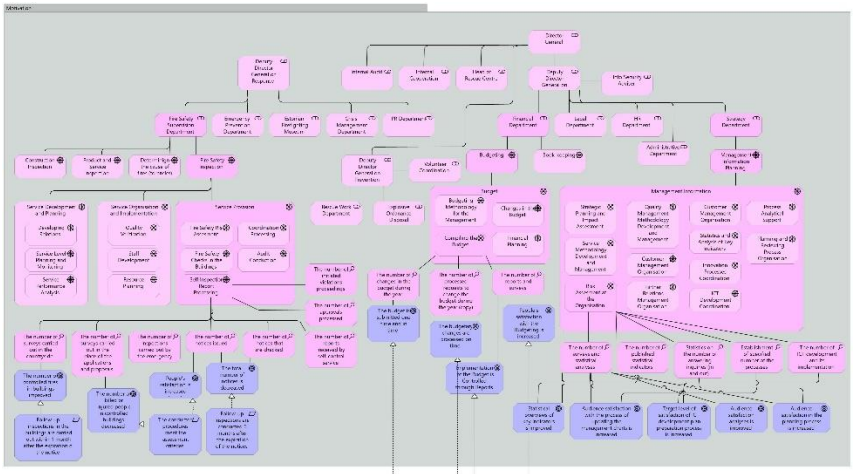
Appendix 11: FEAF TRM

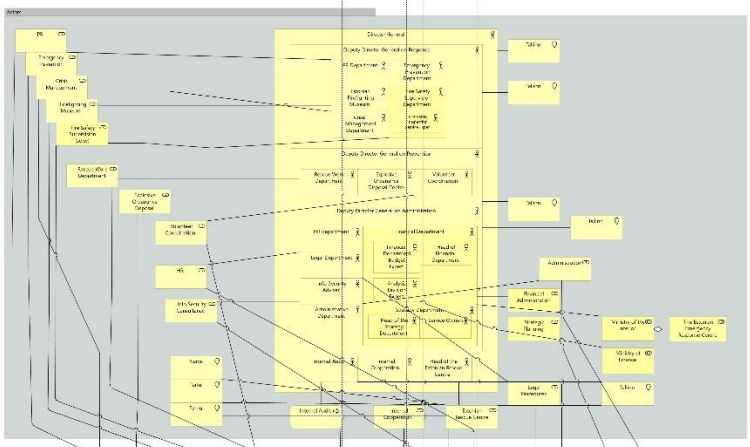


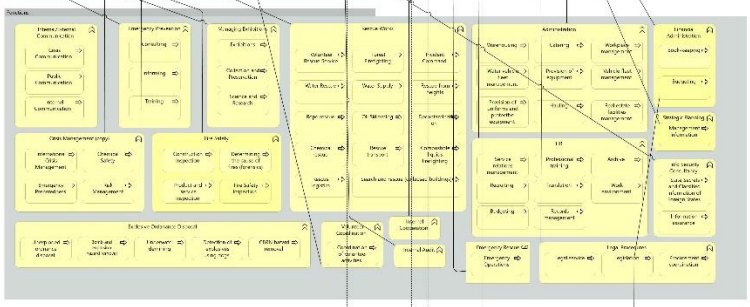
Appendix 12: FEAF CRM

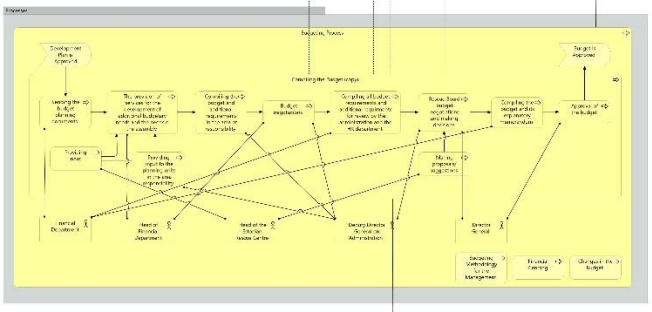


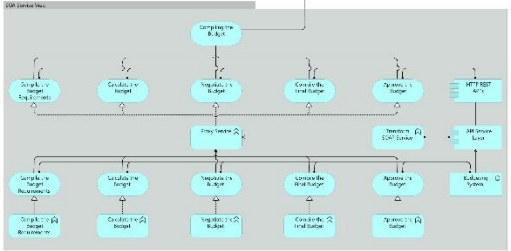
Appendix 13: SOA implementation for “Compiling the Budget” process











Appendix 14: EAF Assessment Criteria

Classification	Criteria
EAFs Modelling Support	1. Organising architecture products into views that are subsets of the organization information architecture.
	2. Supporting views of time-based architecture (current months/quarter/years, target).
	3. Customising and enforcing the relationships between architecture products and architecture data elements.
	4. Performing consistency and completeness checks among the various architecture products.
	5. Choosing modelling notation and methodology.
	6. Encompassing architecture information description for the whole organisation.
	7. Illustrating the essential information flows and process flows.
	8. Customising data dictionary capability with attributes and relationships, as required by the architecture products.
	9. Supporting simulation.
EA Repository Tools	1. Maintaining architecture data in a repository/database using a non-proprietary, commercial database based on relational technology, persistent object storage, or using XML.
	2. User customisation and manipulation of the data schema or the persistent object attributes.
	3. Generating custom reports.
	4. Creating, updating, deleting, and retrieving data from repository using a graphical user interface.
	5. Using simple queries to generate high-level, summary reports for management from the architecture data that facilitate acquisition, requirements generation/management, or budgeting decisions.
	6. Populating data repository by importing architecture data elements and data from external sources.
Customisation Support	1. Providing formal graphical modelling symbols.
	2. Adding custom icons to the tool's set of modelling symbols.
	3. Customising diagrams.
	4. Creating report templates.
	5. Providing an easily extendable internal structure (adding user defined properties).
	6. Collecting and publishing various architecture products (diagrams, tables, and requirements) in standard document templates.
	7. Ability to support queries and custom reports within specific architectures and across groups of architectures.
Interoperability	1. Integrating with other systems.

	2. Importing/exporting database information (entities, attributes, and relationships) from other existing DBMSs, or object-based storage using open standards and techniques (Open Data Base Connectivity).
	3. Supporting multiple data exchange formats.
	Enable data sharing (import/export) with other tools via standard formats (CSV, XML, ISO AP233).
	4. Supporting defined, published import/export interface (XMI).
	5. Providing open standard Application Program Interface (API).
General Purpose Characteristics	1. Configuration Management of model data
	2. Creating, maintaining, and comparing different versions
	3. Grouping versions by architecture and by product within the architecture.
	4. Supporting other Configuration Management functions such as change management and status accounting.
	5. Tracking ownership of data entered.
	6. Enforcing/customising various security standards.
	7. Supporting a multi-user environment.
	8. Supporting collaboration among project team members.
	9. Providing read-only Intranet access or ability to generate HTML.
	10. Supporting direct HTML publishing and offer a free viewer.
	11. Supporting a Web interface (with access to the models or data repository from geographically distributed locations).
	12. Scalability to thousands of architectural elements and relationships, and multiple versions of the architecture.
	13. Adaptability to new standards, techniques, etc.
	14. Supporting various IT platforms (Windows, Unix, or both).
	15. Calculating cost of ownership (initial and ongoing maintenance costs, training costs).
	16. Usability to the quality of a user's experience when interacting with the EA tool.
	17. Spell check capability.
	18. Adaptable/customisable user interface.

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