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Towards a method for improving the coherence between the reference architectures within the Dutch public sector

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Abstract

Enterprise Architecture plays a crucial role in supporting organisations' digital transformations by designing and realising an enterprise's organisational structure, business processes, information systems and technology infrastructure. A reference architecture is a generic (enterprise) architecture for a class of systems that is used as a foundation for the design of concrete architectures from this class. Within the Dutch public sector, reference architectures are used to align and improve (digital) public services. Every sector has a reference architecture that the organisations within that sector can use. Sectors are intertwined with each other, so reference architectures also have overlaps. This research aims to improve the coherence between reference architectures.

First, the benefits of Enterprise Architecture and reference architectures for organisations in the public sector were found. After that, the use of semantic wikis for organising and structuring architecture knowledge was investigated. Semantic wikis are equipped with an underlying knowledge model, providing meaning to the information in the wiki. Most reference architectures within the Dutch public sector have their architectural knowledge published on semantic wikis. In the last few years, the number of reference architectures has increased, and there is a growing desire for improved coherence between reference architectures. Digital architects argue that a lack of coherence has emerged, resulting in stakeholders experiencing problems using these reference architectures. Therefore, the current state of coherence between reference architectures within the Dutch public sector was investigated by conducting a focus group and a survey.

One aspect of improving coherence involves defining and establishing explicit relationships between components of reference architectures. However, no standardised approach exists for defining and establishing these relationships. This research bridges this gap by providing a method that can be used by digital architects to define and establish relationships between components of reference architectures within the Dutch public sector. These relationships can be established by using linked data principles and techniques. Eventually, the additional information about how components of reference architectures relate to each other can be made visible within the semantic wikis. The method was designed based on the findings of the focus group, survey and unstructured interviews. The method was validated by one case study. It was concluded that the method is useful for defining and establishing relationships between components of educational reference architectures. While proven useful, the method may require adjustments for direct application to every reference architecture due to variations in semantic wikis and architectural knowledge.

Keywords: Enterprise Architecture, reference architecture, architectural knowledge, semantic wiki, public sector, coherence, method

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List of Abbrevations

DT Digital Transformation

EA Enterprise Architecture

ERA Enterprise Reference Architecture

RM Reference Model

DSM Design Science Methodology

SLR Systematic Literature Review

FGDAF Focus Group Data Analysis Framework

BPMN Business Process Modelling Notation

TOGAF The Open Group Architecture Framework

FEAF Federal Enterprise Architecture Framework

NORA Nederlandse Overheid Referentie Architectuur

GEMMA GEMeentelijke Model Architectuur

ROSA Referentie Onderwijs Sector Architectuur

WILMA Waterschap Informatie en Logisch Model Architectuur

FORA Funderend Onderwijs Referentie Architectuur

MORA Middelbaar Onderwijs Referentie Architectuur

HORA Hoger Onderwijs Referentie Architectuur

CORA COrporatie Referentie Architectuur

VERA Volkshuisvesting Referentie Architectuur

VeRA Veiligheidsregio Referentie Architectuur

XML eXtensible Markup Language

RDF Resource Description Framework

W3C World Wide Web Consortium

URI Uniform Resource Identifier

URL Uniform Resource Locator

OWL Web Ontology Language

SKOS Simple Knowledge Organization System

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Chapter 1

Introduction

This chapter introduces the topic, motivation and objective of this master's thesis research project. First, the topic of the research will be introduced, followed by the context in which this research is conducted. The research revolves around reference architectures that are used in the Dutch public sector. After that, the problem statement and the research objective including the research questions are presented. Lastly, the outline of the thesis is presented.

1.1 Digital Transformation in the public sector

Organisations in the Dutch public sector have been working on their Digital Transformation (DT) for many years now. Digital Transformation can be defined as the continuous process that aims to improve an entity by triggering significant changes to its properties through combinations of digital technologies [6]. One of the main goals of DT for organisations in the public sector is to improve their (digital) services for citizens and businesses. Society and businesses expect public services to be highly available, efficient, and flexible [7]. Digital Transformations can also lead to various benefits for public organisations, such as improved processes and services, the organisation's ability to change and the reduction of costs [8].

Despite the high expectations regarding Digital Transformation, there is little empirical evidence on how organisations in the public sector are approaching DT. Enterprise Architecture (EA) is a powerful tool to support the analysis of flexibility that is needed at different levels in an organisation to progress through their Digital Transformation [6]. EA offers a high-level overview of the business structure and IT systems of an organisation and their interrelationships. The design of (Enterprise) architectures can be guided by reference architectures, which provide principles, architecture models, and a common language for digital architects. Therefore, a reference architecture can be defined as a generic architecture for a class of systems used as a foundation for the design of concrete architectures from this class [9].

The Dutch public sector is divided into different domains, each with a specific purpose. To improve the (digital) public services, a concerted effort across many organisations within the public sector is required. To guide this effort, consisting of different programs and projects, reference architectures have been developed for different domains within the Dutch public sector.

1.2 Reference architectures

Reference architectures ensure that public (digital) services are designed consistently, according to the overall goals and objectives of the Dutch government. Reference architectures should be aligned for this purpose to ensure different services from different organisations in the public sector can work together seamlessly. Reference architectures contain principles and architecture models that can be reused in concrete (enterprise) architectures. Furthermore, reference architectures can consist of frameworks and agreements for the information provision of public organisations.

One of the reference architectures within the Dutch public sector is the Nederlandse Overheid Referentie Architectuur (NORA), the Dutch Government Reference Architecture. The NORA contains frameworks and existing agreements for setting up the information provision of the whole Dutch government. In addition to NORA, many other reference architectures are designed for a specific type of organisation in the public sector. Together these reference architectures form the NORA family[1] and contribute to a collective approach for digital transformations within the Dutch public sector, by reusing architecture principles, applying (open) standards and complying with established agreements.

As the number of reference architectures continues to grow, a complex system of reference architectures has originated. At this moment, 22 reference architectures are active, and this number is still growing. The architectural knowledge of many of these reference architectures is organised and structured on a platform called WikiXL, which is a semantic wiki. A semantic wiki is a wiki that has an underlying model of the knowledge described in its pages. In table 1.1 all reference architectures that are used within the Dutch public sector can be found.

No.	Abbreviation	Reference Architecture	Documentation
1	AORTA	Landelijke infrastructuur voor berichtuitwisseling in de zorg	Yes, website
2	Astra	Architectuur strafrechtketen	Yes, WikiXL & ArchiMate models
3	CORA	COrporatie Referentie Architectuur	Yes, WikiXL & ArchiMate models
4	DERA	Digitale Erfgoed Referentie Architectuur	Yes, WikiXL & ArchiMate models
5	DIZRA	Duurzaam Informatiestelsel Zorg Referentiearchitectuur	Yes, website & models
6	EAR / RORA	Enterprisearchitectuur Rijksdienst / RijksOverheid Referentie Architectuur	Yes, website & models
7	FORA	Funderend Onderwijs Referentie Architectuur	Yes, WikiXL & ArchiMate models
8	GA	GDI-Architectuur	Yes, website & models
9	GEMMA	Gemeentelijke ModelArchitectuur	Yes, WikiXL & ArchiMate models
10	HORA	Hoger Onderwijs Referentie Architectuur	Yes, WikiXL & ArchiMate models
11	KarWeI	Ketenarchitectuur Werk en Inkomen	Yes, website & models
12	MARA	Model Architectuur voor Rijks Archiefinstellingen	Yes, PDF from 2016 & ArchiMate models
13	MARTHE	Model Architectuur RijksToezichts- en HandhavingsEenheden	No documentation
14	MORA	Middelbaar beroepsOnderwijs Referentie Architectuur	Yes, WikiXL & ArchiMate models
15	NBility	Netbeheerders Business Capability	Yes, PPT & ArchiMate models
16	PETRA	Provinciale EnTerprise Referentiearchitectuur	Yes, WikiXL & ArchiMate models
17	PURA	Publieke gezondheid Referentie Architectuur	Yes, PDF from 2019 & ArchiMate models
18	-	Referentiearchitectuur Jeugdketens	Yes, PDF from 2009 & models
19	ROSA	Referentie Onderwijs Sector Architectuur	Yes, WikiXL & ArchiMate models
20	VeRa	Veiligheidsregios Referentie Architectuur	Yes, WikiXL & ArchiMate models
21	WILMA	Waterschaps Informatie & Logisch Model Architectuur	Yes, WikiXL & ArchiMate models
22	ZiRA	Ziekenhuis Referentie Architectuur	Yes, website & (ArchiMate) models

Table 1.1: Reference architectures within the Dutch public sector (November '23)

Most of the reference architectures are intertwined with each other, as one specific domain for which a reference architecture is designed can overlap with another domain. Because of the overlaps between certain domains, reference architectures should be related to each other. Examples of

[1]NORA familie, `https://www.noraonline.nl/wiki/NORA_Familie`

domains in the Dutch public sector are Healthcare (Gezondheid en zorg), education and science (Onderwijs en wetenschap), and public order and safety (Openbare orde en veiligheid).

1.3 Problem Statement

In recent years, the NORA family has seen considerable growth. The concept family is primarily used because reference architectures should be related to each other. The architecture community desires coherence between reference architectures. However, one of the problems is that relationships between reference architectures are not explicitly formulated and established.

Examples of related reference architectures are the GEMeentelijke Model Architectuur (GEMMA) and Waterschap Informatie en Logisch Model Architectuur (WILMA), respectively the reference architectures for municipalities and water authorities of the Netherlands. The WILMA has the NORA and GEMMA as a starting point. Whenever components of the NORA or GEMMA are relevant to the WILMA, it will inherit these components. When an issue is sector-specific for the water authorities, information from the NORA or GEMMA will be further complemented or deepened, specific to the water authorities.

Other examples of related reference architectures can be found in the educational sector, which is part of the education and science domain. The educational sector has one special overarching reference architecture called the Referentie Onderwijs Sector Architectuur (ROSA). This reference architecture is a cross-educational chain reference architecture (onderwijsketen referentiearchitectuur), which focuses on components that are common in the whole educational sector (or multiple parts thereof) when it comes to collaboration in chain processes. The sector-specific reference architectures are called Funderend Onderwijs Referentie Architectuur (FORA), Middelbaar Onderwijs Referentie Architectuur (MORA) and Hoger Onderwijs Referentie Architectuur (HORA). The FORA is developed for the primary school (primair onderwijs, po) and secondary school (voortgezet onderwijs, vo). The MORA is developed for the vocational education (Middelbaar beroepsonderwijs, MBO). The HORA is developed for higher education (Hogescholen en universiteiten).

These related educational reference architectures should have explicit relationships with each other. This is needed as many components of these reference architectures can be reused or complemented by each other, which leads to reduced efforts for digital architects. When all reference architectures of the NORA family consistently use generic and commonly accepted components, this leads to improved consistency and efficiency in the delivery of public services.

As of the start of NORA as the first reference architecture, there is a continuous desire for improved coherence between reference architectures [10]. The coherence, if explicitly present, is currently only textually described and can be found on knowledge management platforms, such as WikiXL and on other websites and documents where reference architectures are described. For example, the ROSA has a page[2] on its WikiXL platform in which the coherence with other architectures is described. However, other reference architectures do not provide information about their coherence with other reference architectures.

At this moment, an advisory group of experts in the educational sector is working on improved coherence between the sector-specific and the cross-educational chain reference architectures. The three sector-specific reference architectures mentioned were independently developed from each other. The FORA, MORA and HORA are similar when it comes to providing a steering instrument for educational institutions to organise and structure their Enterprise Architecture. The ROSA, a cross-educational chain reference architecture, should function as a connector for all the sector-specific reference architectures. However, conflicting design decisions are made in these reference architectures, which makes it difficult to improve the coherence.

[2] ROSA, Samenhang met andere architecturen `https://rosa.wikixl.nl/index.php/Samenhang_met_andere_architecturen`

To conclude, there is a lack of coherence between reference architectures within the Dutch public sector. Furthermore, there is no collective approach on how to improve this coherence. Currently, relationships between components of reference architectures exist only implicitly. Hence, there is a desire for research on reference architectures within the Dutch public sector and how to improve the coherence between these reference architectures.

1.4 Research Objective

The objective of this research is to address the aforementioned problem. The main research objective is thus to design a method to improve the coherence between the reference architectures within the Dutch public sector.

1.4.1 Research Questions

The main research question that will guide this research is:

"How can a method be designed to improve the coherence between the reference architectures within the Dutch public sector?"

To answer the main research question, a couple of research questions first need to be answered.

- *RQ1 How can organisations in the public sector benefit from Enterprise Architecture?*

  Reference architectures play an important role in Enterprise Architecture by providing a structured approach based on best practices for designing and implementing concrete (enterprise) architectures. To explain the importance and benefits of reference architectures, the benefits of Enterprise Architecture for organisations in the public sector should first be examined. These benefits should be found in the literature. The answer to this research question aims to provide clarity on whether these types of organisations use Enterprise Architecture, and what the benefits are for them. Eventually, these benefits of EA for organisations in the public sector should be described and visualised in a theoretical model.

- *RQ2 How can reference architectures improve Enterprise Architecture practices?*

  Reference architectures can be perceived as blueprint Enterprise Architectures. The answer to this research question aims to provide clarity on the use of reference architectures for Enterprise Architecture and the potential benefits of these generic architectures. These benefits should be found in the literature. This is needed to understand how reference architectures can improve Enterprise Architecture practices in organisations.

- *RQ3 How is the architectural knowledge of reference architectures within the Dutch public sector organised and structured?*

  Reference architectures consist of architectural knowledge in the form of principles and architecture models. This knowledge needs to be organised and structured somewhere. Semantic wikis can be used for that, which are wikis with an underlying knowledge model that describes the information a wiki contains. Most of the reference architectures use a platform called WikiXL, which is a semantic wiki. By browsing through and searching in semantic wikis, digital architects can reuse architectural knowledge for their architectural purposes. The answer to this research question aims to explain how these semantic wikis can be used to organise and structure architectural knowledge of reference architectures and what their benefits are.

- *RQ4 What is the current state of coherence between reference architectures within the Dutch public sector?*

  The current state of coherence between reference architectures within the Dutch public sector should be examined. The answer to this research question aims to provide clarity regarding the definition of coherence between reference architectures, the desire for improved coherence and the problems of a lack of coherence. Through conducting a focus group and a survey with digital architects who have knowledge of and experience with reference architectures within the Dutch public sector, the current state of coherence can be examined.

- *RQ5 What types of relationships are desired between the reference architectures within the Dutch public sector?*

  One aspect of improving coherence between reference architectures within the Dutch public sector is by defining and establishing relationships between reference architectures. However, the desired types of relationships between reference architectures should first be known. These types of relationships should be investigated by conducting a focus group and a survey with digital architects who have knowledge of and experience with reference architectures within the Dutch public sector.

- *RQ6 What are existing methods and techniques for defining and establishing relationships between different architectures?*

  Existing methods and techniques for defining and establishing relationships between architectures should be found in the literature and by searching on the internet for existing practical applications. The answer to this research question is an overview of existing (practical) methods and techniques that can be used to define and establish relationships between reference architectures.

- *RQ7 How can a method be designed to define and establish relationships between reference architectures within the Dutch public sector?*

  A method should be designed to define and establish relationships between reference architectures. This method should include formal steps for defining the types of relationships between reference architectures as well as how to establish these relationships. This implies that the method should also consist of technical steps for establishing these relationships. The method should be a step-by-step guide for digital architects to define and establish relationships between components of reference architectures.

- *RQ8 Can the designed method effectively be used in practice, i.e. in the Dutch educational sector?*

  Finally, the educational sector can be used as an experimental context for validating the designed method. This sector seems suitable, as coherence between the reference architectures within this sector is highly desirable and an advisory group of experts is already working on improved coherence. The different sector-specific reference architectures should be related to each other to lower the borders for people changing their learning paths. Based on a case study in the educational sector, conducted by the researcher, the designed method can be validated.

1.5 Thesis outline

The thesis starts with the abstract. After that, chapter 1 introduces the research. Chapter 2 of the research presents the research design, which describes the research methodologies used throughout this research. Chapter 3 forms a theoretical background that serves as a foundation for the rest of the thesis. In this chapter research questions RQ1, RQ2 and RQ3 will be answered. It consists of two Systematic Literature Reviews and exploratory literature reviews.

Chapter 4 consists of an examination of the current state of coherence between reference architectures within the Dutch public sector. Also, the desired types of relationships between reference architectures are investigated. Moreover, existing methods and techniques for defining and establishing relationships between architectures are explored. The research questions RQ4, RQ5 and RQ6 will be answered in this chapter.

In chapter 5 the artefact of this research is designed, which is a method that can be used by digital architects to define and establish relationships between components of reference architectures. So, research question RQ7 will be answered in this chapter.

In chapter 6, a case study is conducted in the educational sector to validate the designed method. The last research question, RQ8, will be answered in this chapter.

Eventually, in chapter 7 and 8 the research results are discussed and a conclusion is drawn.
Lastly, the appendices and the references are presented. The complete outline of the thesis can be found in figure 1.1 below.

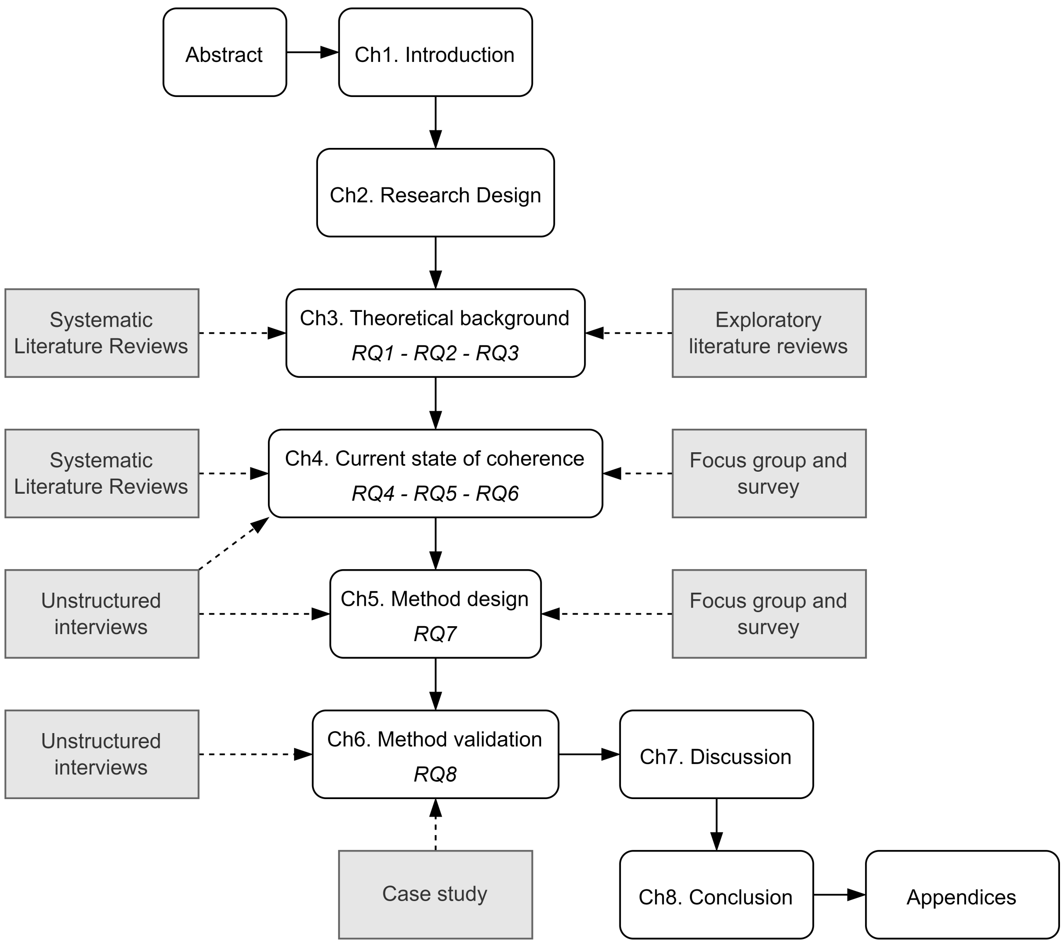


Figure 1.1: Thesis outline

Chapter 2

Research Design

This research attempts to design an artefact to improve the coherence between reference architectures within the Dutch public sector. To design the artefact, a suitable research methodology was first selected. This research followed the Design Science Methodology (DSM) proposed by Wieringa [1]. The Design Science Methodology describes how to solve design problems and answer knowledge questions.

In the problem investigation phase, the context of the problem was first understood, after which the actual problem was investigated. To gather knowledge on the research context, exploratory literature reviews and two Systematic Literature Reviews (SLRs) were conducted. The SLRs were conducted according to the guidelines of Kitchenham [11]. To gather knowledge about the actual research problem, a focus group was conducted with four architects who have knowledge of and experience with reference architectures within the Dutch public sector. The focus group data was analysed according to a framework of Nili et al [2]. To validate and complement the findings of the focus group, survey research was conducted. The survey was meant for digital architects who have knowledge of and experience with reference architectures within the Dutch public sector.

In the treatment design phase, the artefact of this research was designed. The artefact of this research is a method. To design the method, the findings of the focus group, survey and unstructured interviews were used. A part of the focus group and survey was focused on the desired relationships between reference architectures. The unstructured interviews were used to steer the design of the method. One aspect of improving coherence between reference architectures is realising relationships between reference architectures. The method is therefore a step-by-step guide that can be used by digital architects to define and establish relationships between components of reference architectures.

Lastly, in the treatment validation phase, a case study was conducted in which the researcher used the method to define and establish relationships between components of reference architectures in the educational sector. Advisory documents from an expert group working on improved coherence in the educational sector were used and unstructured interviews were conducted with two digital architects having knowledge of and experience with the FORA and the ROSA.

2.1 Design Science Methodology

Design Science is the design and investigation of artefacts in context, whereby the artefact is something to be designed and the given context is something to be influenced. Wieringa [1] designed a methodology that guides researchers in design science. This methodology is the so-called 'Design Science Methodology (DSM)' and is a proven methodology for conducting design science research in information systems research. The artefact to be designed should interact with the problem context to improve something in that context. The design of an artefact is seen as a design problem for improving a problem context to help stakeholders achieve their goals.

To solve such a design problem, an iterative process known as the design cycle can be used. The design cycle of DSM provides guidelines for researching an artefact in a context. Such an artefact may be a method, technique or algorithm. The design cycle is part of a larger cycle, the engineering cycle. However, for the scope of this research, only the phases of the design cycle are considered. The design cycle is decomposed into three phases, namely, problem investigation, treatment design and treatment validation. The design cycle can be found in figure 2.1.

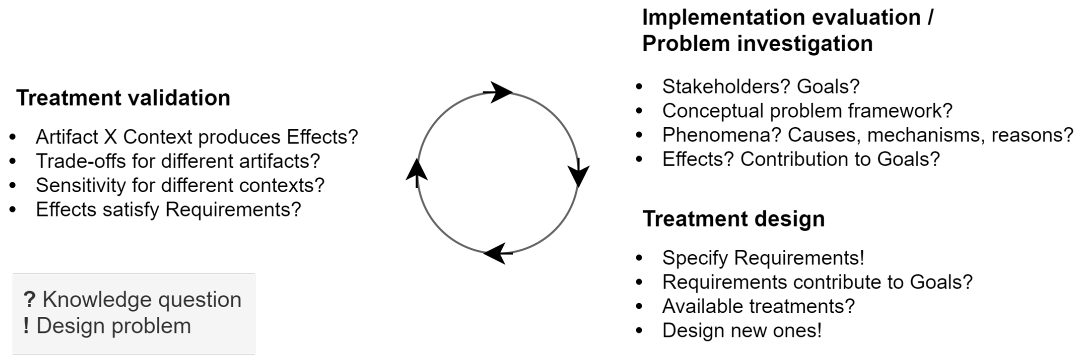


Figure 2.1: Design Cycle from Wieringa [1]

To apply the design cycle within this research, the three phases are explained below:

1. **Problem investigation**: The goal of the problem investigation phase is to understand the problem. The research goal is to improve a problematic situation, and the first task is to identify, describe, explain and evaluate the problem to be treated. In this research, the problem investigation was executed by first understanding the context of the problem. To achieve this, multiple literature reviews 2.2 were conducted to understand the research topics. The results of these literature reviews are documented in chapter 3. To understand the actual problem, the current state of coherence between reference architectures was investigated by conducting several unstructured interviews with digital architects 2.3, conducting a focus group 2.4 with digital architects and conducting a survey 2.5 completed by 40 digital architects. The digital architects all have knowledge of and experience with reference architectures within the Dutch public sector. The problem investigation phase of the design cycle is documented in chapters 3 and 4.

2. **Treatment design**: The goal of the treatment design phase is to define the requirements of the artefact and to design the artefact. In this research, the artefact to be designed is a method to guide digital architects in defining and establishing relationships between components of reference architectures. The method consists of formal steps for defining relationships as well as technical steps to establish relationships between components of reference architectures. These components are ArchiMate elements, published on semantic wikis. So, the established relationships are between multiple ArchiMate elements. With knowledge from unstructured interviews, a focus group and a survey, a method was designed. The design of the method is documented in chapter 5.

3. **Treatment validation**: The goal of the treatment validation phase is to validate that the method contributes to stakeholder goals in the problem context. This was done by conducting a case study 2.6 in the educational sector. In this case study, the method was used by the researcher and a concise prototype was developed. To follow the method, several advisory documents were consulted and unstructured interviews were conducted. A small number of relationships between ArchiMate elements of different reference architectures in the educational sector were established in a data model. Eventually, this data model was published on a triple store, which

can be queried by wiki pages on the WikiXL platform to retrieve relevant additional information about an ArchiMate element. The results of the case study are presented in chapter 6.

2.2 Literature reviews

To understand the context of the problem, literature reviews were conducted. To study the available literature, both exploratory literature reviews and two Systematic Literature Reviews were conducted.

2.2.1 Exploratory literature review

An exploratory literature review aims to get a general feel of a research topic. For this research, the used concepts must be understood to properly work with them. Keywords such as ”architecture”, ”Enterprise Architecture”, ”reference architecture” and ”referentiearchitectuur”, ”Reference Model” and ”Enterprise Reference Architecture” were used to find relevant research papers about the concepts. Google Scholar was used to search for research papers. The research papers with the most citations were chosen to get information when searching for a keyword.

2.2.2 Systematic Literature Review

To conduct the Systematic Literature Reviews, the guidelines of Kitchenham were used [11]. One reason Kitchenham mentioned for performing an Systematic Literature Review (SLR) is to summarise the existing evidence concerning a treatment or technology. In this case, the existing evidence in the literature on the benefits of Enterprise Architecture for public organisations is summarised. This way, important knowledge within the literature can be taken into account in this research. The importance of systematic literature reviews is outlined in the quote of Richard Hamming of 1968 and reads:

”Systematic literature reviews in all disciplines allow us to stand on the shoulders of giants and in computing, allow us to get off each others’ feet.”

With the guidelines of Kitchenham, I aim to identify, evaluate and interpret all available research papers relevant to the first two research questions. The three main phases of a SLR are *planning the review*, *conducting the review* and *reporting the review*. In the first phase, a search protocol was developed. In the second phase, the complete process of searching for research papers and selecting them was documented. In the last phase, the results of the selected papers were documented.

2.3 Unstructured interviews

At the start of the research project, many interviews were conducted with digital architects working in the Dutch public sector. These interviews were the basis for identifying the actual problem. However, no documentation was made of these. The interviews can be seen as ’unstructured interviews’ as many questions were asked about the research problem and solution directions. Because no documentation was made of these interviews, it can not be classified as a research method but it has steered the research in a specific direction.

2.4 Focus group

Focus groups are a social method to gather research data through group discussions on a specific topic [2]. In contrast to other research methods, such as interviews and surveys, the interactive and synchronous group aspect of focus groups allows participants to discuss, (dis)agree with and build upon each other’s ideas. The Enterprise Architecture research domain, part of Information Systems (IS) research, has numerous examples of studies that include focus groups as (one of) the research method(s). The multi-disciplinary characteristics and social aspect of IS research suggest that various IS studies can benefit from focus group data. The data may include verbal and non-verbal data and interaction data. In the context of this research, the decision was made to include verbal and interaction data, as the voices of the participants were recorded.

A Focus group is an extended way of the interview method. It is a more specific and in-depth group interview that brings about a group discussion. Through this interactive group discussion, often more in-depth and richer data can be generated [12]. With the help of a moderator, the selected topics can be explored in a structured and organised way. The focus group was held at the beginning of this research project and the structure of it can be found in section 4.1. The findings of the focus group are used throughout this research.

2.4.1 Data analysis

The focus group was analysed according to the Focus Group Data Analysis Framework (FGDAF). Nili et al. [2] provides a systematic and integrative approach for qualitatively analysing different types of focus group data for the Information Systems domain. However, first, the type of data that should be captured was selected. After that, the data should be captured by an audio recorder. Eventually, a transcript should be written of the complete audio recording. To analyse the transcript of the focus group data, the FGDAF had been partially used, which will be explained in section 2.4.2.

Types of data

According to Nili et al. [2], there are two primary data types, content data and interaction data. These types can be further divided into verbal and non-verbal data. The non-verbal can further be divided into multiple data types. For this focus group, the blue marked cells, indicating the type of data, were used during the data analysis. The verbal data was necessary to analyse to follow the discussion and to gather insights from the discussion. Next to the verbal data, the paralinguistic data was taken into account. An overview of the types of data that were analysed can be seen in figure 2.2.

Raw audio recording

The focus group data was originally an audio recording with the voices of the moderator and the participants during the focus group.

Transcript

With the help of multiple AI tools, a concept of the transcript of the audio recording was generated. However, this transcript did not match the actual data. So, after completely listening to the audio recording, the complete transcript of the focus group was written. This included the verbal data of the categories 'content data' and 'interaction data', as well as the tone and strength of statements (paralinguistic data). The paralinguistic data was indicated by exclamation marks and bold text in the transcript.

2.4.2 The Focus Group Data Analysis Framework

In this section, the Focus Group Data Analysis Framework (FGDAF) and its usability in the data analysis process are presented. In figure 2.3 the steps of the framework can be seen. Not all types of data were analysed, so some of the steps of the framework were partially executed. After explaining all the steps, the complete process of analysing the focus group data is presented in the Business Process Modelling Notation (BPMN) model in figure 2.4.

Step 1: Determine and organise theoretically sensitive data

This step involves identifying the types of data that are relevant to the research question and organising them in a way that facilitates analysis. For this focus group, the types of data marked in blue in figure 2.2 are relevant to the research questions. After that, a format was created in which the transcript of the focus group can be structured. One example of this format can be found in table E.1 in Appendix E.

Types of data			Example
Content data	Verbal		Any participant comment or expression in the form of words and/or sentences that can be taken at face value and does not require knowledge of any conversation/interaction that it may be embedded in.
	Non-verbal	Kinesic	* Bending down the whole body (showing shame); * Hanging head on chest (showing sadness); * Showing the extent or magnitude of something with hands.
		Proxemic	* Guard oneself, looking around, or opening hands (to express how a person feels about their personal space).
		Paralinguistic	* Loudness, tempo, or pitch fluctuation, to show the level of a participant's emphasis, or the extent that they believe in something.
		Choronemic	* A long period of silence, possibly indicating the participant does not have a ready answer, or is deeply thinking on an issue.
Interaction data	Verbal		Any participant's response, comment, or expression, to one or more people in the form of words and/or sentences.
	Non-verbal	Kinesic	* Clapping hands after hearing a well-considered response; * Expanding chest with head erect, possibly indicating a show of aggression towards a comment.
		Proxemic	* Getting close to a person to show friendship or affection.
		Paralinguistic	* Fluctuating pitch or changing the loudness of voice to remind a member of a group about something or to offer a clue.
		Choronemic	* Silence, which could express any of: a feeling of being treated disrespectfully, a desire to avoid intimacy, or to avoid disclosing any information in relation to a personal question.

Figure 2.2: Used types of focus group data, adapted from Nili et al. [2]

1. Determine and organize theoretically sensitive types of data	
2. Identify content areas	
In each content area	3. Conduct a manifest analysis of content data
	4. Conduct a latent analysis of content data
	5. Analyze interaction data
	6. Integrate the results in each content area (integrate the results obtained through steps 3 to 5)
7. Integrate and report the results of all previous steps for all content areas	

Figure 2.3: The focus group data analysis framework, adapted from Nili et al. [2]

Step 2: Identify content areas

In this step, the entire focus group transcript was read twice to gain a sense of the whole. After that, content areas (parts of the text that are directly related to each other) were identified. By analysing the answers and discussions related to the specific questions, the transcript was transformed into content areas. The content areas that were identified are: ’Definition of coherence’, ’Current state of coherence’, ’Desire for improved coherence’, ’Current problems’ and ’Desired relationships between reference architectures’.

Step 3: Conduct a manifest analysis of content data

In the third step, each content area was separately analysed and the main statements of the transcript corresponding to that content area were placed in the spreadsheet with data analysis results.
This step included the following sub-steps:

- Identify the meaning units in the manifest content of each content area and condense them into a description close to the original statement in the transcript.
- Name each of these condensed meaning units with a code.
- Sort the codes into subcategories based on their similarities. Name each of the subcategories with a name that represents its content. Organise the subcategories and apply an overarching category to them. Similarly, name each category with a name that represents its subcategories. This was an iterative process.
- Express the overall interpretation of the underlying meaning of all categories in each content area via one theme.

Step 4: Conduct a latent analysis of content data

After conducting the manifest analysis of the data, the latent analysis of the data was conducted. A deeper understanding of the statements was retrieved and described in the spreadsheet with data analysis results.
This step included the following sub-steps:

- Identify the meaning units in the latent content of each content area and condense them into a description close to the content area's original text.
- Concisely write the interpretation of each of these condensed meaning units.
- Lastly, the results of the previous steps are integrated into a table.

Step 5: Analyse interaction data

This step was already included in the first step, by structuring the statements of the moderator and participants into an organised format. Within this format, the interaction between the moderator and participants(s) became clear. Phrases such as ”To all participants” and ”To P4” and chronology were applied to the format.

Step 6: Integrate the results in each content area

The sixth step was about integrating the results of the manifest and latent analysis. So, integrate all (sub-)categories and themes into a whole. The result was a spreadsheet with all analysis results, consisting of two themes, five categories and 14 sub-categories.
These analysis results can be found in Appendix E tables E.2 and E.3.

Step 7: Integrate and report the results of all content areas

In the final step, the results of the focus group were summarised in a textual document called 'Bevindingen focusgroep'. Next to this document, an ArchiMate view presenting the concise findings of the focus group was developed.

2.5 Survey

Forming conclusions about the desires of the whole architecture community solely based on the focus group data was not feasible. Consequently, it was essential to gather the opinions of a larger group of digital architects working within the Dutch public sector to derive meaningful insights.

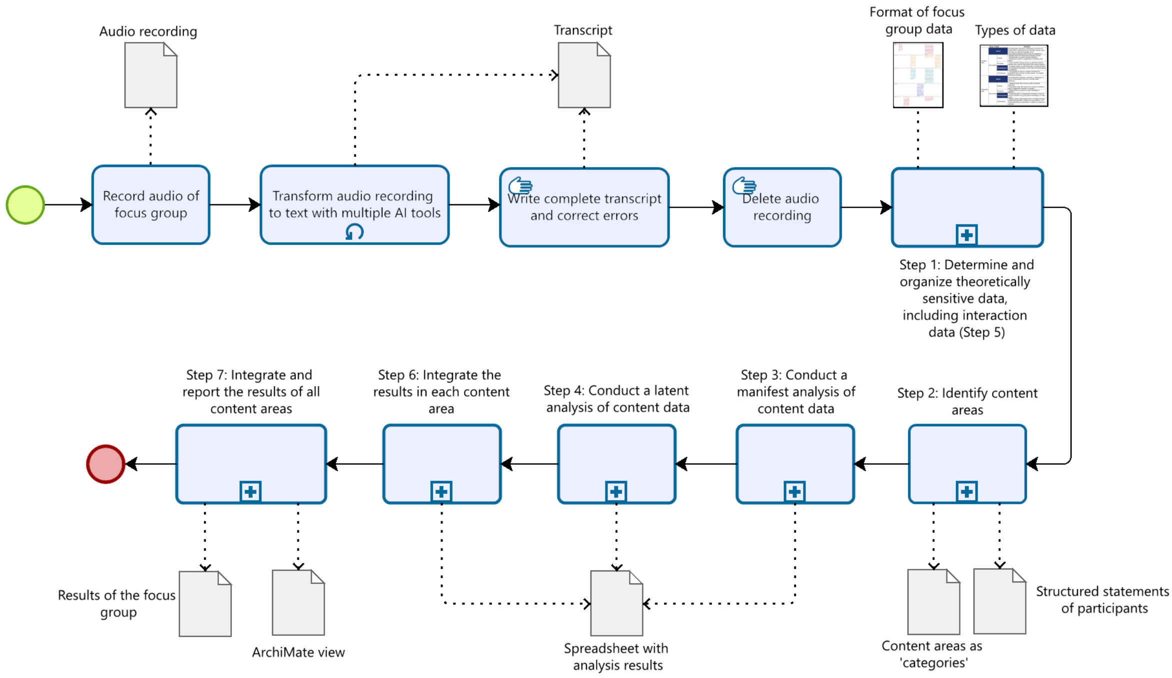


Figure 2.4: The focus group data analysis process (in BPMN)

These opinions were gathered by conducting a survey. The survey was built with a tool called Qualtrics[1], which the BMS faculty of the University of Twente offered. This tool offers a diverse range of question types. The types of questions that were chosen for this survey are: 'multiple choice', 'text entry', 'form field' and 'matrix table'. In total, the survey contained 12 questions, which can be found in Appendix G.

The survey's purpose was twofold, on one hand, the focus group data should be validated and on the other hand, complemented. The questions of the survey ask for both quantitative and qualitative data. The quantitative data was derived from the judgements of digital architects about the focus group data. These judgements are about the stakeholders of the problem of a lack of coherence between reference architectures, the problems at hand and the drivers for improved coherence. The qualitative data was derived from asking the participants to come up with extra stakeholders, problems and drivers. Lastly, the participants were asked to provide desired relationships between components of reference architectures.

2.6 Case study

Given the scope of this research, it is worth highlighting that the treatment implementation phase of the design cycle, outlined by Wieringa [1], will not be conducted. However, the most effective approach to validate the research outcomes lies in their real-world implementation. This provides insights from the users who would be actively applying the designed method. To simulate this implementation, a qualitative case study was undertaken to assess the artefact within its problem context. Baxter and Jack [13] highlight that a qualitative case study is useful for exploring phenomena within the problem context.

According to Baxter and Jack [13], the initial step in conducting a qualitative case study involves determining the case. This case must be bounded to ensure it remains focused and does not have a scope that is too broad. The case that is used in this research is that of defining and establishing relationships between reference architectures in the educational sector. Currently, an advisory group

[1] Qualtrics for the University of Twente, `https://utwentebs.eu.qualtrics.com/`

is working on improved coherence between the educational reference architectures. This group consists of digital architects who have contributed to (one of) the educational reference architectures. The advisory documents and agreements of this advisory group were used by the researcher to conduct the case study.

To conduct the case study, the researcher used the designed method to define and establish some relationships between ArchiMate elements of reference architectures in the educational sector. The types of relationships were already defined by the advisory group or by the experts who have contributed to the educational reference architectures ROSA and FORA. These relationships are triples that were established in a data model, which was published on a triple store. The relationships were queried from wiki pages of the semantic wikis of reference architectures. So, the additional information about the relationships of components of reference architectures became visible to stakeholders browsing the semantic wikis.

2.7 Summary

To summarise the research design chapter, a schematic overview was developed. This overview can be found in figure 2.5 below. In the overview, one can see which research questions belong to which phase of the design cycle of Wieringa [1] and which research methods are used. Furthermore, the research questions that correspond to the three phases of the design cycle are included.

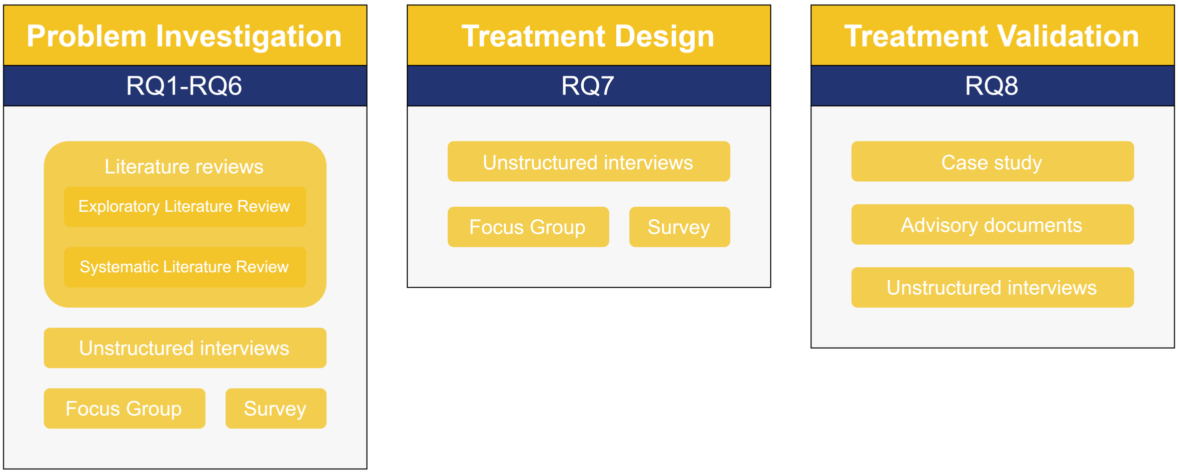


Figure 2.5: Research design

Chapter 3

Theoretical Knowledge

In this chapter, first, a theoretical background is provided about the research context. After that, the benefits of Enterprise Architecture (EA) for organisations in the public sector are investigated. After that, the benefits of using reference architectures for EA practices are investigated. Lastly, the use of semantic wikis for organising and structuring architectural knowledge of reference architectures is explored. The findings are based on systematic and exploratory literature reviews.

In section 3.1, several concepts that are used in this research are explained and the definitions of these concepts are given. In sections 3.2 and 3.3, the results of the two systematic literature reviews are presented. The first systematic literature review resulted in a theoretical model with benefits of Enterprise Architecture for organisations in the public sector. The second systematic literature review resulted in a list of benefits of using reference architectures for EA practices. In section 3.4, semantic wikis are explained and how these can be useful for reference architectures. These wikis are used to organise and structure architectural knowledge of most of the reference architectures within the Dutch public sector. The results are based on an exploratory literature review and knowledge of reference architectures.

3.1 Background

This section provides a theoretical background that was gathered to understand the different concepts used throughout this research. The knowledge was retrieved during an exploratory literature review. Keywords such as ”architecture”, ”Enterprise Architecture”, ”reference architecture” and ”referentiearchitectuur”, ”Reference Model” and ”Enterprise Reference Architecture” were used to find relevant research papers about the concepts. Google Scholar is used to search for research papers. In the first section the concept ’architecture’ is discussed. Secondly, the background of the field of ’Enterprise Architecture’ is described. Third, the concept ’reference architecture’ is discussed. Fourthly, ’Reference Model’ and the relationship with reference architectures are explained. Finally, we delve into the concept of ’Enterprise Reference Architecture’, which is less frequently used in literature.

3.1.1 Architecture

The term architecture has been known in the context of construction engineering for a long time, however in the IT context it is also widely used. Architecture in IT can be defined as the fundamental concept or properties of a system in its environment embodied in its elements, relationships, and in the principles of its design and evolution. This definition comes from the ISO/IEC/IEEE 42010:2011 [14] standard which addresses the creation, analysis and sustainment of architectures of systems through the use of architecture descriptions. Architecture Descriptions are briefly the documents that express an architecture. A concise definition of architecture is a ”structure with a vision”. The Open Group elaborates on the definition of ISO/IEC/IEEE and defines it as: 1. a formal description of a system, or detailed plan of the system at component level to guide its implementation; 2. The structure of components, their interrelationships, and the principles and guidelines governing their design and evolution over time [15]. The Open Group uses this definition in the context of the The Open Group Architecture Framework (TOGAF) standard, which is an architecture framework. This architecture framework comprises methods and tools for assisting in the acceptance, production, use, and maintenance of an Enterprise Architecture [15]. This concept will be further elaborated upon in the next section.

3.1.2 Enterprise Architecture (EA)

The enterprise engineering discipline views enterprises as a whole and considers them as purposefully designed systems that can be adapted and redesigned in a systematic and controlled way. Enterprise Architecture (EA) can therefore be defined as a coherent whole of principles, methods and models that are used in the design and realisation of an enterprise's organisational structure, business processes, information systems and infrastructure [16]. An enterprise is any set of organisation(s) that has common goals and/or a single 'bottom line'.

EA provides the blueprint for systematically defining an organisation's current and future environments, integrated with a process for development and maintenance. EA as a key planning discipline guides and optimises an organisation's IT investments and translates business strategies into implementable technology solutions [17]. EA can be considered as three different things, namely a discipline in which changes in organisations are steered. It can be considered as a design product, which shows the coherence between products, processes, organisation(s), information provision and infrastructure. And lastly, it can be considered as a process, in which it is viewed as a 'way of working'. The most important characteristic of an EA is that it provides a holistic view on the enterprise. This characteristic points to one of the most important roles of an EA: it serves as an instrument in the communication among diverse groups and interests and provides a common ground for discussion and decision-making [17].

The EA research domain originated after the publication of the Zachman framework developed by John Zachman in 1987 [18]. According to Zachman [19], it is necessary to use some architecture for defining and controlling the interfaces and the integration of all of the components of a system, as information systems are increasing in size and complexity. Throughout the years, the Zachman framework has been revised a couple of times. As mentioned, the first published and original version, appeared in the 1987 IBM Systems Journal. The latest version was established in 2011 and is referred to as an Enterprise ontology. The ontology is a complete set of all the elements that should exist in an Enterprise.

After the Zachman Framework was published, the application of EA practices followed shortly. Richardson, Jackson and Dickson [20] reported in 1990 the emerging Enterprise Information Technology Architecture for a new joint venture. The paper brought two contributions, namely the identification of principles upon which the architecture is being developed and a review of the learning process of implementing the architecture.

Furthermore, different stakeholders can use different perspectives of Enterprise Architecture to look at a certain Enterprise. There is a distinction made between stakeholders, their viewpoints, their views, and their concerns. In the ISO/IEC/IEEE 42010 standard [14] these concepts are clearly defined together with the relationships between these concepts. The stakeholder has one or more concerns about a system. This results in a perspective on the system of interest, which is called the viewpoint. The view is the representation of the system from a certain perspective, i.e. viewpoint. The conceptual model is represented in figure 3.1.

In current research, not only the Zachman Framework appears as an EA framework. Other important frameworks are for example TOGAF [15] and the Federal Enterprise Architecture Framework (FEAF) [21]. Most of the EA frameworks in the industry are methodologies derived from the Zachman Framework, however in the Zachman Framework itself clearly no methodological implications are provided.

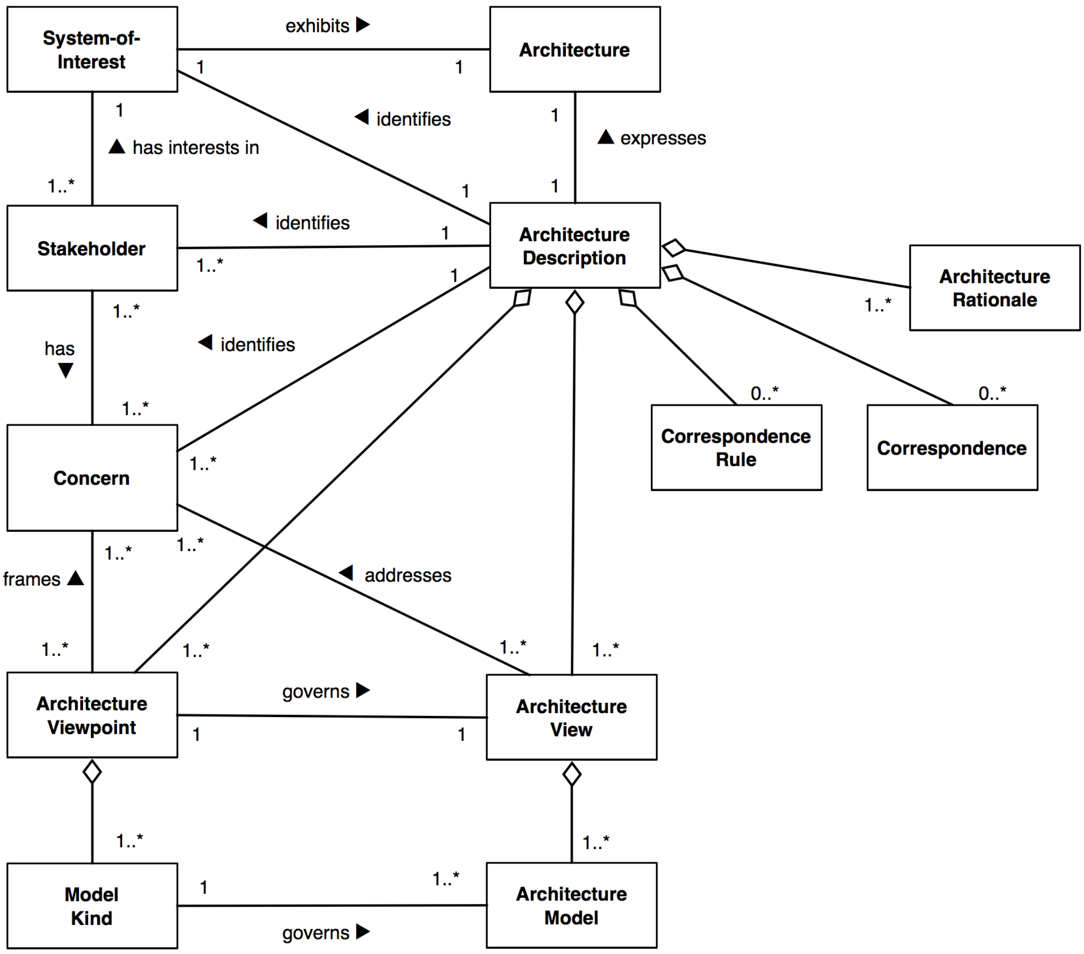


Figure 3.1: A conceptual model of Architecture Description - ISO/IEC/IEEE 42010

More recently, ArchiMate as an EA modelling language and framework classification scheme has arisen. Within this modelling language, EA representations can be developed in which concepts from three architecture layers are distinguished: Business architecture, Application architecture and Technology architecture [3]. The initial motivation for the adoption of ArchiMate was as follows: to mobilise the EA practitioners to design EA models for the three partial architectures in a service-oriented way in a formal language that is understandable and readable for all architects. The core layers (business, application and technology) form the ArchiMate core framework, which is illustrated in a simplified meta-model in figure 3.2. The core layers can be extended by the motivation layer, implementation & migration layer, strategy layer and physical layer.
For about the last 35 years, EA has evolved and matured leading to the emergence of several studies, conferences, frameworks and training programs. Even though the EA research domain is relatively new, there are currently 5200 documents found on Enterprise Architecture in Scopus, which means the domain has become mature over the years.

3.1.3 Reference architecture

The fast increase and diversification of architecture models over time have led to a broad and somewhat divergent set of interpretations and conceptualisations of the concept of reference architecture. When terms such as ”Enterprise Architecture”, ”reference architecture”, ”Reference Enterprise Architecture” and ”Enterprise Reference Architecture” tend to be used interchangeably in the literature, it becomes even more indeterminate. According to [22] there is a lack of maturity of the term ”reference architecture”, since the form that it takes is not solidified, and has become a term to mean many things to different people either within the same industry or not. In a general sense, a reference

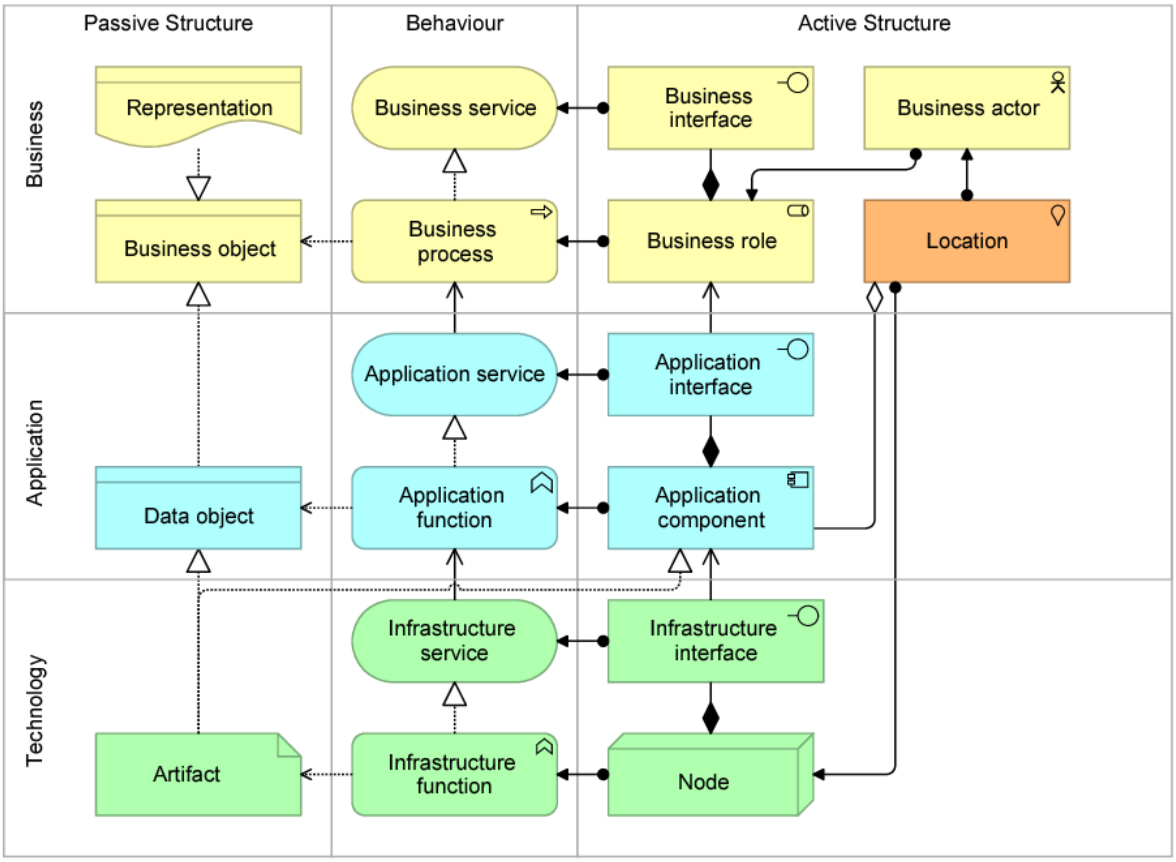


Figure 3.2: Simplified ArchiMate meta-model [3]

architecture can be seen as an abstract and generic architecture description for a class of systems or a concrete targeted domain. Reference architectures emerge as abstractions of concrete solution architectures from a certain class of systems used as a foundation for the design of concrete architectures from this class, although their generic nature leads to a less defined architecture design and application contexts [9].

It becomes clear from the literature that there are reference architectures for an architecture for a particular domain, whereas there is a distinction between a Software Architecture (SA) and an Enterprise Architecture. For both cases, the reference architecture provides a template solution for architecture (respectively software – or Enterprise Architecture) for a particular domain. A reference architecture also provides a common vocabulary with which to discuss implementations, often with the aim of stressing commonality. The reference architecture concept is less investigated in the Enterprise Reference Architecture (ERA) field than in Software Reference Architecture (SRA). The definition of the SRA is a generic software architecture for a class of software systems that is used as a foundation for the design of concrete architectures of systems from this class [23]. A concrete architecture is the architectural description document of a concrete software system. Throughout this research, the concept reference architecture will only be referred to as an Enterprise Reference Architecture, instead of a Software Reference Architecture.

3.1.4 Reference Model

Reference Models (RMs) can be defined as the core building blocks of a reference architecture, as they provide a clear view of the domain of interest of the reference architecture incorporating best-practice solutions as reusable knowledge that can be later adjusted or tweaked for context-specific needs [9]. However, Reference Model (RM)s are not always part of a reference architecture. In those cases, the RM exists independently and works autonomously. Reference Models can also be referred to as model patterns. One could argue that every (partial) model that can be used to support the development of another model can be seen, in this sense, as a reference model.

3.1.5 Enterprise Reference Architecture

The definition of an Enterprise Reference Architecture is a generic EA for a class of enterprises, that is a coherent whole of EA design principles, methods and models which are used as a foundation in the design and realisation of the concrete EA that consists of three coherent partial architectures: the business architecture, the application architecture and the technology architecture [4]. To visualise the definition of an ERA, a conceptual model is provided, which can be found in figure 3.3.

In Dutch, the term Enterprise Reference Architecture does not occur, only that of reference architecture (Dutch: referentiearchitectuur). Because of this, and because of the comprehensive definition of reference architecture earlier given, the following definition will be used throughout this research. This definition reads: "A reference architecture is a generic architecture for a class of systems that is used as a foundation for the design of concrete architectures from this class." [9] So, when the term reference architecture is used, also the term Enterprise Reference Architecture is meant in this research.

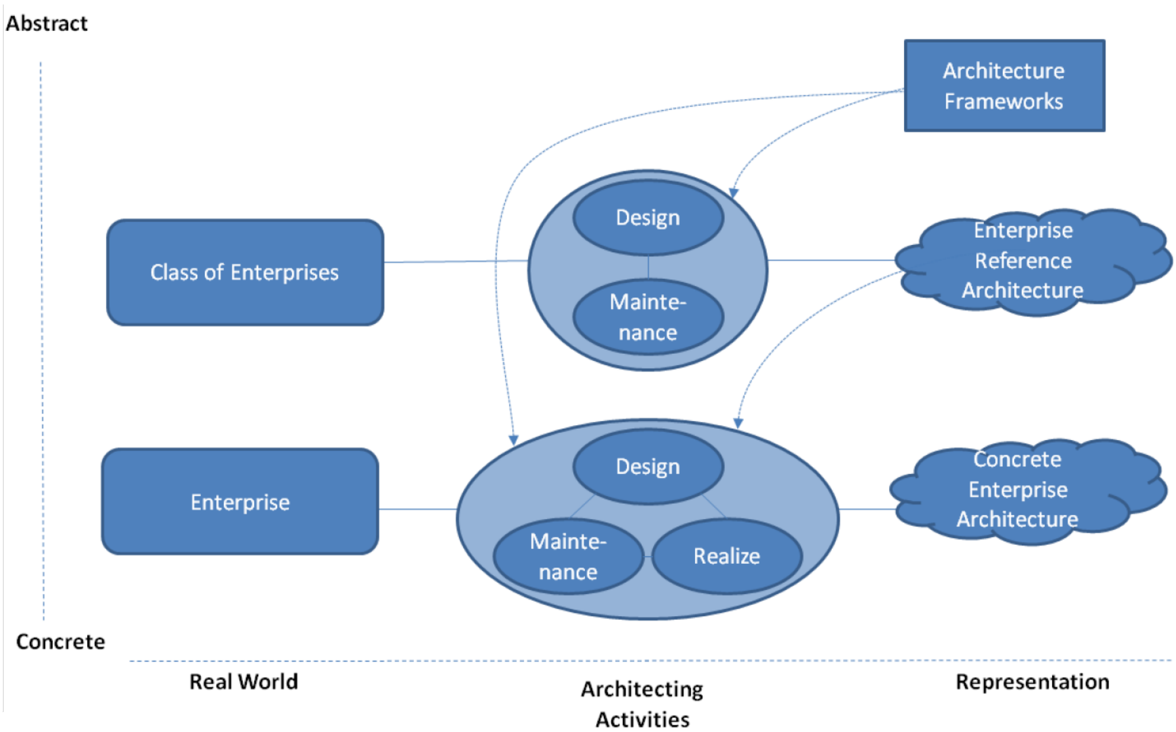


Figure 3.3: Conceptual model for reference architectures, adapted from [4]

3.2 Enterprise Architecture benefits for the public sector

In this section, the benefits of Enterprise Architecture for organisations in the public sector are described. The benefits are based on the found research papers in a Systematic Literature Review (SLR). The corresponding research question (RQ1) is: "How can organisations in the public sector benefit from Enterprise Architecture?". The SLR will follow the phases described by Kitchenham [11], which are *planning the review*, *conducting the review* and *reporting the review*. The following sections provide further elaboration on the steps associated with each phase.

3.2.1 Planning the review

Before conducting a SLR, a review protocol should be developed. The development of the review protocols for both SLRs was based on the adoption of the following methods from Kitchenham [11]:

- The search query is appropriately derived from the research question.
- The data to be extracted will properly address the research question.
- The data analysis procedure is appropriate to answer the research questions.

3.2.2 Conducting the review

In this section, the documentation of the execution of the first SLR can be found. A complete visualisation of the process can be found in Appendix A figure A.1.

Search Strategy

The first step in conducting a SLR is defining a search strategy. The goal of the first SLR is to find primary studies with the main topic being EA benefits for organisations in the public sector. To find relevant papers, I made use of the following digital libraries: Scopus, Web of Science, IEEE Xplore and ACM. The digital libraries contain mainly (peer-reviewed) publications from significant journals and conferences. I assume that this set of digital libraries ensures sufficient coverage of the Enterprise Architecture research domain because Scopus and Web of Science are considered the two most extensive digital libraries [24]. Furthermore, I used Google Scholar and FindUT to retrieve PDF formats of the research papers.

To search within the digital libraries, some choices need to be made about the search parameters. By applying an iterated search approach I defined the search parameters per digital library, which can be found in table 3.1. These search parameters are based on the amount of relevant documents that were found in a digital library and the options that were available within these libraries.

Digital Libraries	**Search Parameters**
Scopus	[title — abstract — keyword]
Web of Science	[topic]
IEEE Xplore	[title — abstract — keyword]
ACM	[abstract]

Table 3.1: SLR1 and SLR2 search parameters

In order to answer RQ1: "How can organisations in the public sector benefit from Enterprise Architecture?" a specific search query is constructed. A search query is nothing more than a series of keywords together with a couple of operators and probably wildcards (AND, OR, * and ?). In order to develop a search query, I have evaluated a series of keywords using synonyms from a thesaurus[1]. The "AND" operator is used to ensure that in the searches, there is a connection between Enterprise Architecture, benefits and governmental organisations or organisations in the public sector. The "OR"

[1] Thesaurus, `www.thesaurus.com`

operator was used for the synonyms of the word ”benefit” to increase the variety of search results. Eventually, the focus of the research will be on the whole public sector in the Netherlands, so I choose to include ”public sector” and ”government” as keywords. The search query that was used is stated below.

”Enterprise Architecture” AND government OR “public sector” AND benefit OR improvement OR profit OR gain OR advancement OR advantage OR success OR value OR contribution OR valuation OR effectiveness

When using this search query in the four digital libraries resulted in 401 found documents. The execution of the search query was on the 26th of April 2023. Publications after that date are not taken into account. The number of publications per year in the most comprehensive digital library Scopus can be found in figure 3.4.

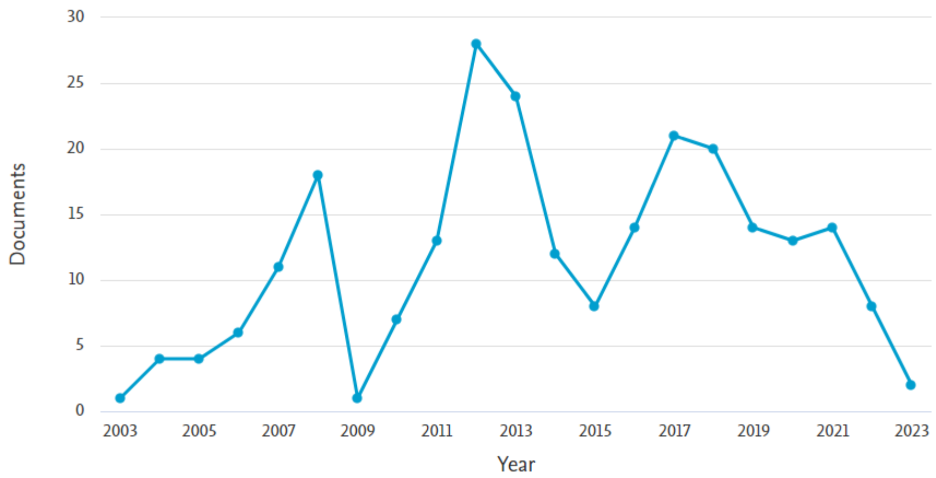


Figure 3.4: Publications per year in Scopus of SLR1 (2003-2023)

As can be seen from figure 3.4, the first publication on the topic was in 2003. After that, there are steep increases in publications visible from 2006 to 2008, from 2009 to 2012 and from 2015 to 2017. In 2009, again only one document was published, which is noteworthy. In the years 2012 and 2013, most of the publications occurred. From the graph, it can be concluded that from 2008 until 2021 (with 2009, 2010 and 2015 as outliers) researchers found the topic highly relevant. Because of this and because of the fact that older publications discuss obsolete issues, publications before 2008 are not taken into account. Currently, the research topic has experienced a slight decrease in popularity. This analysis is done with some cautiousness, as the figure only shows the number of publications available in Scopus and the publications partly related to the ’topic’ are also included, since no selection procedure was yet conducted.

Study selection process

The study selection process of the SLR consists of a couple of steps, namely: removing duplicates, filtering on document type, reviewing the papers on title and abstract, applying the in- and exclusion criteria, applying the forward and backward snowballing technique and critically reviewing the papers. I have made use of Zotero, a reference management tool, in which the different reference sets could be stored and altered.

First, the duplicate items were removed (Step I). This was still a manual operation, as all duplicate items could be merged with each other by a single click. This action resulted in a remaining set of 232 papers.

Filtering the set of papers on document type was the second step and resulted in a remaining set of 214 documents, which were only journal articles, conference papers and book chapters (Step II). The distribution of journal articles, conference papers and book chapters can be seen in figure 3.5. This figure reveals a substantial presence of 146 conference papers (68%), a smaller number of 45 journal articles (21%), and a limited number of 23 book chapters (11%).

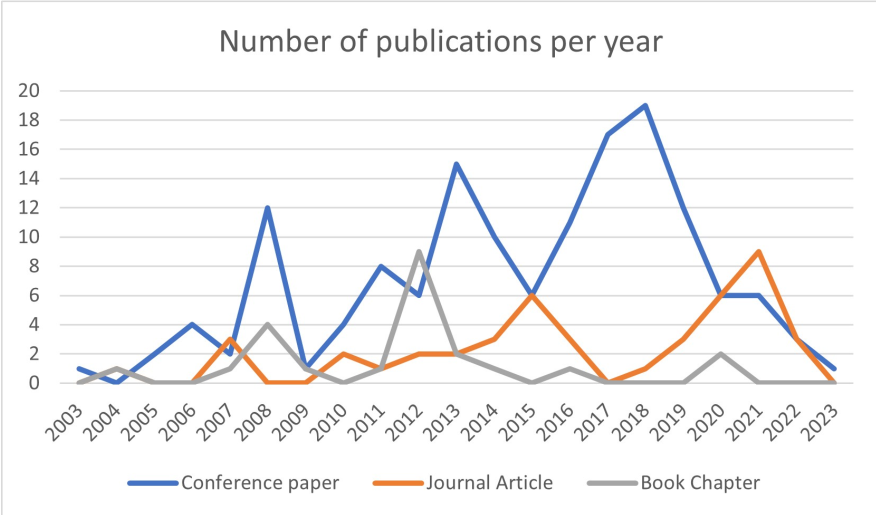


Figure 3.5: Distribution of document types of SLR1 (2003-2023)

From this moment, the papers were reviewed by reading the title and abstract of every paper (step III). This action resulted in 71 papers that were in the remaining set of papers. The reasons for exclusion, based on the title and abstract of the paper, are stated in table 3.2

Reason for exclusion	Excluded papers
Irrelevant, other research topic	114
Irrelevant, public sector context is missing	29
Total	**143**

Table 3.2: Reviewing the papers on title and abstract for SLR1 (step III)

These 71 papers were further reviewed, by applying the in- and exclusion criteria. The criterion IC1 was applied by skimming the full text of the research papers and searching for the words ”Enterprise Architecture”, ”public sector” and ”benefit” and the chosen synonyms. This way, not the full text had to be read, which fastened the process. All inclusion criteria were also used in an opposite way, as exclusion criteria. For example, papers written in another language than English (IC2) were excluded. Next to the language, I checked on the document type and whether these were published in a journal, conference or book (IC3). The in- and exclusion criteria can be found below.

- **Inclusion criteria**
  - IC1 The paper relates to the research interest, i.e. it addresses the information on the interest of the research questions.
  - IC2 The paper is written in English.
  - IC3 The paper was published in a journal, conference or book.
- **Exclusion criteria**
  - EC1 Non-studies, e.g. introduction texts for conference proceedings or introductions of books.
  - EC2 There is no access available to the paper.

– EC3 The paper was published before 2008.
– EC4 The paper discusses Enterprise Architecture benefits as a side topic.

Fourthly, the first three exclusion criteria (EC1-EC3) were applied, which was a relatively simple step and finished before applying the fourth exclusion criterion (step IV). To further elaborate on this step, the number of papers that were excluded based on these three criteria are stated in table 3.3.

Exclusion Criteria	Excluded papers
EC1: There is no access to the paper	17
EC2: Non-studies, e.g., introduction texts for conference proceedings or introductions of books	2
EC3: The paper is published before 2008	8
Total	**27**

Table 3.3: Application of exclusion criteria EC1-EC3 for SLR1 (step IV)

After the application of exclusion criteria EC1-EC3, a shortlist consisting of 44 papers remained. This shortlist can be found in Appendix B, tables B1 and B2. To categorise the papers in this shortlist based on the type of contribution, I have divided the papers into ten categories, which can be seen in table 3.4. Some papers can be in multiple categories, however, for clarity reasons, there was chosen to place them in the most suitable category. When a paper was not related to one of the categories, it was placed in the category 'other research'. The 'Paper No.' column refers to the paper numbers that can be found in Appendix B, tables B1 and B2.

In a large number of papers, a framework/methodology is developed to guide or analyse Enterprise Architecture practices. Moreover, the assessment of Enterprise Architecture is often addressed by models developed in the papers. Furthermore, a large number of papers analyse EA adoption in organisations in the public sector and address the readiness factors of organisations. The most relevant category is the 'Analysis of EA benefits and value', in which seven papers are included. A few papers address EA challenges that occur during adoption or implementation. Furthermore, a few papers address EA implementations in specific contexts. Moreover, the relationship between EA and Risk Management has been addressed in two papers. Additionally, the analysis of EA maturity in organisations has been addressed in two papers. Lastly, one can conclude from this shortlist that a large number of papers consist of artefact development or EA analysis and most of the papers mention EA benefits briefly in the introduction section.

No.	Category Description	Paper No.	Total
1	Development of a framework for EA	2, 4, 9, 20, 26, 35, 44	7
2	Development of a methodology for EA	5, 29, 32, 34	4
3	Development of a model for EA assessment	1, 14, 25, 38, 40	5
4	Analysis of EA adoption and readiness	3, 15, 17, 27, 28, 31, 39, 41	8
5	Analysis of EA benefits and value	7, 8, 13, 23, 24, 29, 37	7
6	Analysis of EA implementation	12, 18, 19, 22	4
7	Analysis of EA and Risk Management	6, 10	2
8	Analysis of EA maturity	11, 21	2
9	Analysis of EA challenges	30, 33	2
10	Other research	16, 24, 36, 42, 43	6
Total			**44**

Table 3.4: Categorisation of shortlist papers of SLR1

The fifth step was that of applying EC4, which was an important and lengthy process (step V). The complete shortlist of papers including the application of EC4 can be found in tables B1 and B2 of Appendix B. When applying EC4: "The paper discusses Enterprise Architecture benefits as a side topic.", 34 papers were excluded from the set, as the papers were critically scanned through and the number of papers that discuss EA benefits as a main topic is low.

The inclusion and exclusion criteria were used to identify the papers that support the interest of the research to the highest extent. After applying all in- and exclusion criteria ten papers were remaining. To further reduce the probability of missing relevant information from papers that have not been included, another two papers were identified by using the snowballing technique [25] (step VI). This technique consists of a backward and forward search and was conducted by analysing the bibliographies and citations of the ten papers.

The final step of the study selection process was to critically review the remaining set of papers by reading the full text of the papers (step VII). When reading the full text, it became clear that another two papers could be excluded from the set of papers, which resulted in a final set of ten papers. These papers were relevant enough to include in the results of the first SLR, aiming to answer the first research question.

3.2.3 Reporting the review

In table 3.5 the final set of research papers can be found, with descriptive information on the publication year, author, document type and used research methods. One of them is a PhD thesis, of which part of it is published in a book. The research methods of the papers are indicated with the following characters: Case Study (C), Design Theory research (D), Delphi study (DE), Design Science Research (DS), Expert workshop (E), Expert Interview (I), Literature review (L) and Survey (S).

Ref.	Year	Author	Type	Research methods
[26]	2008	Dyer, A.	PhD thesis	D, L
[27]	2011	van Steenbergen et al.	Conference paper (EDOCW)	S
[28]	2012	Janssen, M. & Klievink, B.	Journal article (TGPPP)	C, E
[29]	2013	Janssen et al.	Conference paper (EGOV)	L
[30]	2014	Carvalho, J. & Sousa, R.D.	Conference paper (AMCIS)	C, I, L, S
[31]	2016	Niemi, E.I. & Pekkola, S.	Journal article (SIGMIS)	C, I
[32]	2017	Syynimaa, N.	Conference paper (LNBIP)	DE, DS
[33]	2019	Pandurangi, G. & Nagalakshmi, V.	Journal article (IJERT)	E, I, L
[34]	2020	Niemi, E.I. & Pekkola, S.	Journal article (BISE)	C
[35]	2021	Espinosa et al.	Journal article (IEEE T.E.M.)	C

Table 3.5: Final set of papers of SLR1

Enterprise Architecture and organisational benefits

Van Steenbergen et al. [27] analysed the relationship between EA techniques being used and the benefits that are perceived. This analysis was based on 293 survey responses from EA experts, with a large representation (32.8%) of people active in the public sector, either from the government (31.1%) or education and research (1.7%). Eventually, five organisational benefits were widely perceived as being contributed to by EA. These were:

- 'accomplish enterprise-wide goals instead of (possibly contradictory) local optimisations'
- 'provide insight into the complexity of the organisation'
- 'integrate, standardise and/or deduplicate related processes and systems'
- 'depict a clear image of the desired future situation'
- 'enable different stakeholders to communicate with each other effectively'

However, [27] also indicates that the public sector appears to reap less benefits from EA than organisations in other sectors. Furthermore, projects in the public sector less frequently comply with EA than in other sectors. Evidence of this could not be found in the other research papers.

Carvalho and Sousa [30] investigated if EA enables organisational agility for an organisation in the public sector. As described by them "Any public administration looking to strive and prepare for organisational change requires data, applications and technology models to provide a holistic view of the organisation in a business context. Business-IT alignment seems to be central to enabling organisational agility and EA is a way of achieving that alignment.". The use of Enterprise Architecture (EA) facilitates the attainment of organisational agility by offering a comprehensive and forward-looking perspective on business processes, systems, and technologies. This enables the organisation to anticipate on future changes and prepare accordingly. The study is based on a single Case Study at a large Portuguese municipality.

Janssen et al. [29] have researched the Government Architecture in two countries, Norway and the Netherlands. They stated that organisations in the public sector can benefit from Enterprise Architecture (EA) by using it as a tool to guide and direct the development of ICT projects in the government. EA provides a framework for decision-making when designing new systems, and it is concerned about "doing the right thing" and not about "how" it should be accomplished. The direct benefits that were claimed in this research are better interoperability, reuse, improved flexibility/agility and information quality. The indirect benefits claimed are improved communication and decision-making, and an optimal fit between organisation and technology. All claimed benefits are based on the literature and on observations, which makes the conclusions of the paper not strong.

According to Syynimaa [32], EA is supportive in aligning business and IT, improving decision-making, improving operations, managing complexity and reducing duplication. Furthermore, EA can provide a holistic view of the organisation's current and future state, which can help in identifying gaps and opportunities for improvement. Additionally, EA can help in managing risks and compliance with regulations. The focus of this paper was more on the development of a methodology around EA benefits, to get a mandate in an organisation to use Enterprise Architecture.

Pandurangi and Nagalakshmi [33] came up with EA benefits for governmental organisations that can be classified into the following categories: Enhancing the Citizen Service Delivery, Refining the Systemic Processes and Competencies, Standardisation and reducing the Risk, Providing Common Insights and Overviews, Communicating and Handling the effect of Change and Enabling Modernisation / Improvement / Innovation. The research paper also proposes the 4-PM model, which includes four major EA value promoters: business process re-engineering, adoption of standards, resources optimisation and change management.

Niemi and Pekkola [34] suggest that Enterprise Architecture (EA) can benefit organisations in the public sector by providing a planning and governance approach to manage complexity and constant change, and to align the organisation towards a common goal. The paper highlights that EA can help organisations and their people to comprehensively understand their business functions, processes, information systems, and their mutual dependencies. So, organisations in the public sector can improve their organisational communication, provide directions for improvement, improve resource consolidations, reduce costs and reduce complexity.

Espinosa et al. [35] stated that Enterprise Architecture (EA) offers various benefits to organisations in the public sector. These include reduced redundancy, improved integration, and effective reuse of data, processes, and technology. These benefits will eventually lead to cost savings, increased efficiency, and better IT-business alignment. EA also facilitates collaboration among stakeholders, enhancing communication and coordination. As organisations become more proficient in architecting (conducting EA practices), the benefits create an iterative effect, strengthening shared understanding and coordination across the organisation. This fosters a continual improvement process.

Enterprise Architecture and Knowledge Management

In 2008 Dyer identified a gap in the literature, which was concerned about the following question: "How do we know if creating an Enterprise Architecture is beneficial for an organisation?" [26]. At that time, there were no contributions to the identification of organisational benefits yielded by Enterprise

Architecture. The question of his PhD thesis was narrowed down to ”Does creating an Enterprise Architecture improve the Knowledge Management of an organisation?”. In other words, another organisational factor that influences organisational performance is linked to Enterprise Architecture. In his work there is a strong focus on public organisations, however, private organisations were not excluded. This, and the fact that there is no empirical evidence for the relation, limits the conclusion of Dyer’s work. Eventually, Dyer concluded that formalising the architecture of an enterprise has multiple benefits and that Knowledge Management can be an indicator for organisations to measure the benefits of EA.

Enterprise Architecture and project benefits

According to Janssen and Klievink [28], organisations in the public sector can benefit from Enterprise Architecture (EA) by incorporating risk management as an integral part of the architecture. EA can be viewed as an instrument for risk management that is complementary to risk mitigation in project management approaches. One can conclude that when including risk management in Enterprise Architecture, IT project failure can be decreased. Furthermore, the findings suggest that projects giving less attention to EA or risk management separately have a higher failure rate.

Furthermore, van Steenbergen et al. [27] concluded that when projects conform to the Enterprise Architecture of the organisation, projects more often deliver the desired quality than projects that do not conform to the EA.

Enterprise Architecture benefit realisation

Niemi and Pekkola [31] primarily focused on analysing the existing EA benefit realisation models and developing a new EA benefit realisation model. In their new model, they differentiate between first, second and third-level EA benefits. Furthermore, they claim that EA benefits can only be realised by the appropriate use of EA results and the successful day-to-day functioning of the EA processes. The benefits that are included in their model are vaguely described and are therefore not included in this research. Furthermore, it is claimed that direct benefits seem to have more impact on individual stakeholders whilst the indirect benefits are more organisational.

Mapping the benefits

The research papers of the final set are different in context, purpose and research methods, however, each paper addresses the topic of Enterprise Architecture in (an) organisation(s) and whether or not this is beneficial for the organisation(s). Based on a synthesised list of benefits constructed by [34], all claimed and empirically tested benefits are listed in a table. Most of the benefits are mapped on the benefits from [34], which was not a one-on-one task but needed to fit the benefits in a theoretical model. So, some benefits are merged and summarised in one overarching benefit. An overview of all benefits, including the corresponding references, can be found in table 3.6.

In table 3.7 there can be found a complete overview of the final set of papers of SLR1. This table includes characteristics of the studies, such as the empirical evidence (if existing), the research setting, the country in which the study was performed and a short description of the contribution of the paper.

Theoretical model

To conclude this part of the research, a theoretical model is developed based on the perceived benefits that are claimed or empirically tested by the studies found during the first SLR. Not every benefit in the literature has been empirically tested, as the measurement of benefits for (public) organisations remains complex and sometimes even not doable.

The main constructs of the theoretical model are ’successful EA adoption’, ’organisational benefits’, ’project benefits’ and ’organisational performance’. To further develop the model, all benefits from

Benefit	Reference
Improve Knowledge Management	[26]
Improve communication	[29], [30], [33], [34]
Improve organisational agility	[29], [30]
Insight into organisational complexity	[27], [34], [35]
Reuse of components	[29], [34], [35]
Improve interoperability	[29], [32]
Improve information quality	[26], [29]
Improve Business-IT alignment	[27], [35]
Reduction of duplication	[29], [30], [35]
Improve decision-making	[26], [29], [30], [31]
Cost reduction	[30], [31], [35]
Deliver desired quality of project	[27]
Less project failure	[28]

Table 3.6: Perceived benefits of Enterprise Architecture for public organisations

table 3.6 are placed in the organisational benefits section or the project benefits section. This distinction is made, as studies explicitly mentioned this distinction in the results. All relationships, e.g. arrows, are positive relationships. So, a successful EA adoption at a public organisation implies to have a positive effect on the organisational benefits. There is a legend included with indicating colours.

Furthermore, the benefits are defined as 'empirically tested' when there is empirical evidence found for the benefit in at least one of the research papers. When no empirical evidence was found, the benefits were defined as 'claimed, not empirically tested'.

Moreover, two requirements were included in the model, which are requirements for the relationship between a 'successful EA adoption' and 'project benefits'. These requirements were included in the studies about these benefits. The relationship between a 'successful EA adoption' and 'deliver the desired quality of project' can be read as: 'A successful EA adoption at a public organisation delivers the desired quality of projects more often when these projects conform to EA'. The other relationship can be read as: 'A successful EA adoption at a public organisation ensures less project failure when Risk Management is included in the EA'.

Additionally, I assume that 'deliver desired quality of project' and 'less project failure' has a positive effect on the benefit 'improve project performance', which is a benefit included by the author of this research.

Lastly, the benefit 'improve knowledge management' is claimed and not empirically tested, however, it is a strong indicator for measuring the organisational benefits in general, according to [26]. The theoretical model can be found in figure 3.6.

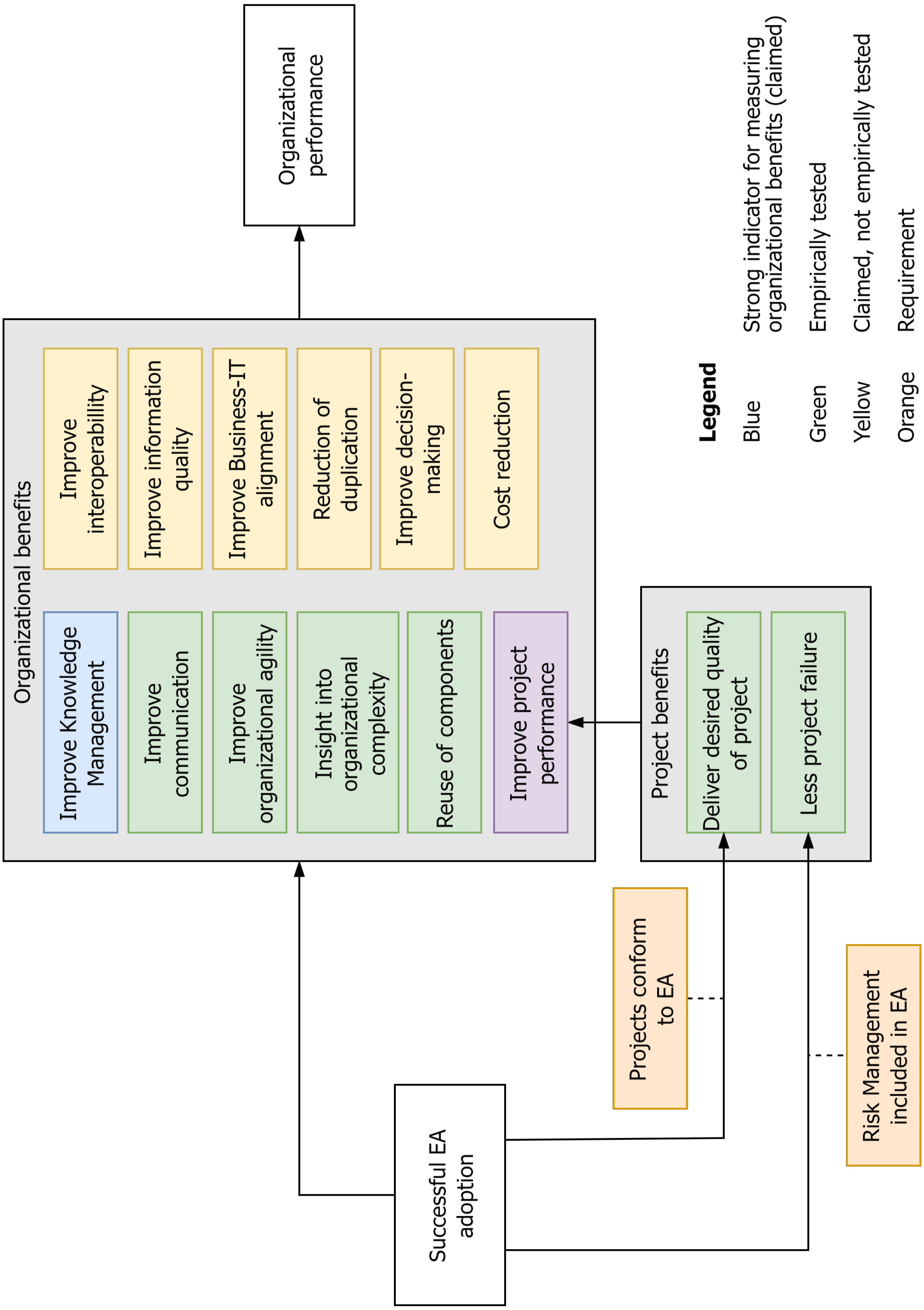


Figure 3.6: Theoretical model on EA benefits for organisations in the public sector

3.2.4 Discussion

Apparent from this Systematic Literature Review is that there is a lack of empirical studies on this research topic. Eight of the ten papers have empirical evidence for their results. Furthermore, six analysis studies were found. In two of the papers, a conceptual model is developed, in one of the papers a framework and in one of the papers a methodology. Moreover, it is remarkable that three included research papers were written in The Netherlands and three in Finland.

3.2.5 Conclusion

This part of the research aimed to get a thorough understanding of the perceived benefits of EA for organisations in the public sector, by doing a state-of-the-art Systematic Literature Review (SLR). The first research question, related to this SLR was: "How can organisations in the public sector benefit from Enterprise Architecture?". Based on the found and selected literature, 11 organisational benefits have been found of which four were empirically tested and seven were claimed and not empirically tested. Furthermore, two benefits of EA for projects are found, that were both empirically tested in the literature. These benefits are based on ten research papers that can be found in table 3.7.

The benefits that were empirically tested in one or more studies are in bold text. The organisational benefits include 'improve knowledge management' (1), **'improve communication' (2)**, **'improve organisational agility' (3)**, **'insight into organisational complexity' (4)**, **'reuse of components' (5)**, 'improve interoperability' (6), 'improve information quality' (7), 'improve Business-IT alignment' (8), 'reduction of duplication' (9), 'improve decision-making' (10) and 'cost reduction' (11). The project benefits that are found are **'deliver desired quality of project' (12)** and **'less project failure' (13)**. From the two project benefits, I assume that these yield an affiliated organisational benefit 'improve project performance'. To summarise the findings of this SLR, a theoretical model is developed based on the found studies that provide a clear overview of the (claimed) benefits of EA for organisations in the public sector. The theoretical model model can be found in figure 3.6.

Ref.	Result	Empirical evidence	Research setting	Country	Contribution of the paper
[26]	Framework	None	Literature/observations on EA and Knowledge Management & informal validation of the framework in a small Australian enterprise providing services to the Government.	Australia	Development of a framework to measure the effectiveness of EA implementation by looking at the Knowledge Management perspective.
[27]	Analysis	Survey	A survey from 2010 with a total of n = 293 valid responses. The responses came from a wide variety of organisations, the public sector was strongly represented (31.1%).	The Netherlands	Analysis of the relationship between EA techniques being used and benefits that are perceived, as well as the influence of contextual factors.
[28]	Analysis	Case Study	A workshop session in 2009 with in total 15 participants involved in EA and ICT projects of the Government.	The Netherlands	Analysis of the relationship between project failure and the attention to EA or Risk Management.
[29]	Conceptual model	None	Literature/Observations of Government Architecture practices in The Netherlands and Norway.	The Netherlands	Development of a conceptual model illustrating the relationships between Government Architecture concepts, its use, benefits and public value drivers.
[30]	Analysis	Case Study	A Case Study at a large Portugese municipality using a mixed-methods approach (document analysis, interviews and questionnaires).	Portugal	Analysis of the relationship between the development and use of EA and the enabling of organisational agility.
[31]	Analysis	Case Study	A Case Study in a large Finnish public sector organisation. The organisation was observed and 14 semi-structured EA stakeholder interviews were held.	Finland	Development of a model and criteria for analysing the existing EA benefit realisation models.
[32]	Methodology	Delphi Study	A Delphi Study with a panel of EA experts, the focus of the study was on the Finnish public sector	Finland	Development of an EA adoption methodology, with a large focus on EA benefits.
[33]	Conceptual model	Focus group study	Literature on EA benefits and EA value proposition & focused discussions with experts heading the EA development teams of the Government of India.	India	Development of the 4-pillar model (4PM) of EA value promotors. The benefits are derived from EA adoption.
[34]	Analysis	Case Study	Case Study at a large Finnish public sector organisation.	Finland	Analysis of the EA benefit-realisation process with a specific focus on strategies, resources, and practices which the EA benefits stem from.
[35]	Analysis	Case Study	A multiple-Case Study of six organisations, including two government agencies, one institution and two private companies in the U.S., and one government agency in Asia.	United States	Analysis of how implicit and explicit coordination influence architecting effectiveness.

Table 3.7: Overview of papers in the final set of SLR1

3.3 Reference architecture benefits for EA practices

This section describes the benefits of using reference architectures for Enterprise Architecture practices, based on a Systematic Literature Review (SLR). The corresponding research question (RQ2) is: "How can reference architectures improve Enterprise Architecture practices?". To conduct this SLR, I have used a similar approach as in the first SLR. Therefore, not the whole process of planning, conducting and reporting the review is described but minimised to the most essential and differing elements of the phase 'conducting the review', followed by 'reporting the review'. The main differences with the first SLR are the use of different in- and exclusion criteria and no snowballing technique is used, but a manual search for Dutch papers in Google Scholar.

3.3.1 Conducting the review

In this section, the documentation of the execution of the second SLR can be found. A complete visualisation of the process can be found in Appendix A figure A.2.

Search Strategy

To find relevant papers on the benefits of reference architectures, related to Enterprise Architecture instead of Software Architecture the following search query is constructed:

(("reference architecture" AND "Enterprise Architecture") OR "reference Enterprise Architecture" OR "enterprise reference architecture") AND (benefit OR improvement OR profit OR gain OR advancement OR advantage OR success OR value OR contribution OR valuation OR effectiveness)

This search query resulted in 116 documents that were found within the four digital libraries. The execution of the search query was on the 6th of June 2023. Publications after that date are not taken into account. The number of publications per year in the most comprehensive digital library Scopus can be found in figure 3.7.

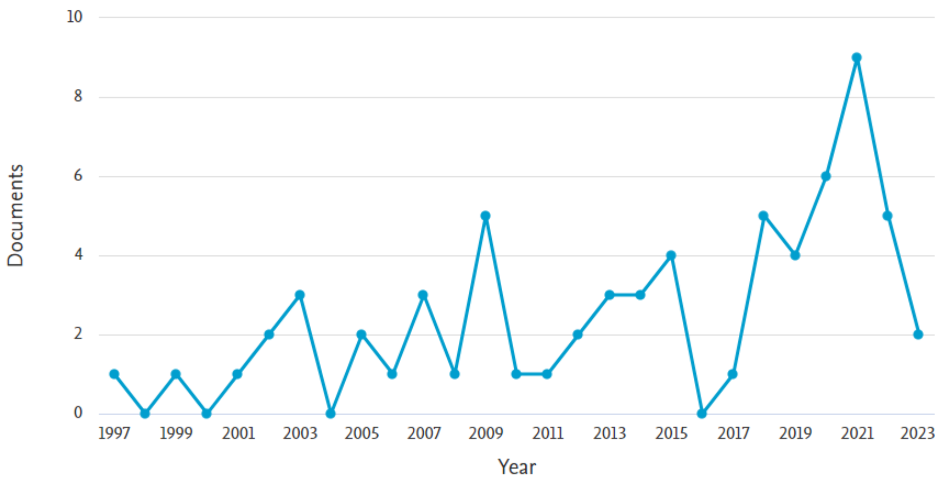


Figure 3.7: Publications per year in Scopus of SLR2 (1997-2023)

This figure illustrates the publication trend over time. From 1997 to 2001, there were a limited number of publications. Between the years 2001 and 2017, there was a relatively steady and consistent trend in the number of publications. Notably, starting from 2017, a sharp increase in publications can be observed, peaking in 2021 with a total of nine publications on this research topic. This analysis is done with some cautiousness, as the figure only shows the number of publications available in Scopus and the publications partly related to the 'topic' are also included, since no selection procedure was yet conducted.

Next to the search query, there is also manually searched for relevant research papers in Google Scholar by using the search query and search terms such as ”referentiearchitectuur”, ”referentie architectuur” and ”referentie-architectuur”. The reason behind this is that the focus of this research is on reference architectures within the Dutch public sector, which means that research papers in Dutch could be relevant.

Study selection process

The study selection process of the second SLR is slightly different than that of the first one. The steps of removing duplicates (step I), filtering on document type (step II) and reviewing the papers based on title and abstract are the same (step III). After removing the duplicates and filtering the set of papers on document type, there were 75 papers left, which were only journal articles, conference papers and book chapters. The distribution of journal articles, conference papers and book chapters can be seen in figure 3.8. This figure reveals a substantial presence of 54 conference papers (72%), a smaller number of 19 journal articles (25%), and a limited number of 2 book chapters (3%).

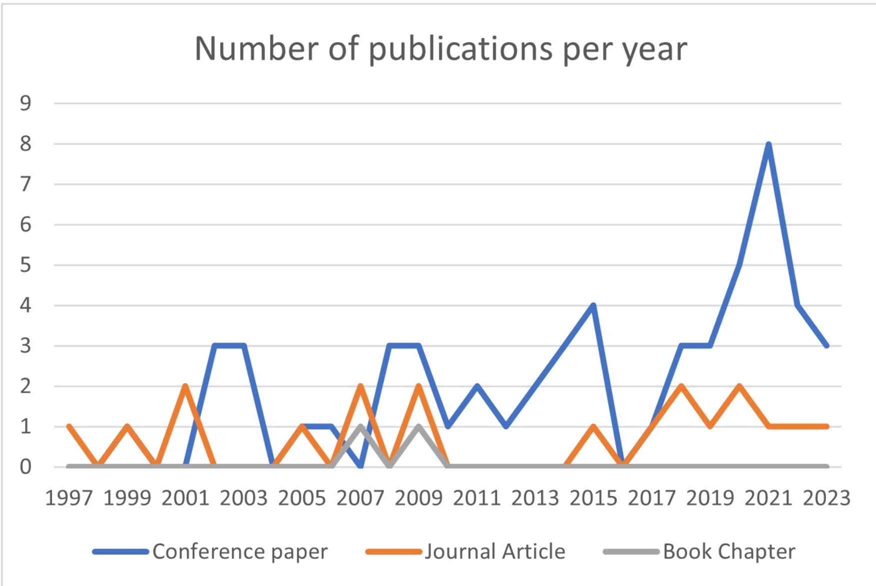


Figure 3.8: Distribution of document types of SLR2 (1997-2023)

From this moment, the papers were reviewed by reading the title and abstract of every paper (step III). This action resulted in 46 papers that were in the remaining set of papers.

These 46 papers were further reviewed, by applying the somewhat different in- and exclusion criteria. EC3 of the first SLR was removed, as the number of papers is relatively small, and there is no steep increase in publications visible around a certain year. The new EC3 will now be: ”The paper discusses reference architectures and the benefits of it for EA practices as a side topic.”. All in- and exclusion criteria for the second SLR are for clarity reasons listed below.

- **Inclusion criteria**
  - IC1 The paper relates to the research interest, i.e. it addresses the information on the interest of the research questions.
  - IC2 The paper is written in English.
  - IC3 The paper was published in a journal, conference or book.
- **Exclusion criteria**

- EC1 Non-studies, e.g. introduction texts for conference proceedings or introductions of books.
- EC2 There is no access available to the paper.
- EC3 The paper discusses reference architectures and the benefits of them for EA practices as a side topic.

Fourthly, the first two exclusion criteria (EC1-EC2) were applied (step IV), which was a relatively simple step and finished before applying the third exclusion criterion. To further elaborate on this step, the number of papers that were excluded based on these two criteria are stated in table 3.8.

Exclusion Criteria	**Excluded papers**
EC1: There is no access to the paper	7
EC2: Non-studies, e.g., introduction texts for conference proceedings or introductions of books	2
Total	**9**

Table 3.8: Application of exclusion criteria EC1-EC2 for SLR2 (step IV)

After the application of exclusion criteria EC1-EC2, a shortlist consisting of 37 papers remained. The contributions of the papers, however, are too diverse to categorise the papers. Therefore, I have chosen to not perform a categorisation as in the first SLR.

The fifth step was that of applying EC3, which was once more an important and lengthy process (step V). The complete shortlist of papers including the application of EC3 can be found in tables C1 and C2 of Appendix C. When applying EC3: ”The paper discusses reference architectures and the benefits of it for EA practices as a side topic”, 32 papers were excluded from the set, as the papers were critically scanned through and the number of papers that discusses reference architectures and the benefits of using them for EA practices is low.

After applying all in- and exclusion criteria five papers were remaining. To further reduce the probability of missing relevant information from papers that have not been included, another four papers were identified by manually searching in Google Scholar (step VI). This included the search for papers in Dutch.

The final step of the study selection process was to critically review the remaining set of papers by reading the full text of the papers (step VII). When reading the full text, it became clear that one paper could be excluded, which resulted in a final set of eight papers. These papers were relevant enough to include in the results of the second SLR, aiming to answer the second research question.

3.3.2 Reporting the review

In table 3.9 there can be found descriptive information about the final set of research papers, with the publication year, author, document type and used research methods. The research methods are abbreviated with the following characters: Literature review (L), Case study (C), Expert interviews (I) and Design Science (DS).

In 2017, Sanchez-Puchol & Pastor-Collado published a primer literature review on Enterprise Reference Architectures (ERAs) [41]. The review resulted in a comprehensible overview of high-quality studies for ERAs. They stated that there is a lack of empirical studies on this research topic, especially concerned with proving the benefits of reference architectures. During this Systematic Literature Review, I can confirm that this topic is still under-researched and lacks empirical research. However, from the literature, a clear view is developed of the functions of reference architectures.

The working definition of a reference architecture is a generic architecture for a class of systems that is used as a foundation for the design of concrete architectures from this class [9]. It becomes

Ref.	Year	Author	Type	Research method
[36]	2003	Vesterager et al.	Conference Paper (VTT)	C
[37]	2009	Lankhorst et al.	Book chapter	C
[38]	2011	Becker et al.	Conference Paper (ICPS)	L, C
[39]	2011	Greefhorst, D.	Journal Article (NOVA)	C
[4]	2012	Ten Harmsen van der Beek et al.	Conference paper (LNBIP)	L, DS, I
[40]	2015	Zimmermann et al.	Conference paper (EDOCW)	C
[41]	2017	Sanchez-Puchol et al.	Conference paper (MCIS)	L
[42]	2018	Sanchez-Puchol et al.	Journal Article (IJCSIS)	L

Table 3.9: Final set of papers of SLR2

clear from the literature that reference architectures are beneficial and have multiple functions for EA practitioners, which will be discussed in this section. The potential users of reference architectures are enterprise architects, solutions architects, project architects, architecture governance boards, business managers, program managers, business consultants, information managers, CIOs and suppliers [4].

Improved stakeholder communication

First, reference architectures can provide a common language for EA stakeholders to communicate effectively [36] [37] [4]. A common 'ground' is created for architects working on the same type of enterprise. A reference architecture can ensure that all stakeholders have a shared understanding of a specific type of an enterprise's goals, processes, and systems, i.e. its architecture.

Instrument for guidance

Secondly, reference architectures can help to reduce the complexity of developing an EA by providing a set of generic architecture principles, predefined models, reusable patterns, and best practices that can be reused across different projects and initiatives [36] [37] [43]. This can save time and resources, and also improve the consistency and quality of EA deliverables [4] [36] [43].

Quality and consistency of Enterprise Architectures

Thirdly, reference architectures are perceived as directional during the design, realisation and maintenance of the Enterprise Architecture for a specific type of enterprise [4] [40]. The collected knowledge and best practices that are available within the reference architectures can be leveraged to improve the quality and consistency of Enterprise Architectures.
Becker et al. [38] state that reference architectures can improve Enterprise Architecture (EA) practices by providing a framework for accommodating the concerns of digital preservation in EA practice. Reference architectures can help reconcile potentially conflicting domain-specific knowledge sources, align viewpoints, and foster common understanding. In [37], a service-oriented reference architecture for the Dutch government, i.e. NORA, is developed and future directions are described. This reference architecture is seen as an important guideline for the architectural practices of many institutions of the Dutch public sector. Greefhorst [39] developed a generic IT reference architecture in 2011, based on best practices in architecture projects. This was needed, as a couple of reference architectures only consist of a collection of architectural principles, which could not easily be translated towards concrete architectural designs. This generic reference architecture can be used to improve the efficiency of architecture design processes.

Lastly, Sanchez-Puchol et al. [43] researched the different reference architectures and models that are available for higher educational institutions. They claim that reference architectures for Enterprise Architectures are a particular sub-type of reference architectures when the targeted domain is set to a "class of enterprises". This type of reference architecture is there to leverage the reuse of knowledge by identifying, grouping and abstracting common features of a particular domain in a unique model, which can be used as a reference for all the specific models of such domain.

In table 3.10 there can be found a complete overview of the final set of papers of SLR1. This table includes characteristics of the studies, such as the empirical evidence (if existing), the research setting, the country in which the study was performed and a short description of the contribution of the paper.

3.3.3 Discussion

In this SLR, only one of the eight papers included in the results has empirically tested their results through the use of interviews. Furthermore, five analysis studies were found. In three of the eight papers, a reference architecture is developed, in one paper an architectural approach and in one paper a conceptual model. Moreover, it is remarkable that three included research papers were written in The Netherlands, however, this is also caused by the manual search of papers written in Dutch.

3.3.4 Conclusion

This part of the research aimed to find the benefits of reference architectures for EA practices by doing a state-of-the-art Systematic Literature Review. The second research question was: ”How can reference architectures improve Enterprise Architecture practices?”. A reference architecture is a generic architecture for a class of systems that is used as a foundation for the design of concrete architectures from this class. A comprehensive reference architecture includes a set of generic architecture principles, pre-defined models, reusable patterns and best practices.

I can conclude that there is a lack of empirical studies on this research topic, as the benefits of reference architectures for EA practices are barely studied. The found studies have an exploratory nature and often discuss use cases of reference architectures for EA practices. However, the measurable benefits of using these reference architectures have not been studied. One reason for this is that the benefits for organisations using Enterprise Architecture are also not extensively studied and often difficult to make them measurable.

From the literature, three benefits of reference architectures for EA practices can be considered. First, reference architectures improve the communication between various EA stakeholders, by creating a common ground. Secondly, reference architectures guide the design, realisation, and maintenance of Enterprise Architectures, which reduces the time being used for developing Enterprise Architectures. Thirdly, by leveraging the reuse of knowledge and best practices, reference architectures improve the quality and consistency of EA deliverables. These benefits are based on eight research papers that can be found in table 3.10.

Ref.	Result	Empirical evidence	Research setting	Country	Contribution of the paper
[36]	Analysis / reference architecture	None	Case Study on the development of the VERA and Methodology, using the international standard GERAM.	Denmark	Analysis of the main components of the Virtual Enterprise Reference Architecture (VERA) and examples of its use and potentials.
[37]	Reference architecture	None	Case Study on the development, structure and first results of a service-oriented reference architecture for e-government.	The Netherlands	Development and future directions of a service-oriented reference architecture for the Dutch government.
[38]	Architectural approach	None	Discussion of key elements of a generic reference architecture for DP.	Portugal	Development of an architectural approach that enables Business-IT alignment by accommodating the concerns of Digital Preservation in EA practices.
[39]	Analysis	None	Observations and insights about the development and structure of the generic IT reference architecture of ArchiXL.	The Netherlands	Analysis of the generic reference architecture for the structuring of information provision and technology of organizations.
[4]	Analysis / conceptual model	Interviews	Literature review and a small set of interviews for validating the conceptual model.	The Netherlands	Literature review on the definition of Enterprise Reference Architecture and the development of a conceptual model in which Enterprise Reference Architecture is positioned.
[40]	Reference architecture	None	Case Study on the integration of EA and IoT based on the Enterprise Services Architecture Meta-model Integration.	Germany	Development of an extended service-oriented Enterprise Architecture reference model and ontology for an integrated approach of EA and IoT.
[41]	Analysis	None	Literature review in combination with a classification framework based on Gregor's theory types of IS	Spain	Literature review on Enterprise Reference Architectures following general guidelines proposed for undertaking information systems reviews.
[42]	Analysis	None	In-depth analysis process for the identification, analysis and comparison and classification of REAMs	Spain	Analysis of comparing 20 existing Enterprise Reference Architectures and Reference Models targeted to the Higher Education domain.

Table 3.10: Overview of papers in final set of SLR2

3.4 Reference architectures and semantic wikis

This section details the utilisation of semantic wikis for the organisation and structuring of architectural knowledge of reference architectures. The focus is on addressing the research question (RQ3): "How is the architectural knowledge of reference architectures within the Dutch public sector organised and structured?" Given that WikiXL[2] often serves as a semantic wiki-based platform for organising architectural knowledge of reference architectures, a search was conducted for relevant information using terms such as "semantic web", "web 3.0", "architectural knowledge", "architecture knowledge management", "Enterprise Architecture", and "semantic wiki." Multiple papers retrieved from Google Scholar contribute to an exploration of how semantic wikis facilitate the organisation and structuring of architectural knowledge, drawing insights from both literature and existing knowledge on reference architectures published in semantic wikis.

Before delving into semantic wikis, this section introduces the semantic web (or Web 3.0) and Linked Data. Additionally, it provides an overview of the WikiXL platform and explains the common structure of reference architectures. The section concludes by showcasing three reference architectures published on the WikiXL platform.

3.4.1 The semantic web and linked data

Before understanding the use of semantic wikis, it is necessary to understand how the semantic web functions. The semantic web can be considered as the third generation of the Web and is based on Linked Data. The World Wide Web initiative, or 'Web 1.0' was started in 1989 by Tim Berners-Lee [44]. The initiative was a practical project designed to bring a global information universe into existence using available technology. The technologies that were used for this global information universe are based on a combination of hypertext, information retrieval and wide-area networking.

In 1999, Darcy DiNucci published an article entitled "Fragmented Future", in which the term 'Web 2.0' was first introduced [45]. In 2004, Tim O'Reilly and Dale Dougherty held the first Web 2.0 conference, during which the term Web 2.0 was brought to the attention of a wider public. Web 2.0 is the second generation of the World Wide Web and is characterised by two-way communication and user participation [46].

In 2001 Tim Berners-Lee published an article named "The Semantic Web" [47], in which the concept "semantic web" was introduced. This marked the beginning of a new research field. In the following sections, the aspects of the semantic web are discussed.

Expressing meaning

Berners-Lee argued that until 2001, computers had no reliable way to process the semantics of web pages. The idea of a semantic web will bring structure to the meaningful content of these web pages, creating an environment where software agents roaming from page to page can readily carry out sophisticated tasks for users [47]. In other words, the semantic web means sharing data and facts rather than sharing the text of a page [48].

The semantic web is usually envisioned as an improvement of the current World Wide Web and Web 2.0 [49]. Information on the Web should be machine-understandable instead of mostly targeted at human consumption. Besides understanding the information, machines should be able to use the information. The essential property of the WWW is its universality. Web technology must therefore not discriminate between different sources of information, which is supported by the semantic web, as it is structured in a decentralised way.

[2]WikiXL, `https://www.archixl.nl/en/products/wikixl-knowledge-management-platform/`

Knowledge representation

To enable the semantic web, computers must access structured collections of information, referred to as Linked Data. Traditional knowledge representation systems typically have been centralised, requiring everyone to share the same definition of common concepts. The semantic web is there to provide a language that expresses both data and rules for reasoning about the data and that allows rules from any existing knowledge-representation system to be exported onto the Web. Adding logic to the Web means using rules to make inferences, choose courses of action and answer questions.

Semantic web technologies

Semantic web technologies are used for querying, knowledge representation and storage of linked data. An important technology for the semantic web is Resource Description Framework (RDF). eXtensible Markup Language (XML) and RDF can both be used to represent structured data on the web. However, XML says nothing about the actual meaning of that structure. In 2004, the Resource Description Framework (RDF) became a World Wide Web Consortium (W3C) standard [49]. The meaning of data can be expressed by RDF, which is graded with four stars by the 5-star scheme suggested by Tim Berners-Lee [50].

RDF data consists of sets of triples, with each triple consisting of the subject, verb and object of an elementary sentence. In this Linked Data structure, expressed in RDF, a particular ‘thing’ has ‘properties’ with certain ‘values’. This structure turns out to be a natural way to describe the vast majority of the data processed by machines. Subjects, objects and verbs are identified by Uniform Resource Identifiers (URIs). The most common form of these URIs is the Uniform Resource Locator (URL). Eventually, the RDF triples form webs of information about related things, that are represented by links between different URLs.

Ontologies

Another component of the semantic web is the use of ontologies. According to a many cited source, an ontology is a formal, explicit specification of a shared conceptualisation [51]. In the jargon of information science, an ontology is a document or file that formally defines the relations among terms. Another formal definition of ’ontology’ is a knowledge base of concepts and their relationships, specified in a knowledge representation language based on formal logic [49]. In this research, the definition of Hitzler [49] is used. Ontologies have stronger semantics than taxonomies, which have stronger semantics than thesauri. Taxonomies define classes of objects and relations among them. Thesauri map terms to concepts in a controlled vocabulary. The inference rules in ontologies supply further power to the meaning of data. Using ontologies, machines or ’software agents’ can understand the meanings of data. This shared understanding between consumer and producer agents can be reached by exchanging ontologies.

RDFS and OWL

The RDF Schema language (RDFS) and the Web Ontology Language (OWL) together provide a common data modelling (schema) language for data on the Web. In 2004, OWL became a W3C standard. It can be seen as the topmost knowledge representation language for the semantic web, which is based on RDF/XML [48]. RDFS provides a data modelling vocabulary for RDF data. RDF Schema is an extension of the basic RDF vocabulary [52]. So, RDF provides the data model explaining how to build a graph. RDFS is a vocabulary, in RDF, that explains how nodes of a graph relate.

SPARQL

The SPARQL Query Language and Protocol provide a standard means for interacting with data on the Web. In 2008, SPARQL became a W3C standard for querying RDF data. With SPARQL, semantic data can be retrieved and manipulated. SPARQL is a semantic query language that is similar to the SQL query language, which is meant for relational databases.

Overview of the semantic web

The semantic web consists of a couple of essential components. These are RDF, ontologies, OWL, RDFS, and SPARQL. They have the capacity to encode semantics and to provide automated reasoning, and sharing and management of information from various sources.

One representation of the semantic web technology stack can be seen in the figure below. This representation is based on the W3C standards.

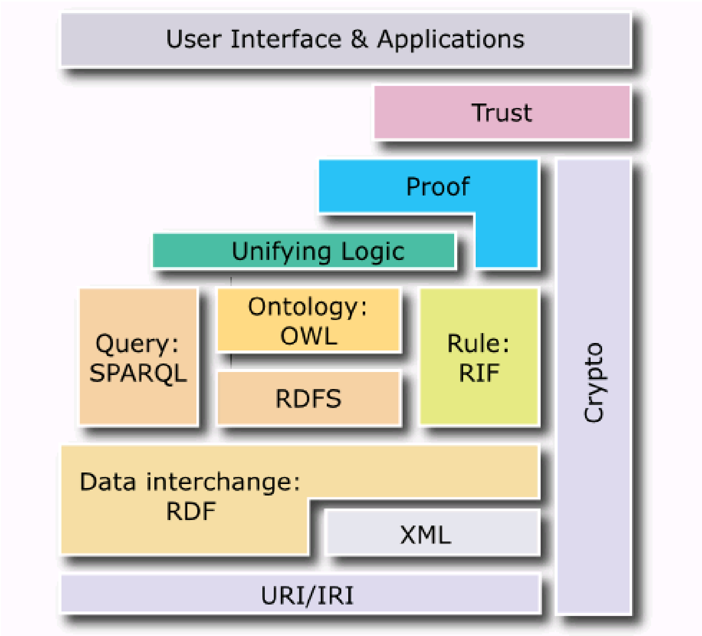


Figure 3.9: The semantic web technology stack [5]

3.4.2 Semantic wikis

As already mentioned in the introduction, the architectural knowledge of most of the reference architectures within the Dutch public sector is currently organised and structured on semantic wikis. A semantic wiki is an extension of a regular wiki. A regular wiki is a collaborative platform that strongly invites users to share their knowledge [53]. However, regular wikis have some shortcomings, as the knowledge that is available on the wiki pages is in the form of unstructured (textual) information. This has no actual meaning. When questioning about the meaning of the information, no answers can be given.

A semantic wiki combines traditional wiki systems with semantic web technology. A semantic wiki adds an underlying knowledge model to a regular wiki, which describes the data the wiki contains. Such a description makes the facts and relationships in the wiki meaningful, for humans and information systems. From this meaning (or 'semantics'), new relationships and facts can be derived. Moreover, the wiki can be directly queried for the knowledge it contains. So, knowledge can be retrieved that is not textually described on a web page but is retrieved by combining multiple facts and relationships on various wiki pages. A simple example that can be given is the creation of a table with the top 10 largest cities in the world, based on the populations of these cities. This data is namely already available in single Wikipedia pages containing the property 'population' of cities.

Throughout the years, wikis are increasingly used in organisations as tools to support knowledge management. People within the organisation can create, maintain and share knowledge easily via a wiki. However, the retrieval of knowledge becomes more and more difficult as the number and size of wiki pages increase. Semantic wikis solve this problem by strongly linking pages to make a coherent structure of the wiki. These strong links are semantic annotations, which are machine-readable. These semantic annotations are useful for many purposes, such as enhanced presentation by displaying contextual information, enhanced navigation by giving easy access to relevant related information, and enhanced "semantic" search that respects the context in addition to the content [54].

Architectural knowledge

Architectural knowledge is increasingly regarded as an organisational asset that should be managed properly [53]. Architectural knowledge consists of the architecture design as well as the design decisions, assumptions and the context of the architecture design [55]. Architectural knowledge of reference architectures primarily consists of principles and architecture models. This knowledge should be transferred from the tacit level (in the architect's head) to a documented and eventually formalised level (structured information). A semantic wiki can be a suitable tool to organise and structure (formalised) information. Therefore, semantic wikis are becoming more and more popular as tools for (architectural) knowledge management.

In the Dutch public sector, digital architects have used semantic wikis to publish architectural knowledge of sector-specific reference architectures with the intention that this information is reused by organisations within that sector. From experience within these sectors, it can be stated that the publication of architectural knowledge in semantic wikis has helped organise the semi-structured nature of that knowledge in the form of combinations of text and model elements [56]. These model and text elements foster the desire to share and link that knowledge. Currently, this knowledge is only linked within isolated repositories and published on a single semantic wiki. Hence, there is a growing interest in breaking out the architectural knowledge from its isolated repositories. This means linking architectural knowledge from different reference architectures to each other.

3.4.3 Structure of a reference architecture

Reference architectures are generic architectures for a class of systems that are used as foundations for the design of concrete architectures from this class. The architectural knowledge that is included in a reference architecture is of large value for a digital architect developing concrete (Enterprise) architectures. However, also other stakeholders can benefit from this knowledge. Reference architectures that are used in the Dutch public sector consist mainly of principles and architecture models. Next to principles and architecture models, reference architectures can also consist of standards and conceptual frameworks. The information in a reference architecture conforms to a knowledge model that is specifically developed for that reference architecture.

In the end, reference architectures are used to improve stakeholder communication, guide digital architects and improve the quality and consistency of (Enterprise) architectures. These benefits of reference architectures for EA practices are studied at the start of this research project and the results are presented in section 3.3.

WikiXL

The architectural knowledge of many reference architectures is currently organised and structured on a knowledge management platform called WikiXL, which can be seen in table 1.1. This platform is based on Semantic MediaWiki[3], an extension for managing structured data in a wiki and for querying that data to create dynamic representations [57]. The platform allows users to implement and manage knowledge models that structure the data in the system. So, the underlying knowledge model provides meaning to the information that is available in the wiki. Some reference architectures are published on other websites and a few are documented in PDF or PPT format.

As mentioned, reference architectures often consist of principles and architecture models. Principles are often textually described, but can also be made visible in architecture models. Within WikiXL, principles are often mapped onto wiki pages such that a single principle corresponds to a single

[3]Semantic MediaWiki, https://www.semantic-mediawiki.org/wiki/Semantic_MediaWiki

page in the wiki. The rationales and implications of these principles can be expressed in plain text or as references to other wiki pages. This way, a graph-like structure is created, which improves the traceability of principles.

The architecture models of reference architectures are often developed with an EA modelling language called ArchiMate [3]. The tool that is often used for that is called Archi[4]. ArchiMate models consist of elements and relationships between those elements. Each element has a single page in the wiki, which provides additional information about the element. Furthermore, each ArchiMate view, which is part of an architecture relevant to a stakeholder's concern(s), has a single page in the wiki.

Most of the digital architects maintain their architecture models in an architecture repository. Users of architectural knowledge can benefit from the architecture models when they are available in a user-friendly interface. Therefore, on top of the WikiXL platform, ArchiMedes[5] is built. ArchiMedes can link WikiXL to the architecture repository and shows the repository contents in a browsable interface on a wiki page. It reconstructs the views developed in the repository and incorporates an element catalogue that provides links to additional details about the elements depicted in the diagram [57]. An example of a detailed description of an ArchiMate element by ArchiMedes can be found in figure 3.10.

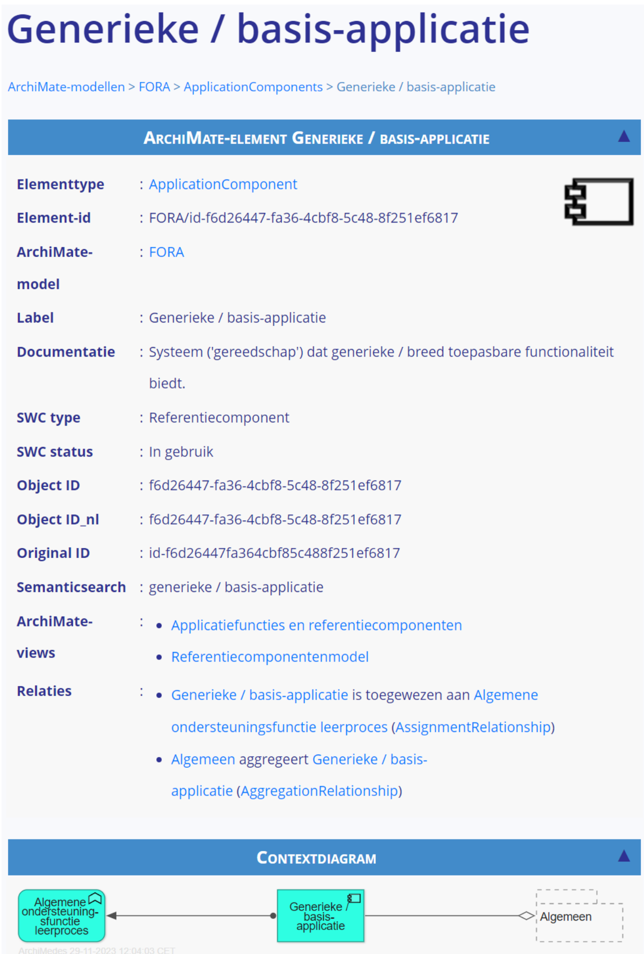


Figure 3.10: Example of an ArchiMate element in ArchiMedes

[4]Archi, `https://www.archimatetool.com/`

[5]ArchiMedes, an architecture publication platform, `https://www.archixl.nl/en/products/archimedes-architecture-publishing-platform/`

Many reference architectures consist of standardised views, which are architecture models with a specific perspective. The reason for this is that an organisation is typically confronted with standard business operations. So, reference architectures often have so-called business function models. Furthermore, reference architectures often consist of information models, process models and reference components models (in Dutch: referentiecomponentenmodel). These standardised views ensure that reference architectures can be compared more easily.

In the following sections, a couple of examples of reference architectures that are published on WikiXL are showcased. The contents of the reference architectures NORA, ROSA and FORA are explained.

NORA

The Dutch Government Reference Architecture (in Dutch: Nederlandse Overheid Referentie Architectuur (NORA)) was established in 2009 as a norm by the Dutch Government and is developed for the whole public sector. The NORA is part of the NORA family[6], which consists of all the reference architectures that are used within the Dutch public sector. NORA provides principles, definitions and models for the design of the information service of the Dutch Government and the services to the citizens and businesses. It is an instrument that can be used by digital architects, project leaders and managers to improve their services and the ability for the cooperation of their organisation.

The NORA is intended as a guiding and steering instrument [10]. It contains frameworks and existing agreements for organising the information provision of the Dutch government. NORA's content can be related to the "Dutch Service Delivery Concept", which is the structure that underlies the government's service delivery. It ensures the structural coherence between the vision of service delivery, the policies, the execution and the management of the quality and continuous improvement of service delivery. In addition to policy frameworks, the NORA includes core values for service delivery, quality goals, architecture principles, implications for architecture principles, standards, building blocks, and a conceptual framework. For each element, an overview page is included with an explanation of the insights of NORA.

ROSA

The Reference Education Sector Architecture (in Dutch: Referentie Onderwijs Sector Architectuur (ROSA)) is developed for the whole educational sector. The goal of ROSA is to improve the cooperation between chain partners in the field of information provision[7]. ROSA is describing and prescribing, as it delivers insights about information provision for organisations in the educational sector. Next to these insights, frameworks and agreements are also presented to which organisations should conform.

ROSA serves as a guide for the educational sector in which relevant architecture concepts can be found, such as goals, principles, frameworks, models and other artefacts. Furthermore, ROSA presents the coherence between concepts and artefacts. Also, ROSA is actively involved in the different sector-specific reference architectures and sector architectures. Lastly, ROSA ensures the connection between several chain initiatives in the educational sector, because of their use of ROSA.

FORA

The Primary Education Reference Architecture (in Dutch: Funderend Onderwijs Referentie Architectuur (FORA)) has been developed for primary and secondary education to provide a standardised view of the processes and activities that take place in a typical school [58]. The FORA is primarily intended for information specialists, and its implementation can improve cooperation between schools. The government requires many of the processes and activities described in the FORA to be implemented by schools, making it a useful tool for schools to ensure that their information provision is

[6] NORA familie, `https://www.noraonline.nl/wiki/NORA_Familie`
[7] ROSA, `https://rosa.wikixl.nl/index.php/Hoofdpagina`

correctly implemented. Many processes and activities within the FORA are obliged by the government, so schools can also test whether their information provision is correctly implemented.

To optimally guide the users of the FORA, a fictive school named 'FORA onderwijsgroep' is used. The objective of this is to make the use of FORA more accessible, thereby promoting its use by schools and school boards. Using this fictive school as a reference, concrete issues from educational practice are elaborated upon based on FORA principles, explaining how and why this is done. In this way, use cases are created that can serve as a source of inspiration for schools and boards to embark on architecture initiatives themselves.

In figure 3.11 a snapshot can be found of the FORA, which is published on the WikiXL platform.

Figure 3.11: Snapshot of FORA in WikiXL

3.4.4 Conclusion

In conclusion, this section investigated the organisation and structuring of architectural knowledge of reference architectures within the Dutch public sector, with a focus on the use of semantic wikis. To start, an introduction to the semantic web and its technologies, including RDF, ontologies, and SPARQL was provided. After that, the use of semantic wikis for organising and structuring architectural knowledge was explained. From experience, one can state that the use of semantic wikis has helped organise and structure architectural knowledge. However, the architectural knowledge of a reference architecture is currently available in a single architecture repository. So, at this moment, reference architectures have no direct links with other reference architectures.

Most of the reference architectures within the Dutch public sector are published on WikiXL, which is a platform based on Semantic MediaWiki. Before further elaborating upon this platform, the general structure of a reference architecture within the Dutch public sector was explained. After that, WikiXL was introduced and a couple of examples of reference architectures were presented to provide an overview of the contents of reference architectures within the Dutch public sector.

Chapter 4

Current state of coherence

In the previous chapter, the context of the problem was investigated. The literature reviews that were conducted resulted in knowledge about Enterprise Architecture, the use of reference architectures for Enterprise Architecture practices and the use of semantic wikis such as WikiXL for organising and structuring architectural knowledge of reference architectures. However, the problem that must be addressed in this research is that of a lack of coherence between reference architectures within the Dutch public sector. Therefore, an investigation of the current state of coherence between reference architectures within the Dutch public sector is presented in this chapter. The term 'state' refers to the following issues: The definition of coherence between reference architectures, the desire for improved coherence, the problems of a lack of coherence and the stakeholders experiencing the problems of a lack of coherence. Furthermore, the desired relationships between reference architectures are investigated. To investigate these issues, a focus group was held, after which a survey was conducted to validate and complement the findings of the focus group. The findings of both research methods are combined and presented in this chapter. However, first, the structure of the focus group and the survey and their questions are presented. The findings of merely the focus group (in Dutch) can be found in appendix F.

In section 4.3, the definition of coherence between reference architectures within the Dutch public sector is given. When referring to the term 'coherence' in this research, I always mean the coherence between reference architectures within the Dutch public sector. In section 4.4, the desire of several stakeholders for improved coherence is explained. After that, the problems that stakeholders experience of a lack of coherence are explained in section 4.5. Furthermore, the stakeholders experiencing these problems and having the desire for improved coherence are presented in section 4.6. Also, other stakeholders that are influenced by this problem are discussed. In section 4.7, a conclusion is given about the current state of coherence. Moreover, the desired relationships between components of reference architectures are discussed in section 4.8. These desires were derived from the answers of digital architects who participated in the focus group or responded to the survey. Furthermore, an explanation is given of using linked data principles and techniques to link ArchiMate elements, which are the components of reference architectures. Lastly, in section 4.9, a conclusion is given on the current state of coherence and desired relationships between reference architectures.

4.1 Focus group

The main research objective is to design a method to improve the coherence between the reference architectures within the Dutch public sector. Before exploring solution directions, it is important to investigate the current state of coherence between reference architectures. Therefore, a focus group was held with four digital architects having knowledge of and experience with reference architectures within the Dutch public sector. The participants even contributed to the following reference architectures: NORA, GEMMA, WILMA, ROSA, FORA, MORA, HORA, CORA/VERA and VeRA.

4.1.1 The session

According to Krueger [59], focus group research should comprise a minimum of three and a maximum of 12 participants. This session had four participants and took 100 minutes to complete. The whole session was in Dutch, as all participants are Dutch and the topics discussed are available in the Dutch language. During the session, I took the role of moderator.

First, I introduced the research and presented the results of the partially complete Systematic Literature Reviews in which the benefits of EA for organisations in the public sector and the benefits of using reference architectures for EA practices were studied. Secondly, the purpose of the session was explained, together with the research method. After receiving consent for recording the rest of the session, part I was started.

In part I the current state of coherence between reference architectures was discussed. The purpose of this part was to explore the following issues:

1. The definition of coherence in its context;
2. the current state of coherence;
3. the desire for improved coherence;
4. the problems of a lack of coherence;
5. the stakeholders of the problem.

In part II the desired relationships between reference architectures were discussed. The purpose of the second part was to explore examples of relationships between reference architectures. Most of the examples were already given in the first part.

During part I and II, respectively ten and six primarily open-ended questions were asked. They were asked through a PowerPoint slide deck, presenting the questions one-on-one. One of the ten questions of the first part was not an open-ended question. The questions can be found in tables D.1 and D.2 in Appendix D. The planning of the session can also be found in Appendix D in table D.3.

4.1.2 Data analysis

The complete focus group was recorded, after which the audio recording was completely transcribed. The transcript was thereafter analysed according to the framework of Nili et al. [2]. The complete data analysis process is explained in section 2.4. After following the Focus Group Data Analysis Framework, the qualitative data was translated into actual findings.

These findings can be found in appendix F and can be visualised by an ArchiMate view, using Motivation elements [3]. This model can be found below in figure 4.1. The original ArchiMate view F.1 is in Dutch, as all answers from the participants of the focus group were in Dutch. These findings formed the basis for constructing the survey, in which the findings should be validated and complemented by a larger group of digital architects in the Dutch public sector.

4.2 Survey

The findings from the focus group suggest that digital architects in the Dutch public sector generally agree on the desire to improve the coherence between reference architectures. It also suggests that multiple stakeholders are experiencing problems of a lack of coherence, especially the digital architects. Furthermore, it suggests that there are three drivers for improved coherence and four practical problems caused by a lack of coherence. With the findings of one focus group, the problem was not completely investigated. So, to validate and complement these findings, the opinions of a larger group of digital architects in the Dutch public sector were needed. To gather insights from a large group of people, a survey is a suitable research method. Hence, a survey was constructed not

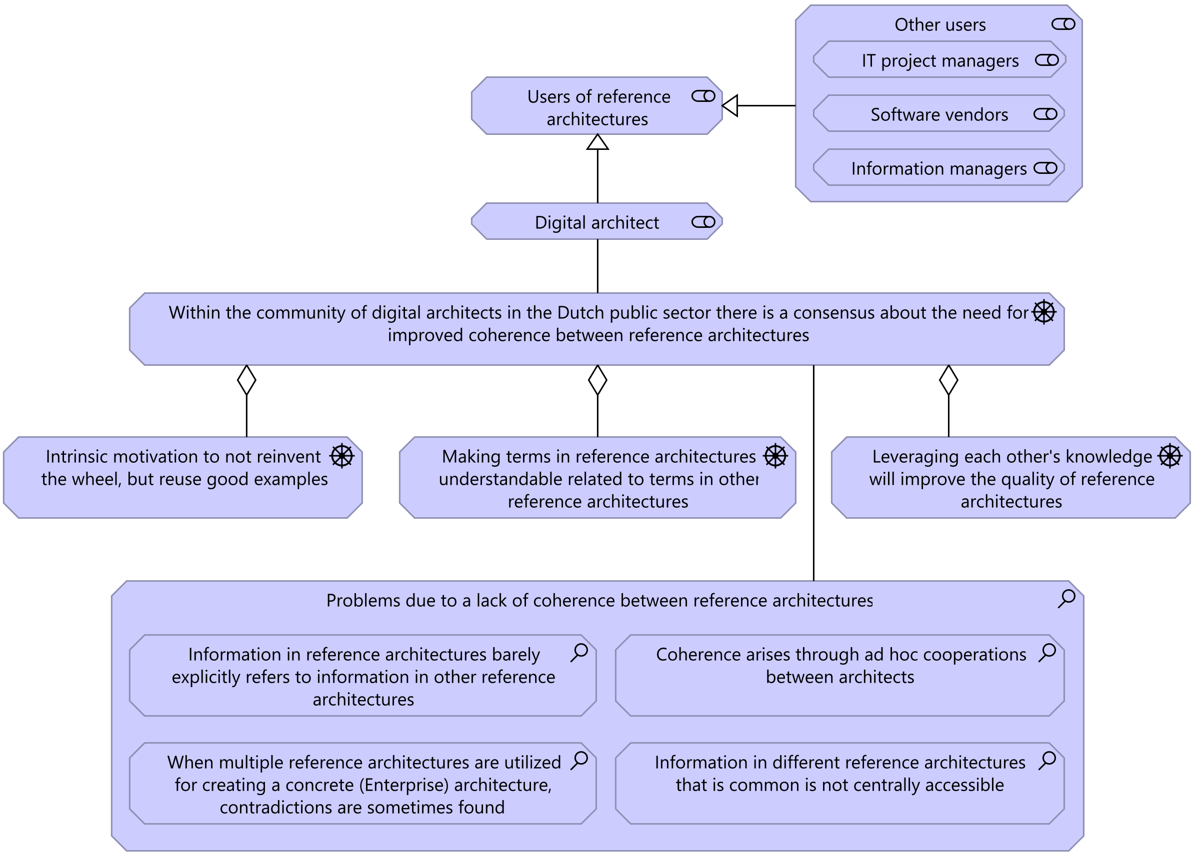


Figure 4.1: Concise findings of the focus group in ArchiMate Motivation elements (Translated to English)

only to validate but also to complement the findings from the focus group. The survey was online from the 8th of September until the 26th of October.

4.2.1 Structure of the survey

In this section, the structure of the survey is presented. The survey was structured into six segments: Introduction, respondents, stakeholders, drivers, problems, and desired relationships.

Introduction

First, when someone clicked on the link to the survey the potential participant was introduced to the survey. The following information was provided to someone: Information on the objective of the survey, what I ask from the respondents, what will happen with the answers they provide and what data will be stored. Afterwards, the participant was asked for consent to use the answers they provided.

Secondly, the research was introduced and a summary of the results of the Systematic Literature Reviews was provided to the participants. This summary can be found in appendix G. The participant did not have to read these results to be able to answer the questions. However, it provides background knowledge about the start of the research project.

Lastly, background information was provided about the findings of the focus group and what the objectives of the survey are. Participants could also download the document 'Findings of the focus group' that can be found in Appendix F. This document explains the findings of the focus group.

Respondents

In the second part, the participants were asked whether they are digital architects, working within the Dutch public sector. By digital architect, I mean 'enterprise architect', 'information architect', 'business architect', 'IT architect', 'solution architect', 'project architect', and so forth. Secondly, participants were asked about their experience with the use of reference architectures within the Dutch public sector. Lastly, participants were asked whether they have contributed to one or more of these reference architectures.

Stakeholders

In the third part, the participants were asked about the stakeholders of the problem. From the focus group, four types of stakeholders were mentioned that experience problems of a lack of coherence between reference architectures. These stakeholders were presented to the participants, after which they should estimate how 'many' problems these stakeholders experience based on their own experiences and observations. The options were: 'No problems', 'few problems', 'several problems', 'many problems' and 'very many problems'. After that, participants were asked whether they could name other stakeholders who experience problems of a lack of coherence between reference architectures.

Drivers

In the fourth part, the participants were asked to rate the three drivers that were considered important within the focus group. Per driver, the participant was asked whether they find the driver 'very important', 'important', 'moderately important', 'somewhat important', or 'not important'. They were also asked to explain their answers to the first question. Lastly, there was asked to the participants whether they have more drivers for improved coherence between reference architectures.

Problems

In the fifth part, the participants were asked to rate the four problems that were considered within the focus group. Per problem, the participant was asked whether they find the problem 'very large', 'large', 'moderate', 'small', or 'not a problem'. They were also asked to explain their answers to the first question. Lastly, there was asked to the participants whether they could name other problems of a lack of coherence they have experienced.

Desired relationships

In the last part, the participants were asked whether they could give examples of specific types of relationships between components of reference architectures that should be made explicit and established somewhere. These examples will be used for the design of the artefact of this research.

4.2.2 Data analysis

In total, 40 participants finished the survey, whereas 32 participants filled in the survey completely. The average time it took to complete the survey was 31 minutes. All respondents are digital architects having knowledge of and experience with reference architectures within the Dutch public sector.

The Qualtrics software tool offers a data analysis and reporting tool to gather insights from the collected survey data. In section 2.5 the complete data analysis process of the survey is explained. Before combining the findings of the focus group and the results of the survey, some information about the set of respondents is given. Respondents were asked how experienced they are regarding the use of reference architectures within the Dutch public sector. In figure 4.2 below the results can be seen regarding the experience of digital architects with using reference architectures.

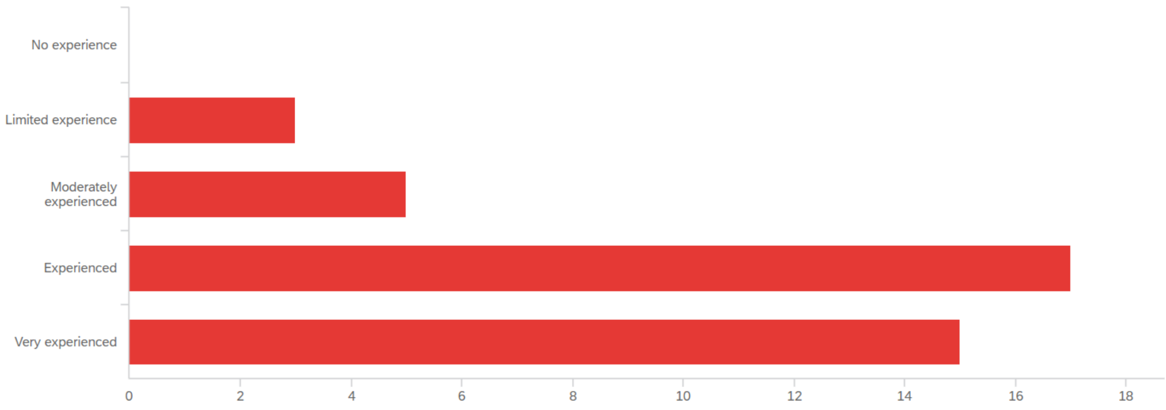


Figure 4.2: Experience with using reference architectures

Furthermore, respondents were asked whether they have contributed to one or more reference architectures. In table 4.1 and figure 4.3 below one can see the contributions of digital architects to the different reference architectures.

Reference architecture	**Abbreviation**	**Contributions**	**Percentage**
Nederlandse Overheid Referentie Architectuur	NORA	17	24.3%
GEMeentelijke ModelArchitectuur	GEMMA	12	17.1%
Hoger Onderwijs Referentie Architectuur	HORA	10	14.3%
Referentie Onderwijs Sector Architectuur	ROSA	6	8.6%
Waterschap Informatie & Logisch Model Architectuur	WILMA	5	7.1%
Middelbaar beroepsOnderwijs Referentie Architectuur	MORA	3	4.3%
Veiligheidsregio Referentie Architectuur	VeRA	3	4.3%
Architectuur strafrechtketen	Astra	2	2.9%
Provinciale EnTerprise ReferentieArchitectuur	PETRA	2	2.9%
Other reference architectures		10	14.3%
Total		70	100%

Table 4.1: Contributions of respondents to reference architectures

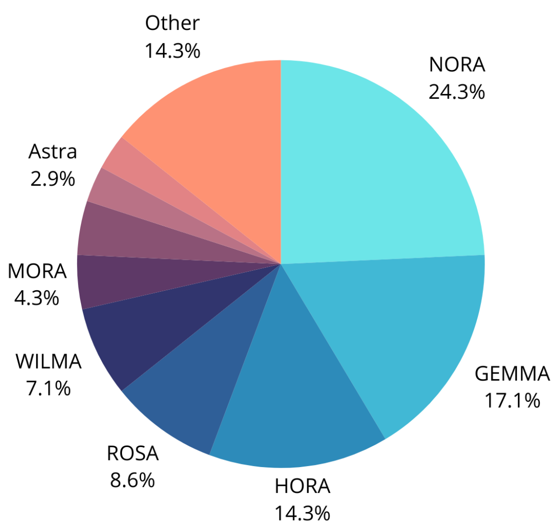


Figure 4.3: Distribution of contributions to reference architectures

4.3 Definition of coherence

First, there should be a clear definition of the term 'coherence' in the context of reference architectures within the Dutch public sector. However, it is difficult to provide an unequivocal definition of 'coherence between reference architectures', as it touches many aspects. It is nevertheless focused on the following aspects:

- Coherence based on semantics
  - Using and applying the same architecture language, e.g. ArchiMate
  - Using the same terms for concepts that are used in the same way
- Coherence based on content
  - Reusing common terms
  - Reusing viewpoints
  - Reusing architecture frameworks (i.e. reusing architecture principles)
  - Reusing information of existing reference architectures
  - Using and applying the same standards, e.g. TOGAF
  - Logical positioning of related reference architectures
  - Explicitly referencing architecture components that are related to each other
- Coherence based on relationships
  - Relationships between architecture principles
  - Relationships between architecture components

In this research 'coherence' means the coherence between reference architectures within the Dutch public sector. However, digital architects also state that there could be a lack of coherence within a single reference architecture. For example, the list of terms within the NORA is not consistent, as independent project groups are working on these terms. When there is no communication between these project groups, an inconsistent list of terms (NORA begrippenkader) will be formed. Digital architects emphasise that common terms should be reused, which is more important than constructing a relationship between two terms used in two reference architectures. So, one can state that implicit relationships between reference architectures by using the same terms for concepts is more important than constructing explicit relationships between the reference architectures.

Furthermore, some digital architects state that all reference architectures should have shared principles. So, the following questions should be asked: What is the goal of a reference architecture? And how should the reference architecture be described? When these questions are answered and digital architects agree on the answers, relationships between components of reference architectures can be defined and established. With these relationships, coherence between reference architectures can be improved.

Defining and establishing relationships between components of reference architectures is merely one aspect of improving the coherence between reference architectures. However, when these relationships are not meaningful, it is not beneficial for the coherence between reference architectures. So, a prerequisite for defining and establishing relationships between components of reference architectures is that the relationships are meaningful and contribute to improved coherence.

4.4 Desire for improved coherence

During unstructured interviews at the start of the research project, the digital architects stated that many digital architects have a desire for improved coherence between reference architectures. They stated there is a consensus reached about this desire within the architecture community. With the opinions of 44 digital architects, participating in the focus group or the survey, there was agreed upon this desire.

4.4.1 Drivers

The desire for improved coherence can also be explained by multiple drivers. From the findings of the focus group, digital architects have three drivers for improved coherence. These drivers are:

1. An intrinsic motivation to not reinvent the wheel, but reuse good examples.
2. Improving the understandability of terms within different reference architectures.
3. Leveraging each other's knowledge will improve the quality of reference architectures.

Digital architects who participated in the survey agree on the fact that these drivers are important. However, the driver that is considered the most important is the first driver. 36 respondents considered this driver as 'important' or 'very important'. The third driver is the least important driver, according to the respondents. In figure 4.4 below, one can see how important the drivers are according to the respondents.

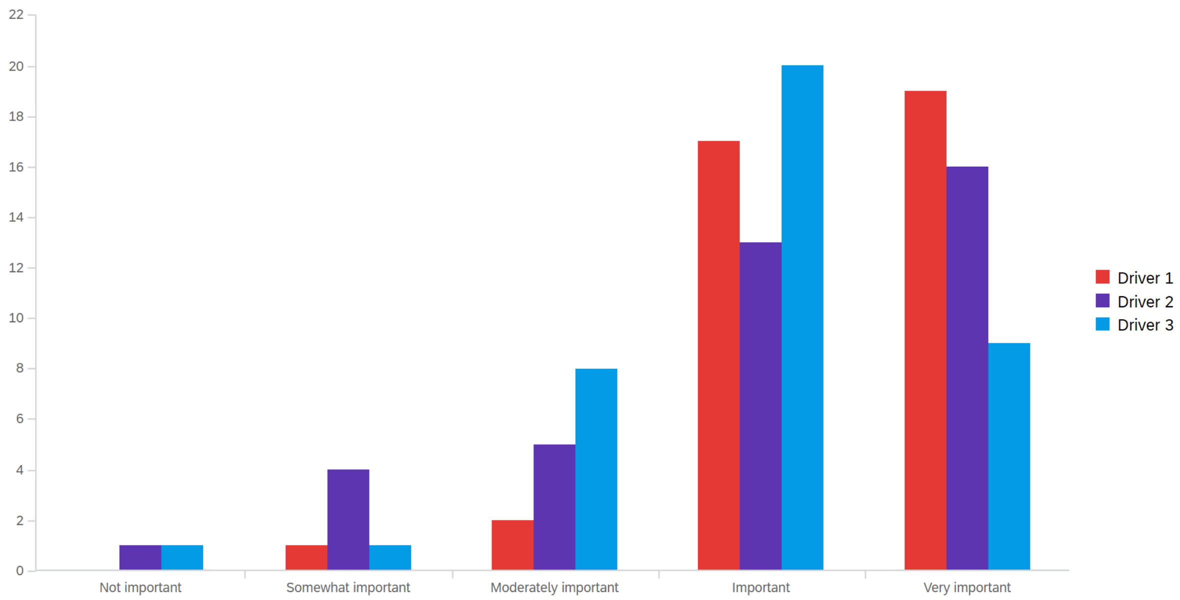


Figure 4.4: Importance of drivers

Besides assessing the drivers by giving them a label from 'not important' to 'very important', respondents were asked to explain their choices. For the first driver, digital architects state that reusing good examples improves efficiency and reduces costs (time), which is very important for organisations in the public sector. Public money must be spent wisely and therefore good examples should be reused. Furthermore, digital architects state that the quality of reference architectures can be improved by reusing good examples. Also, reusing good examples promotes a support base for architectural decisions. Moreover, it improves the consistency of reference architectures, as components of a reference architecture are consistently used in several other reference architectures. Lastly, good examples inspire digital architects for their concrete architectures. To conclude, the most important factors of the first driver are an improved efficiency of developing reference architectures and an improved quality of reference architectures.

The second driver is about the understandability of related terms in different reference architectures. 29 of the respondents consider this driver as 'important' or 'very important'. Respondents expressed a desire for supported definitions of terms to prevent prolonged discussions about these definitions. These definitions are primarily important for cross-sectoral collaborations between organisations. However, terms can have different meanings in different contexts, so the explanation of a term is needed in every context. So, when terms have a divergent definition in a certain reference architecture, this must be explicitly stated.

The third driver is about leveraging each other's knowledge, which improves the quality of reference architectures. 29 of the respondents consider this driver as 'important' or 'very important'. Some digital architects state that this driver is an extension of the first driver. Again, this leads to improved efficiency in developing reference architectures, but it also reduces the risk of making mistakes during the development of a reference architecture. When synergy of knowledge can be achieved, reference architectures reach a higher quality.

4.4.2 Other drivers

Furthermore, respondents came up with extra drivers that were not mentioned during the focus group. First, improving the collaboration between sectors was mentioned as a driver. One example of such a collaboration is migration, where organisations from multiple sectors should collaborate and exchange data to handle asylum requests. Another example is that of the educational sector, where 'a lifelong development' is a common driver. To support this driver, multiple organisations should be able to handle and exchange data about educational participants effectively.

The second driver is the reduction of complexity. Related domains in the public sector have common challenges that can only be solved by having collaborations between the domains and their reference architectures. These reference architectures can also be reduced in size when the unnecessary repetition of information is reduced. Information that belongs to a certain reference architecture should be referred to by another reference architecture instead of repeating the same information in that reference architecture. When reference architectures are smaller in size, the complexity can be reduced.

The third driver is that in a short amount of time, much is expected from digital architects. When information is findable and accessible in a short amount of time, a concrete (start) architecture can be developed fast. Therefore, digital architects need to know in which reference architecture, specific information can be found. When reference architectures are coherent and many explicit relationships between them exist, the source of information can be more easily found.

The fourth driver is improving the interoperability on all architectural layers. This can lead to improved collaboration between organisations in different sectors.

The fifth driver is to reach a uniform way of describing and modelling reference architectures. When having a harmonised way of doing this, reusing knowledge from reference architectures can be made easier.

Other drivers that were mentioned are the reduction of costs, the reuse of software implementations, the continual improvement of government services and the improved maintainability of reference architectures.

4.5 Problems of a lack of coherence

The lack of coherence between reference architectures leads to problems, primarily for digital architects within the public sector. During the focus group, four problems that digital architects face were mentioned. These problems are stated below.

1. Information in reference architectures sometimes does not explicitly refer to information in other reference architectures.
2. When multiple reference architectures are used to create a specific (Enterprise) architecture, they sometimes contradict each other.
3. At present, coherence mainly occurs through ad hoc collaborations between architects.

4. Information in different reference architectures that is common (largely the same) is not centrally accessible.

Digital architects who participated in the survey do not all agree on the problems that were mentioned by the participants of the focus group. Respondents were asked to assess the problems according to their experiences as digital architects. The problem that was considered the largest is problem 4, but there are no significant differences between the problems. In figure 4.5 below the size of the problems, considered by the respondents, can be seen.

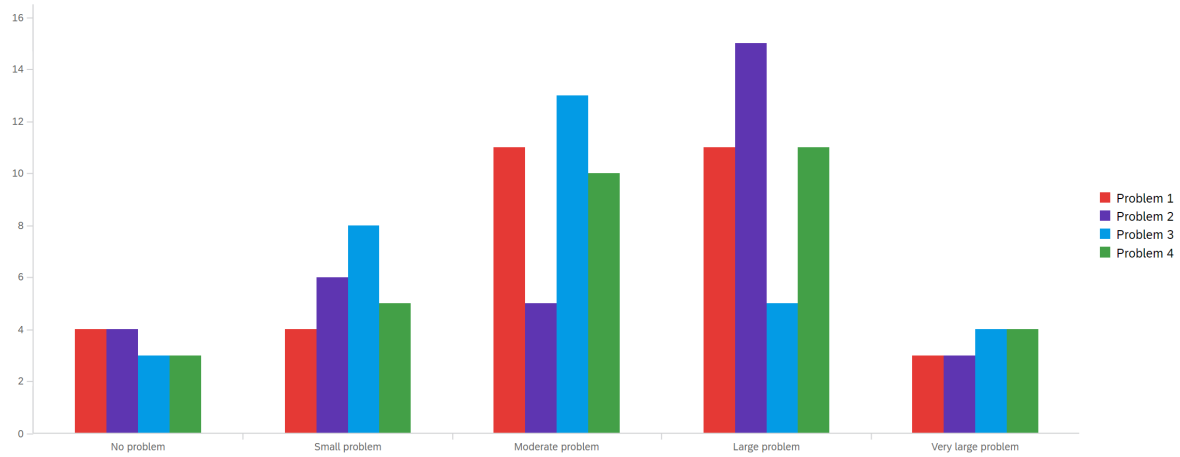


Figure 4.5: Problem size considered by the respondents

Next to assessing the problems on size, the explanations of the digital architects for their choices were also asked. The first problem is not always considered as a large problem, or even as a problem at all. It is considered a (very) large problem by 14 digital architects. However, multiple digital architects state that not referring to information in other reference architectures can lead to inconsistencies between reference architectures.

The second problem is considered a (very) large problem by 18 digital architects. They state that contradictions within multiple reference architectures can lead to difficult decisions during the development of a specific (Enterprise) architecture. When this occurs in practice, enterprise architects often ignore the reference architectures. Furthermore, the respondents indicate that these contradictions are often differences between reference architectures because the context differs.

The third problem is considered a small problem by the respondents. Only 9 digital architects consider this as a (very) large problem. Digital architects state that structured and planned collaboration between architects is much better, however, it is good that these initiatives exist. They also mention that it is very difficult to govern collaboration between architects from different reference architectures.

The fourth problem is on average considered the largest by the respondents, however, the answers again vary much. Digital architects state that reference architectures should have references to each other, instead of copying the information multiple times. The problem can also be considered as an extension of the first problem. When no references between information are made it can again lead to inconsistencies between reference architectures.

4.5.1 Other problems

Respondents were also asked to come up with other problems they experience or know. First, government-wide challenges are not elaborated upon by a central reference architecture. A government-wide challenge one can think of is for example new legislation. When this legislation touches multiple domains, multiple reference architectures must deal with that legislation. Currently, this is not centrally arranged.

Furthermore, many reference architectures are also internally not coherent, as there exist many inconsistencies within the reference architectures. So, to improve the coherence between reference architectures, first, the coherence within a reference architecture must be improved.

Moreover, due to the absence of an overarching overview, multiple initiatives for improvements of reference architectures start separately. Without coherence, there is no overarching roadmap possible, so the pace, dependencies and impact of projects are not visible. This also leads to duplicated work by digital architects.

Another problem is that of a difference in describing and modelling information in reference architectures. This leads to reference architectures that are incomparable with each other.

Lastly, a lack of coherence between reference architectures leads to a lack of coherence between the concrete architectures of organisations from multiple sectors. When these organisations want to exchange data, there are most probably interoperability issues.

4.6 Stakeholder analysis

For a research project in Design Science, it is important to identify the involved stakeholders. In the first phase of the Design Science Methodology, the problem investigation phase, the involved stakeholders should be analysed. A stakeholder is a person, group of persons, or institution that is affected by the treatment of the problem [1].

At the start of the research project, unstructured interviews made it clear that digital architects are experiencing problems of a lack of coherence between reference architectures. During the focus group, it became clear that the community of digital architects within the Dutch public sector indeed experiences a lack of coherence between reference architectures. The survey results have confirmed this observation by validating that digital architects experience most of the problems. However, more stakeholders are experiencing problems and are influenced by a lack of coherence between reference architectures.

In the focus group, three other stakeholders were mentioned that are also experiencing problems of a lack of coherence between reference architectures. The stakeholders that were mentioned are information managers, IT project managers and software vendors. The respondents are not unanimous when it comes to stakeholders and how many problems they experience. In table 4.2 below one can see how digital architects think about the different stakeholders and how many problems they experience.

Stakeholder	No problems	Few problems	Several problems	Many problems	Very many problems
Digital architect	2 (5%)	5 (12.5%)	18 (45%)	11 (27.5%)	4 (10%)
IT project manager	9 (22.5%)	9 (22.5%)	12 (30%)	9 (22.5%)	1 (2.5%)
Software vendor	4 (10%)	11 (27.5%)	12 (30%)	12 (30%)	1 (2.5%)
Information manager	4 (10%)	11 (27.5%)	11 (27.5%)	11 (27.5%)	3 (7.5%)

Table 4.2: Stakeholders experiencing problems

It can be seen that digital architects are experiencing most of the problems, followed by information managers and software vendors. The IT project managers are experiencing the least problems, according to the digital architects who filled in the survey. Respondents were also asked to come up with other stakeholders who could also experience problems of a lack of coherence between reference architectures. These stakeholders were initially not mentioned during the focus group and are listed below.

- CIO office
- Management

- Policymaker
- Business analyst
- Information analyst

The stakeholders that are listed are primarily users of reference architectures, whereas the digital architects can also be the administrators of reference architectures. Digital architects are often contributing to the contents of reference architectures. Users of reference architectures can eventually take advantage of improved coherence between reference architectures.

4.7 Current state of coherence

There is a lack of coherence between reference architectures based on the opinions of many digital architects. When combining the results of the focus group and the survey, a redefined ArchiMate view was made to provide an overview of the stakeholders, their drivers for improved coherence and the problems of a lack of coherence. This view can be seen in figure 4.6. The Dutch version of this ArchiMate view can be found in appendix I. The motivation elements have differences in opacity. The higher the opacity, the more digital architects agree on this element. When an element has the lowest opacity of the view, it is agreed upon by 1 or 2 digital architects. When an element has a full opacity, it is agreed upon by at least 5 digital architects. Elements with half the opacity are agreed upon by 3 or 4 digital architects. The stakeholders, drivers and problems that are mentioned by the focus group participants are all validated by at least 5 digital architects, so they have full opacity.

At this moment, coherence 'emerges' mainly through ad hoc initiatives within reference architectures. The initiatives often have a bottom-up-like form, where a more specific reference architecture describes the relationship with a more abstract reference architecture. The coherence, if explicitly present, is currently merely textually described and can be found on platforms such as WikiXL, on other websites or in documents where reference architectures are documented. For example, the Reference Education Sector Architecture (ROSA) has a page[1] on WikiXL on which the coherence with other reference architectures is described. In the case of other reference architectures, there is a lack of information about the coherence with other reference architectures.

While individual reference architectures are a majority of the time well-organised and structured within semantic wikis, efforts should be directed towards designing a standardised approach for linking reference architectures. This would contribute to an improved coherence between reference architectures, unlocking the full potential of reference architectures in guiding digital architects with consistent and high-quality reference architectures across diverse domains within the Dutch public sector. At this moment, architectural knowledge of reference architectures lives within isolated repositories, i.e. a single semantic wiki. So, there is a need to break out of these single repositories and link the components of different repositories.

To sum up, there is not a collective approach for improving the coherence between reference architectures. Moreover, administrators of reference architectures carry their responsibility for the content and structure of reference architectures. This hinders the collaboration for improving coherence, as administrators of reference architectures have divergent and not always conforming interests. This highlights the desire for a generic method that can be used to improve the coherence between reference architectures within the Dutch public sector. To improve that coherence, multiple aspects of that coherence should be improved. One of these aspects is defining and establishing relationships between reference architectures, to make these relationships explicit and findable. More specifically, relationships between components of reference architectures are needed. What types of relationships are needed is discussed in section 4.8. So, in this research, a method will be designed for defining and establishing relationships between components of reference architectures.

[1] ROSA, Samenhang met andere architecturen `https://rosa.wikixl.nl/index.php/Samenhang_met_andere_architecturen`

4.7.1 Common base of reference architectures

Defining and establishing relationships between components of reference architectures is not sufficient for arriving at improved coherence. Multiple aspects of coherence should be improved. Digital architects state that before relationships can be defined and established, first there should be started with a common base about the goal, core values and contents of reference architectures. So, define the goals and the core values of reference architectures, and define how reference architectures should be described and modelled. By core values, the following issues are meant:

- Policy frameworks (general laws and regulations and general policy for service provision)
- Core values of Service Delivery
- Quality goals
- Generic functions
- Architectural principles
- Standards
- Building blocks (Facilities)
- Themes
- Conceptual framework (Architectural concepts and Information objects)

After that, developers and administrators of reference architectures can come to a common meta-model and conceptual framework. So, answers should be given to the questions: What is meant by a 'business function' or an 'information object', and what is meant by the term 'reference component'? And how do these concepts relate to each other in an architecture model? Also, the use of different terms and definitions should be aligned between different reference architectures. When all these factors are agreed upon, relationships between components of reference architectures can be defined and established. Furthermore, these relationships should be meaningful and contribute to the coherence between reference architectures.

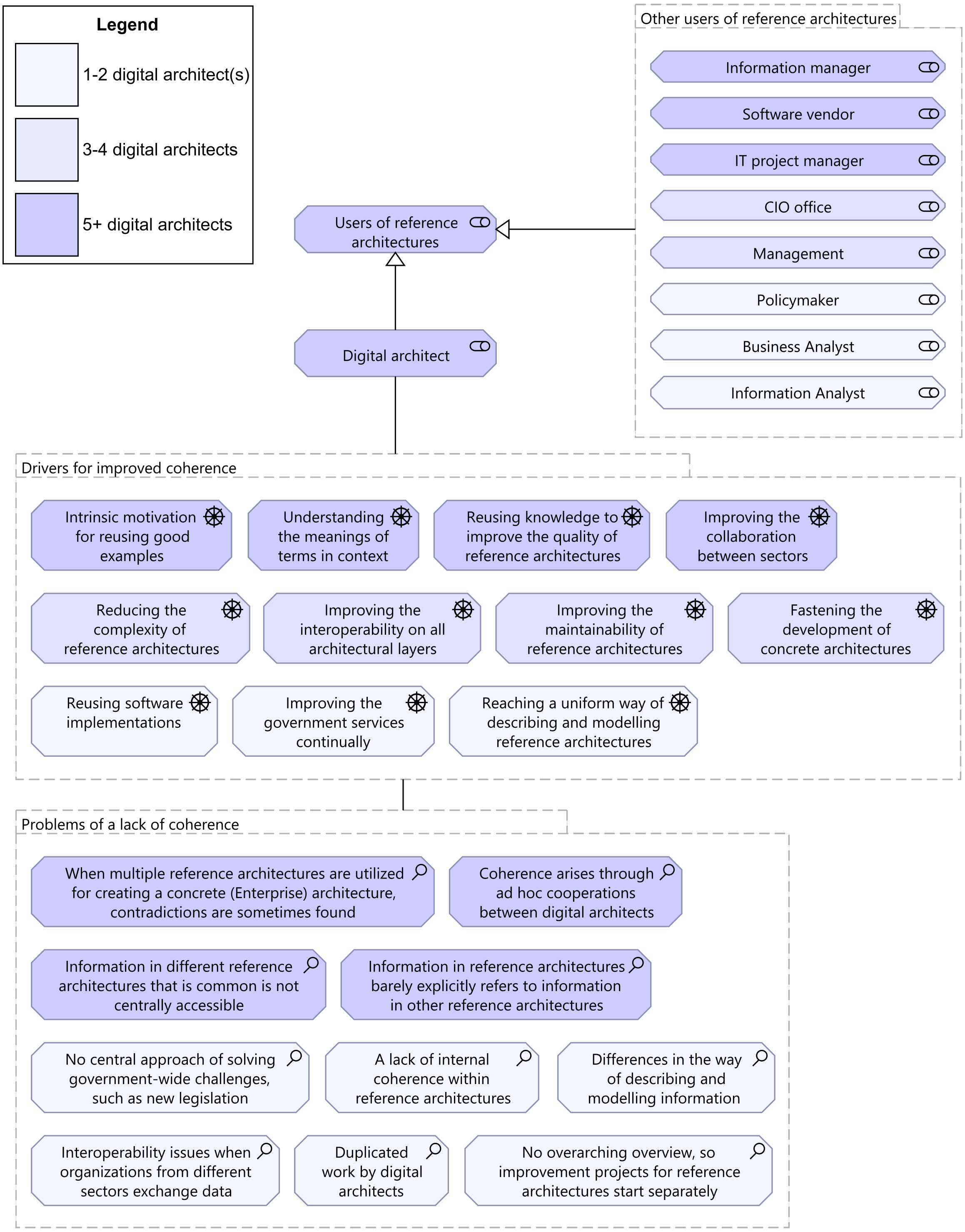


Figure 4.6: Validated ArchiMate motivation view

4.8 Desired relationships between reference architectures

As discussed in the previous section, defining and establishing relationships between components of reference architectures is merely one aspect of improving coherence. Before defining and establishing these relationships, it must first be known what type of relationships are needed. In the focus group, a discussion was initiated on the type of relationships. In the last question of the survey, a couple of examples of relationships between reference architectures were given to the digital architects. Respondents were eventually asked to come up with examples of desired relationships between components of reference architectures. In total, 27 digital architects have responded to this question.

4.8.1 Examples of relationships

Relationships can take different forms. In the focus group, relationships such as ’reuse of’ and ’additional to’ were mentioned as important ones. Another example of a relationship that should be made explicit is the reuse of a principle from another reference architecture. Furthermore a relationship between two similar terms in different reference architectures, and thus in different contexts, can be made. Lastly, when two components are the same, and are used in the same way in two reference architectures, a reference to the original component should be made.

The respondents provided many examples of desired relationships between reference architectures. The digital architects agreed with the examples that were already given by the participants of the focus group. Primarily the ’reuse of’ relationship, which means that the original elements of architecture models can be used in another architecture model. This way, references can be made instead of copies, which reduces the risk of mistakes. However, the ’reuse of’ relationship can be further specified by having the types ’is equal to’, ’expands’ and ’specifies further’. Besides the ’is equal to’ relationship, the ’is not equal to’ relationship is also relevant, as components can be named the same, but the meaning in another context can differ.

4.8.2 Desired relationship between ArchiMate elements

Reference architectures primarily consist of principles and architecture models, so these principles and the elements of the architecture models should be linked to each other. Often, principles are also elements of specific architecture models. Digital architects state that relationships can be made between goals, architecture principles, design principles, design frameworks, architecture patterns, roles, business functions, business processes, terms and reference components (referentiecomponenten). However, the relationships between these components need to be established and machine-readable. Most of the aforementioned components of reference architectures are modelled in ArchiMate and are thus ArchiMate elements. So, to establish relationships between components of reference architectures, these ArchiMate elements should be linked, which improves the coherence between these elements. Eventually, it should be possible to link all ArchiMate elements to each other.

To provide more clarity on the type of relationship this research is about, a small and exceptionally simplified ArchiMate model is developed. This model can be found in figure 4.7. The visual group element represents a reference architecture, which contains multiple ArchiMate views. These views consist of multiple ArchiMate elements. Whenever an ArchiMate element from one reference architecture is related to an ArchiMate element in another reference architecture, an explicit relationship should be defined and established.

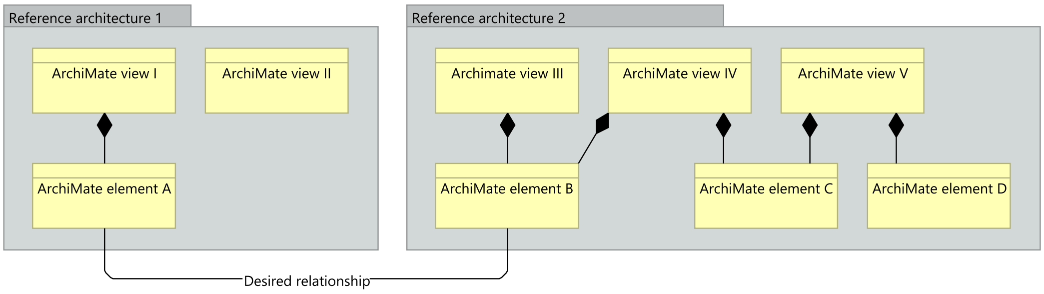


Figure 4.7: Desired relationship between ArchiMate elements of reference architectures

4.8.3 Methods and techniques for linking ArchiMate elements

The desired relationship is one between two ArchiMate elements, which is a relationship between two data elements. These ArchiMate elements are currently often published on a semantic wiki as data elements and have a unique Uniform Resource Locator (URL), which is a subclass of the Uniform Resource Identifier (URI). And when searching for this URL on the web, information about the specific ArchiMate element can be found. When one ArchiMate element is linked to another ArchiMate element, the additional information can be shown on the wiki pages of these ArchiMate elements. So, when linking multiple ArchiMate elements to each other, a structured web of data arises. This web of structured and interlinked data essentially conforms to the principles of linked data, outlined by Berners-Lee [60]. These principles are stated below.

- Use URIs as names for things
- Use HTTP URIs so that people can look up those names.
- When someone looks up a URI, provide useful information, using the standards (RDF*, SPARQL)
- Include links to other URIs. so that they can discover more things.

In section 3.4.1, there have been explained that RDF and SPARQL are powerful semantic web technologies to structure, publish and connect linked data. So, using linked data principles and techniques, a machine can explore the web of data. The data elements in this case are the ArchiMate elements in architecture models of reference architectures, published on a semantic wiki. When linking these data elements from different data sources, the semantic wikis, an improved coherence between the reference architectures can emerge. Also, ArchiMate elements can be enriched with additional information about their relationships with ArchiMate elements of other reference architectures. This may significantly increase the value of architecture knowledge [56].

At this moment, no standardised method exists for defining and establishing relationships between different architectures. In the literature, papers can be found about the relationships between architectural views of a specific system. However, in this research, the focus is on the relationships between components of different reference architectures. From experience in the Dutch public sector, it can also be stated that no method exists for defining and establishing relationships between different reference architectures.

4.9 Conclusion

This chapter investigated the current state of coherence between reference architectures within the Dutch public sector. First, a definition of ’coherence’ is given. Next, the desire for improved coherence among digital architects is explained, as driven by factors such as efficiency and reuse of knowledge. After that, the problems of a lack of coherence are given and the stakeholders experiencing these problems are highlighted.

Eventually, the current state of coherence is concluded and the desired relationships between reference architectures are formulated. Defining and establishing relationships is merely one aspect of improving the coherence between reference architectures. This research focuses on that single aspect. After that, examples of relationships are given, such as 'reuse of' and 'specifies further'. Eventually, the desired relationship between ArchiMate elements, which are the components of reference architectures, is further explained.

Moreover, no methods and techniques are found for defining and establishing relationships between components of reference architectures. So, there is a desire to design a method to define and establish relationships between components of reference architectures. In chapter 5, this method is designed, consisting of a step-by-step (technical) guide that can be followed by digital architects to define and establish relationships between related ArchiMate elements of reference architectures within the Dutch public sector. The additional information these relationships provide can be useful for digital architects and many other stakeholders using reference architectures.

Using linked data principles and techniques, relationships between ArchiMate elements can be established. These relationships can eventually provide digital architects and other stakeholders with additional information about a specific ArchiMate element and how it is related to ArchiMate elements in other reference architectures. Consequently, a more suitable interpretation of the relationships between entire reference architectures can be achieved.

Chapter 5

Method design

The primary goal of this research is to design a method to improve the coherence between the reference architectures within the Dutch public sector. One of the aspects of improving coherence is to realise relationships between components of reference architectures. In this chapter, a method will be designed that guides digital architects in defining and establishing relationships between components of reference architectures. First, requirements are specified to which the method should conform. After that, the decisions made during the design of the method are discussed, including the adoption of ArchiMate as the modelling language for the method. After that, the phases and included steps of the method are explained. The method will be a step-by-step approach for defining and establishing relationships between components of given reference architectures within the Dutch public sector, whose architectural knowledge is published on a semantic wiki.

5.1 Method requirements

To improve the coherence between reference architectures, explicit and established relationships are needed between components of reference architectures within the Dutch public sector. In a few reference architectures information is available about how the reference architectures have relationships with other reference architectures. However, this information is stated as text on web pages, which makes it only useful for humans to understand. When relationships are only textually described, relationships can for example not automatically be queried. Hence, a way to establish and store relationships between components of reference architectures must be designed.

Defining and establishing relationships between components of reference architectures contributes to improved coherence when these relationships are meaningful and add relevant information. With the method designed in this research, relationships are defined and established between existing reference architectures, so no changes are made to the contents of reference architectures. However, the content of reference architectures should probably be changed to arrive at improved coherence.

As earlier mentioned, these components of reference architectures are in fact ArchiMate elements. ArchiMate elements that are part of an ArchiMate model have relationships with other ArchiMate elements in the same model. However, when establishing relationships between reference architectures, relationships between ArchiMate elements of architecture models of different reference architecture should be made. These relationships should be machine-readable.

For the design of a method, it is important to understand the definition of the term method. In this thesis, a method is interpreted as the following: A method is a systematic procedure or technique to a particular discipline for accomplishing or approaching something [61]. In this case, the method should define and establish relationships between ArchiMate elements of reference architectures to provide additional information about that ArchiMate element to stakeholders interested in the relationships of that ArchiMate element.

Before designing the method, the artefact of this research, the requirements of this method must be specified. This is an essential part of the Design Science Methodology by Wieringa [1] and belongs to the 'Treatment design' phase of the design cycle. These requirements describe the desired properties of the method and are based on the desires of the stakeholders. The desires of the stakeholders were investigated by conducting the focus group and survey with digital architects in the Dutch public sector. These desires, such as the desired relationships between reference architectures, are discussed in section 4.8.

In this research, two categories of requirements are specified for the artefact: functional and non-functional requirements. Functional requirements describe the functions an artefact must perform. Evaluating the fulfilment of a functional requirement is typically straightforward, as it involves testing whether the required functionality is present.

The alternative category includes the non-functional requirements, which are global properties of the interaction between the artefact and its context. These requirements outline how the system executes a specific function. Non-functional requirements do not directly influence the functionality of the artefact, but they influence the performance of it.

Distinguishing between the two categories, functional requirements guarantee the delivery of a functional artefact, while non-functional requirements focus on optimising its performance. Therefore, to ensure both functionality and practicality of the method, it is imperative to specify both functional and non-functional requirements. So, in section 5.1.1 and 5.1.2 the functional and non-functional requirements are specified respectively.

5.1.1 Functional requirements

As earlier mentioned, the functional requirements can easily be evaluated, by testing the existence of the functions of the method. Requirement F1 is concerned with the guidance the method must provide to digital architects. Requirement F2 is concerned with the method's manual that explains what Linked Data is and how to use Linked Data techniques to establish relationships between two data elements. In this case, the data elements are ArchiMate elements that are part of a large ArchiMate model that is published on a semantic wiki. Each ArchiMate element has an identifier, which is a URL with a unique identifier.

Requirements F3, F4, F5 and F6 are concerned with the technical guidance the method should provide to digital architects. This guidance is needed to develop an RDF-based data model, publish that data model, query that data model and eventually embed the queried information in the semantic wiki pages. Requirement F7 must ensure that the method establishes the relationships between ArchiMate elements of different reference architectures, which is the desire of digital architects and other stakeholders.

The functional requirements are described in table 5.1, together with a reasoning for their existence. Indicators are not needed to validate these requirements, as it can easily be seen whether a functionality exists.

	Functional requirement	Reasoning
F1	The method must provide guidance to digital architects.	The method must guide digital architects in analysing the reference architectures and their implicit relationships.
F2	The method must provide a technical manual on Linked Data.	The method must provide a technical manual on how to use Linked Data techniques to establish relationships between two data elements. In this case, the data elements are ArchiMate elements.
F3	The method must provide technical guidance to digital architects.	The method must provide technical steps to develop a data model consisting of Linked Data-based relationships between related ArchiMate elements of different reference architectures.
F4	The method must provide technical guidance on the publication of the data model	The method must provide technical steps to publish a data model on a triple store.
F5	The method must provide technical guidance on querying the data model.	The method must provide technical steps to write a SPARQL query that can retrieve the desired information from the published data model.
F6	The method must provide technical guidance on embedding the queried information.	The method must provide technical steps to embed the SPARQL query results in the semantic wiki pages.
F7	The method must establish relationships between reference architectures.	The method must establish relationships between related ArchiMate elements of different reference architectures using Linked Data techniques and supported relationship types. These relationships must be visible on the semantic wikis on which the reference architectures are published.

Table 5.1: Functional requirements of the method

5.1.2 Non-functional requirements

In this section, the non-functional requirements are described as seen in table 5.2. Besides the requirements and the reasoning for their existence, indicators are given that can be used to validate the requirements. These indicators can be found in table 5.3.

Requirements NF1 and NF3 are about the understandability and usability of the method by digital architects. It must not be the case that digital architects with basic knowledge of Linked Data techniques and experience with reference architectures need time to learn how the method can be used.

Requirements NF2, NF4 and NF5 are about the applicability and compatibility of the method. The method must namely be compatible with all reference architectures within the Dutch public sector that are published on a semantic wiki. Furthermore, the method must be compatible with any triple store and all supported relationship types.

Lastly, requirement NF6 is about the performance of semantic wikis. It must not be the case that querying the data model from the semantic wiki pages leads to delays in loading those wiki pages.

	Non-functional requirement	Reasoning
NF1	The method is self-explanatory.	From the start, it must be clear for digital architects how to use the method and what they should do in each phase and corresponding steps.
NF2	The method must be applicable to all reference architectures within the Dutch public sector.	The method must be widely applicable in the Dutch public sector. It must be applicable to all reference architectures that are published on a semantic wiki.
NF3	The method must be understandable and usable by any digital architect.	The method must be understandable and usable for digital architects with basic knowledge of Linked Data techniques and experience with reference architectures within the Dutch public sector.
NF4	The method must be compatible with any triple store.	It must be possible to use the method in combination with any triple store, compatible with RDF-based data models.
NF5	The method must be compatible with all supported relationship types.	The method must be compatible with all relationship types, supported by the SKOS standard or ArchiMate ontology, e.g. 'broader' in SKOS and 'specialization' in ArchiMate.
NF6	The method should avoid causing delays on semantic wikis.	The method should avoid causing delays by embedding the additional information from the data model into the semantic wikis on which reference architectures are published.

Table 5.2: Non-functional requirements of the method

Table 5.3 presents an overview of all non-functional requirements, accompanied by an indicator that operationalises the requirement. With these indicators, the non-functional requirements can be validated. Not every non-functional requirement can be validated as this research does not cover the treatment implementation phase of the design cycle of Wieringa [1]. Ideally, these requirements should be tested in an environment where the artefact is implemented. However, the treatment implementation phase is out of scope in this research, so an ideal test environment can not be created.

	Non-functional requirement	Indicator
NF1	The method is self-explanatory.	Digital architects do not require time how to use the method. So, they can immediately start using the method.
NF2	The method must be applicable to all reference architectures within the Dutch public sector.	The method has no compatibility issues with a specific type of reference architecture. Each reference architecture published on a semantic wiki must be compatible.
NF3	The method must be understandable and usable by any digital architect.	Digital architects do not require time to learn the method. Digital architects must be able to instantly use the method effectively.
NF4	The method must be compatible with any triple store.	All triple stores accepting RDF-based data models can be used.
NF5	The method must be compatible with all supported relationship types.	No relationship type can be found that can not be used to establish relationships between ArchiMate elements in an RDF-based data model.
NF6	The method should avoid causing delays on semantic wikis.	The loading time of a semantic wiki page querying the data model must be equal to a semantic wiki page without an embedded query to the data model.

Table 5.3: Indicators for the non-functional requirements

5.2 Design decisions

The design of the artefact for this research has materialised in the form of a method. Since the artefact must be practically implementable and should describe how digital architects can define and establish relationships between Archimate elements, a method is the most suitable type of artefact. The design of the method is based on data collected from the focus group, the survey and unstructured interviews. These research methods are described in sections 2.4, 2.5 and 2.3. These methods can be considered reliable sources of information if they are used appropriately, which is the case when these methods are objectively processed and the results purely reflect the thinking of the participants and respondents.

In the case of the focus group, a framework is used to analyse the data and in the case of the survey, the data analysis tool is used of the Qualtrics survey software. The unstructured interviews are not in a proper way analysed, however, it has guided the researcher in the design process of the method. The reason behind not properly analysing these interviews is that they are not documented or recorded, so transcripts were not made.

Eventually, the method must guide digital architects in defining and establishing relationships between ArchiMate elements of different reference architectures published on semantic wikis. The method consists of eight phases, that need to be followed by the digital architect. The first four phases consist of non-technical steps to analyse the existing reference architectures, prepare these reference architectures, analyse the ArchiMate elements that need to be related and define relationships between those ArchiMate elements.

The last four phases include technical steps to establish the relationships between ArchiMate elements in an RDF-based data model. Afterwards, this data model should be published on a triple store, so it can be queried from a semantic wiki. Further details about these steps can be found in the method description.

An overview of the method is designed using the modelling language ArchiMate as many digital architects are familiar with this modelling language. The language was already introduced in section 3.1 and a concise meta-model of the language can be found in figure 3.2. The complete ArchiMate language could have been used, however, some elements are simply not needed. The following ArchiMate elements are eventually used to design this overview: Business function, Business process, Application component, Application service and Data object. The explanations [3] of the used ArchiMate elements can be found in table 5.4.

ArchiMate element	Explanation
Business Function	A business function represents a collection of business behavior based on a chosen set of criteria such as required business resources and/or competencies, and is managed or performed as a whole.
Business Process	A business process represents a sequence of business behaviors that achieves a specific result such as a defined set of products or business services.
Application Component	An application component represents an encapsulation of application functionality aligned to implementation structure, which is modular and replaceable.
Application Service	An application service represents an explicitly defined exposed application behavior.
Data Object	A data object represents data structured for automated processing.

Table 5.4: Used ArchiMate elements in the method

These ArchiMate elements are used to develop a view that explains to the digital architect what to do in each phase and step. The phases of the method are modelled by 'business functions', whereas the steps of the phases are modelled by 'business processes'. A semantic wiki is modelled as an 'application component', which is also the case for the triple store. The triple store has a service that serves the process of publishing a data model on the triple store, so this is an 'application service'. 'Data objects' are used for the SKOS standard and ArchiMate ontology. The same holds for the RDF-based data model, which is a TURTLE file. The SPARQL query, which can be seen as a piece of code, is also modelled as a 'data object'. Eventually, the additional information about the relationships of ArchiMate elements with other ArchiMate elements in other reference architectures is also modelled as a 'data object'. This data object can be accessed by the semantic wiki and can be seen by stakeholders consulting the wiki pages of ArchiMate elements.

5.3 The method

In this section, the method that can be used by digital architects to define and establish relationships between ArchiMate elements of different reference architectures is presented. Relationships are considered between existing reference architectures, without changes being made to the reference architectures. The method consists of eight phases, with each phase consisting of multiple steps that can be followed by a digital architect. The phases of the method are:

- (1) Analysis of the reference architectures,
- (2) Preparation of the reference architectures,
- (3) Identification and analysis of implicit relationships,
- (4) Selection of relationship types,
- (5) Implementation of relationships,
- (6) Publication of the data model on a triple store,
- (7) Query triple store
- (8) Inclusion of additional information in a semantic wiki page.

The goal of the method is to first define relationships between components of reference architectures, in this case, relationships between ArchiMate elements. After that, a data model consisting of these relationships can be developed. This data model can be published on a triple store and queried by a semantic wiki. The information that can be retrieved by this query becomes visible on the semantic wiki of a reference architecture. This information is useful primarily for digital architects, but also for other stakeholders. The phases consist of several steps that digital architects need to follow. Eventually, the method is modelled in the ArchiMate language to provide a clear overview of all the phases and included steps.

5.3.1 Phases of the method

Phase 1: Analysis of the reference architectures

In the first phase, a clear understanding of the reference architectures that need to be related to each other should be obtained. This can be done by analysing the underlying knowledge models of the reference architectures and by analysing the content of the semantic wikis. Furthermore, the principles and architecture models should be analysed. Moreover, when there is information available about how to use the wikis for the specific reference architecture, use that information to browse through the wiki contents. Moreover, it is advised to interview experts who have knowledge of and experience with the reference architectures. Lastly, when other information is available about how reference architectures are related to each other, consult that information.

Phase 2: Preparation of the reference architectures

In this phase, the reference architectures that should be related to each other should be prepared. Preparing the reference architecture means that every component of the reference architecture that needs to be related to another component of another reference architecture must have a corresponding ArchiMate element. When this is already the case for every component that needs to be related, then this step is optional. ArchiMate elements in reference architectures should have a unique identifier, which should be included in the URL of that element. This URL points to a specific ArchiMate element, so it is an instance of the complete ArchiMate model. A generic URL to an ArchiMate element of a reference architecture published on the semantic wiki WikiXL is for example:
$http://ReferenceArchitecture.wikixl.nl/ArchiMateModelName/ArchiMateElementID$.
These URLs can eventually be used to link related elements to each other. This way, the relationships between reference architectures can be established.

Phase 3: Identification and analysis of implicit relationships

In this phase, the components of the reference architectures that should be related to components of other reference architectures should be analysed. To do this, ArchiMate elements of the different reference architectures should be analysed to highlight the differences or similarities between the elements. After analysing the differences or similarities, the relationships can be identified. It can also be the case that no relationships are found between ArchiMate elements of different reference architectures. In principle, three scenarios exist, which are listed below:

- ArchiMate element X of reference architecture 1 can be related to ArchiMate element Y of reference architecture 2.
- ArchiMate element X of reference architecture 1 can not be related to any ArchiMate element of reference architecture 2, as X represents an aspect that is outside the scope of reference architecture 2.
- ArchiMate element X of reference architecture 1 can not be related to any ArchiMate element of reference architecture 2, despite the fact that X represents an aspect that is (partially) within the scope of reference architecture 2. This occurs when no suitable relationship type can be found between the two ArchiMate elements.

After that, the relationships between the related ArchiMate elements should be named and defined, so what type of relationship it is. All these defined relationships should be documented to establish them in one of the following steps.

Phase 4: Selection of relationship types

In this phase, the types of relationships should be selected. So, when an implicit relationship between two ArchiMate elements is identified, the type of relationship should be selected. Many types of relationships can be expressed using Linked Data relationship types or the ArchiMate language itself. An example of a relationship is the 'broader'/'narrower' relationship that is available in SKOS [62]. However, within the ArchiMate language also many relationship types exist that can be used. For each relationship, the most suitable relationship type should be selected. In the following two paragraphs, the Simple Knowledge Organization System SKOS and the ArchiMate language and their relationship types are explained.

Simple Knowledge Organization System relationships The Simple Knowledge Organization System (SKOS) data model is formally defined as an OWL Full ontology [62]. SKOS data are expressed as RDF triples and may be encoded using any concrete RDF syntax, such as RDF/XML or Turtle. The SKOS data model views a Knowledge Organisation System (KOS) as a concept scheme, comprising a set of concepts. These concept schemes and concepts are identified by URIs. The following properties belong to SKOS:

- SKOS concepts can be labelled.
- SKOS concepts can be assigned with one or more notations.
- SKOS concepts can be documented with notes of various types, called documentation properties.
- SKOS concepts can be linked to other SKOS concepts.
- SKOS concepts can be grouped into collections, these collections can be labelled and ordered.
- SKOS concepts can be mapped to other SKOS concepts in different concept schemes.

In SKOS, different types of relationships exist that can be used to link subjects and objects to each other. The relationship types are all instances of the ObjectProperty of the Web Ontology Language (OWL) ontology. All the SKOS relationship types are sub-properties of semanticRelation. In table 5.5 these relationship types are presented and a description of them is given.

Relationship Type	Description
semanticRelation	semanticRelation is used when a link between two concepts is inherent in the meaning of the linked concepts.
broader	broader is used to assert a direct hierarchical link between two concepts. One concept is broader in meaning than the other.
narrower	narrower is used to assert a direct hierarchical link between two concepts. One concept is narrower in meaning than the other.
related	related makes an association relationship between two concepts without hierarchy or generality.
broaderTransitive	broaderTransitive means the same as broader and it is transitive. This means that when A is broader than B and B is broader than C, then A is broader than C.
narrowerTransitive	narrowerTransitive means the same as narrower and it is transitive. This means that when A is narrower than B and B is narrower than C, then A is narrower than C.

Table 5.5: SKOS relationship types

ArchiMate relationships In ArchiMate many relationship types exist that can be used internally in architecture models. However, these relationships can also be useful when relating ArchiMate elements of different architecture models. The relationship types can all be found in table 5.6.

Relationship Type	Description
Composition	Represents that an element consists of one or more other concepts.
Aggregation	Represents that an element combines one or more other concepts.
Assignment	Represents the allocation of responsibility, performance of behaviour, storage, or execution.
Realization	Represents that an entity plays a critical role in the creation, achievement, sustenance, or operation of a more abstract entity.
Serving	Represents that an element provides its functionality to another element.
Access	Represents the ability of behaviour and active structure elements to observe or act upon passive structure
Influence	Represents that an element affects the implementation or achievement of some motivation element.
Association	Represents an unspecified relationship, or one that is not represented by another ArchiMate relationship.
Triggering	Represents a temporal or causal relationship between elements.
Flow	Represents transfer from one element to another.
Specialization	Represents that an element is a particular kind of another element.

Table 5.6: ArchiMate relationship types

When agreed upon the type of relationship between two ArchiMate elements, select the most suitable relationship supported by the SKOS standard or ArchiMate ontology.

Phase 5: Implementation of relationships

When a relationship type is selected, this relationship should be implemented to establish it. This can be done by creating an RDF-based data model. To do this, first an RDF file should be created,

in which the relationships will be established. A language to structure such an RDF file is Terse RDF Triple Language (TURTLE). This file should start with defining the prefixes for the SKOS standard and ArchiMate ontology, for the relationship types. The relationship types available in ArchiMate are supported by an unofficial ArchiMate ontology[1] that is used. All reference architectures can have a prefix, which is part of the URL of a wiki page where an ArchiMate element can be found. A generic prefix for a reference architecture published on the semantic wiki WikiXL is for example:
$RefArch :< http : //ReferenceArchitecture.wikixl.nl/ >$.
After that, the specific ArchiMate elements should be defined with the proper relationship type to another ArchiMate element. The two unique identifiers of the ArchiMate elements should be used to link the ArchiMate elements. Establishing a relationship between two ArchiMate elements is thus a manual action, performed by the digital architect.

Phase 6: Publication of the data model on a triple store

An RDF data model, i.e. a RDF file, can not be queried by a SPARQL engine. So, when an RDF file with SKOS and ArchiMate relationships is developed, it should be published on a triple store. A triple store (or RDF store) is a purpose-built database for the storage and retrieval of triples through semantic queries. Such a triple store should also have the possibility to publish a SPARQL endpoint, to which SPARQL queries can be sent. This SPARQL endpoint is needed in the semantic wiki to link the triple store to the semantic wiki.

Phase 7: Query triple store

When a triple store is filled with RDF triples expressing the relationships between ArchiMate elements of reference architectures, this triple store should be linked to the semantic wiki. This can be done by including the SPARQL endpoint in the template of a wiki page. Semantic wikis can namely embed SPARQL queries in wiki pages by using the extension called 'LinkedWiki'[2] of MediaWiki. After that, a SPARQL query should be written that can get the related ArchiMate elements of a specific ArchiMate element.

Phase 8: Inclusion of additional information in a semantic wiki page

Users of reference architectures can benefit from the additional information of ArchiMate elements and their relationships when they can retrieve that information. Therefore, the results of the SPARQL query should be embedded in the wiki page. This can be done by including the SPARQL query in the template of a wiki page. The piece of code that needs to be embedded in the template can be found below.

```
{{#sparql:
PREFIX archimate: <http://bp4mc2.org/def/archimate#>
PREFIX skos: <http://www.w3.org/2004/02/skos/core#>
PREFIX RefArch: <http://{ReferenceArchitecture}.wikixl.nl/>

SELECT ?label ?relatedComponent ?relationshipType
WHERE {
{
RefArch:{{PAGENAME}} skos:related ?relatedComponent.
?relatedComponent skos:prefLabel ?label.
BIND ("Related" AS ?relationshipType)
}
UNION
{
RefArch:{{PAGENAME}} skos:narrower ?relatedComponent.
?relatedComponent skos:prefLabel ?label.
BIND ("Narrower" AS ?relationshipType)
```

[1] [unofficial] ArchiMate ontology, https://bp4mc2.org/def/archimate
[2] LinkedWiki extension, https://www.mediawiki.org/wiki/Extension:LinkedWiki

```
}
UNION
{
RefArch:{{PAGENAME}} skos:broader ?relatedComponent.
?relatedComponent skos:prefLabel ?label.
BIND ("Broader" AS ?relationshipType)
}
}
|config=https://api.triplydb.com/datasets/remcoovervelde/SRA/services/SRA
|headers=Naam, Link, Relatietype
}}
```

5.3.2 Overview of the method

To visualise the method an ArchiMate view is developed. The view consists of eight phases, modelled as business functions, in which the necessary steps are modelled as business processes. As mentioned, the first four phases are necessary to analyse the reference architectures, prepare the reference architectures and analyse the ArchiMate elements that should be related to each other. Furthermore, the relationship types of these relationships are selected, based on the supported SKOS standard and ArchiMate ontology, modelled as data objects.

The first technical phase, phase 5, realises a data model, which is represented by a data object. The RDF-based data model is eventually published on a triple store, represented by an application component realising an application service 'publish data model', in phase 6. This data model consists of the established relationships between ArchiMate elements. For every semantic wiki page of a specific ArchiMate element, a SPARQL query, modelled as a data object, is executed that can retrieve the relationships of that specific ArchiMate element. Another data object represents the data about the relationships, as this information is useful for digital architects working with reference architectures. This data is embedded in the wiki page of the semantic wiki, modelled as an application component.

The method visualised in ArchiMate is a tool for digital architects to follow the method in an organised way. This ArchiMate view can be found in figure 5.1. Since the method is focused on reference architectures within the Dutch public sector and Dutch digital architects, the method is also designed in Dutch. The Dutch version of the ArchiMate view can be found in appendix J.

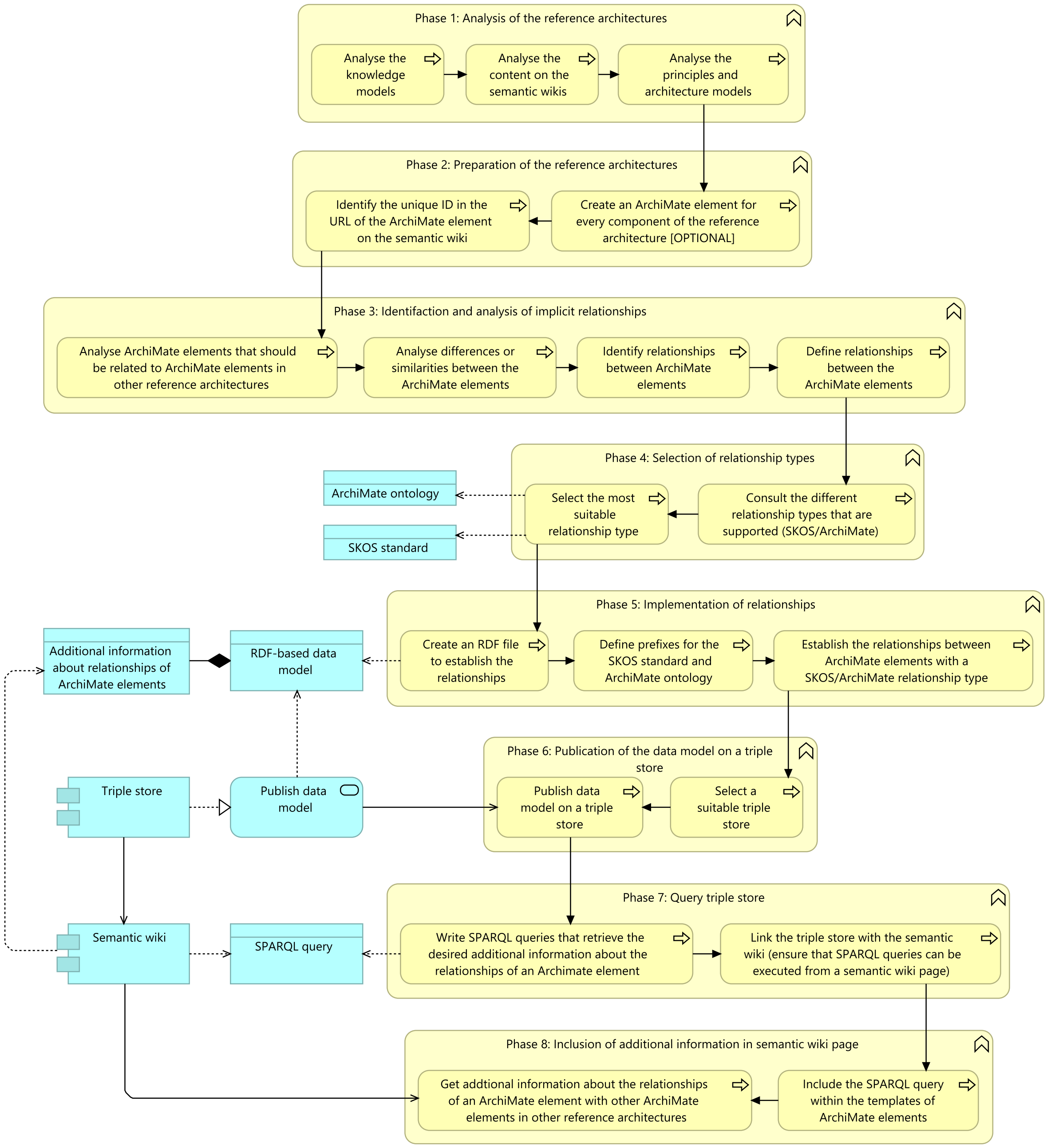


Figure 5.1: The method

5.3.3 Architecture of the implementation

Most of the reference architectures within the Dutch public sector are published on a semantic wiki. For each ArchiMate element, there exists a wiki page with information about that ArchiMate element. So, when following the method and establishing the relationships between ArchiMate elements, a data model is developed. The data model is an RDF file consisting of SKOS or ArchiMate relationships between ArchiMate elements. This data model can be published on a triple store, which can eventually be queried from a semantic wiki page.

A semantic wiki, based on Semantic MediaWiki, can enable the LinkedWiki extension to execute SPARQL queries from within a wiki page. When querying the triple store, additional information about the relationships of the ArchiMate element with other ArchiMate elements in other reference architectures can be retrieved. The additional information can then be shown on a wiki page of the ArchiMate element. This can be done by including the SPARQL query in the template of an ArchiMate element wiki page. The architecture that belongs to this implementation can be found in figure 5.2.

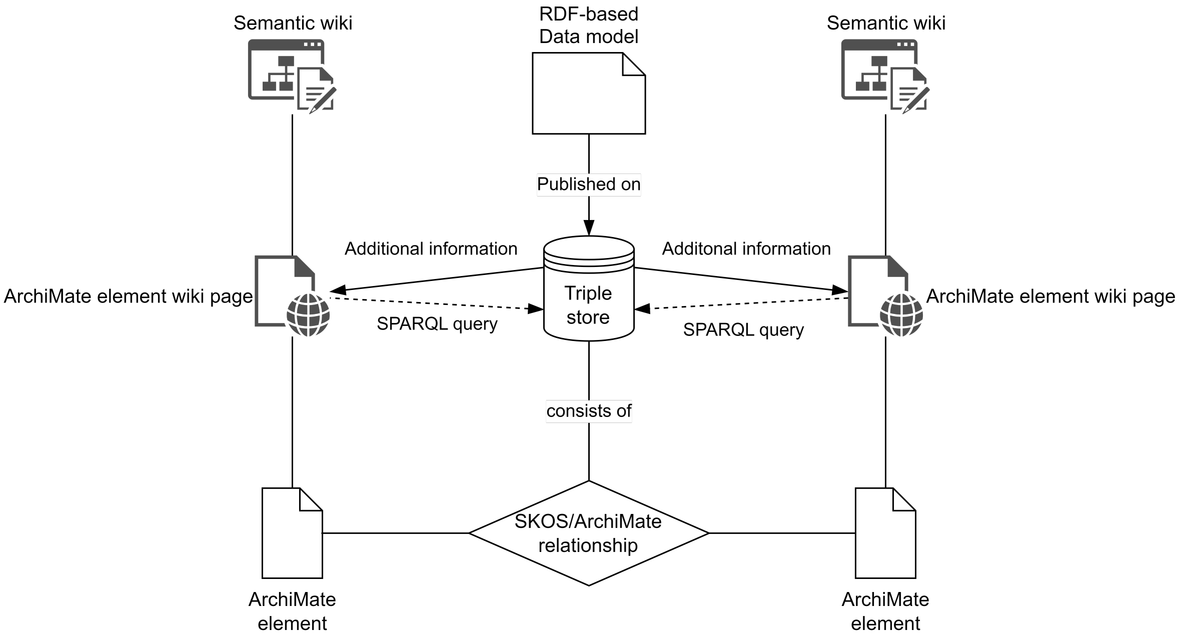


Figure 5.2: The architecture of the implementation

Chapter 6

Method validation

To validate the designed method, a case study was conducted in which the method was used by the researcher in the context of the educational sector. When completing the method, the result is a concise prototype. This prototype shows an implementation of some defined and established relationships between reference architectures in the educational sector. These relationships are available in a data model published on a triple store, which can eventually be queried by the semantic wikis of the reference architectures. The reference architectures within the educational sector are all published on the semantic wiki platform WikiXL. This way, ArchiMate elements of a reference architecture get additional information about how it is related to ArchiMate elements of other reference architectures.

6.1 Case study

A lifelong learning is an important driver in the educational sector in the Netherlands. Therefore, educational sectors must be seamlessly aligned, so a learner can continue to develop across different educational sectors without experiencing disruptions in the chosen learning paths. The coherence between the different sector-specific and cross-educational chain reference architectures should thus be improved. The advisory group 'Coherence'[1] in the educational sector is working on improved coherence between the sector-specific and the cross-educational chain reference architectures. Therefore, the educational sector seems a suitable context to test the designed method and validate it.

In the current state of the educational reference architectures, achieving a coherent system is not possible, as different design decisions are made within the sector-specific reference architectures. Thus, the sector-specific reference architectures are only on a high abstraction level similar to each other. They are using different architectural design decisions and concept names, mainly because of their independent development. To improve the coherence between these educational reference architectures, the architectural design decisions should be aligned. Therefore, design guidelines were developed, which can be found in the list below:

- Use as many of the same terms and definitions as possible
- Meta-models are aligned with each other
- Take generic reference components from ROSA
- Components of the architecture description are included as model elements
- Follow the line of NORA and the other national reference architectures

An example of one of the issues within the educational sector is the inconsistent naming of learning resources. Within the ROSA, FORA, MORA and HORA, there is differently made use of terms such as a Learning Management System (LMS), Learning Content Management System (LCMS), and

[1] Adviesgroep Samenhang Onderwijsarchitecturen, `https://www.edustandaard.nl/standaard_werkgroepen/adviesgroep-samenhang-onderwijsarchitecturen/`

Electronic learning environments (Elektronische Leeromgeving = ELO). To consistently name specific elements, the advisory group agreed upon the definitions of terms and how to use these terms. This is part of an advisory document [63] for the achievement of an agreement on the definitions and use of the different terms within the different reference architectures. This example does not stand on its own. Many examples can be given where terms are inconsistently used or varying definitions for these terms are used. Before the advice about 'learning resources' was presented, an analysis of the differences between the reference architectures was made. In this analysis, the differences and similarities of the sector-specific and cross-educational chain reference architectures were documented.

So, agreements should first be made between the different educational reference architectures about the design guidelines, which can be found in the list above. The next step is to define and establish relationships between components of reference architectures. The relationships are links between ArchiMate elements of different reference architectures, with a specific meaning. Elements can be reused from other architectures or they can be further specified. Another relationship between elements that can be mentioned is that of generic terms used for elements in the ROSA. The ROSA should function as a central point where the other educational reference architectures join. So, in the FORA, MORA and HORA more specific terms are used that are narrowed down from a more generic term. The SKOS relationship type 'narrower' and 'broader' can then be used to indicate these relationships. In the following section, the case study is conducted and some relationships between reference architectures in the educational sector are defined and established.

A case study is conducted to validate the method designed in chapter 5. To conduct this case study, the researcher used advisory documents and agreements of the advisory group 'Coherence'. Furthermore, unstructured interviews with two experts who have contributed to the ROSA and FORA have been conducted to gather specific information about the reference architectures in the educational sector.

6.1.1 Following the method

Eventually, the method is followed by the researcher and for every phase, the outcomes are documented in this section.

Phase 1: Analysis of the reference architecture

First, the reference architectures in the educational sector should be analysed by the digital architect (in this case the researcher). To achieve this, the content on the semantic wikis and their knowledge models were analysed. So, the principles and architecture models of the ROSA, FORA, MORA and HORA are analysed. Furthermore, two experts working on reference architectures in the educational sector were asked about the contents of the reference architectures. Since the advisory group 'Coherence' already published a couple of advisory documents about the reference architectures in the educational sector, these were also studied. These efforts led to a thorough understanding of the different educational reference architectures.

Phase 2: Preparation of the reference architectures

The reference architectures that should be related to each other are ROSA, FORA, MORA and HORA. First, all components of these reference architectures that should be related to other components in other reference architectures should have an ArchiMate element. For this case study, all desired relationships can be established between components with existing ArchiMate elements. So, this step is optional in this case. The ArchiMate elements that should be related to each other must have unique IDs that match the URL of the wiki page of that ArchiMate element. In the case of the reference architectures ROSA, MORA and HORA, the element IDs of the original ArchiMate element match the ID in the URL. These element IDs are not stored in a property of that ArchiMate element. In the case of the FORA, the property 'Original ID' of the ArchiMate element also has the element ID in it that matches the ID in the URL. In the URLs of the ArchiMate elements in the FORA, an extra phrase "FORA/" comes before the element ID.

Phase 3: Identification and analysis of implicit relationships

The analysis of the differences or similarities and the advisory document of the 'learning resources' were used to find relationships between components of the reference architectures. Furthermore, examples of relationships that were mentioned during the focus group were used. Also, unstructured interviews with the two experts indicated the need for some relationships between specific components. The relationships that should be established are documented in a text file for later usage.

Phase 4: Selection of relationship types

To select the relationship types, the advisory documents and agreements are consulted. Furthermore, the opinions of the two experts are taken into account. First, there have been looked at the application components (in Dutch: referentiecomponenten) of the reference architectures. In the ROSA, the application component 'Administratiesysteem onderwijsdeelnemer' is a generic term that can be further specified in the FORA, MORA and HORA. In these reference architectures, this application component is named 'Leerlingadministratiesysteem (LAS)', 'Kernregistratie Systeem Studenten (KRS)' and 'Studentinformatiesysteem (SIS)' respectively. So, when relating the generic term with the more specific terms, the relationship type 'broader/narrower' can be used. Furthermore, when application components are named the same, the relationship 'related' of SKOS can be used.

The relationships are visualised in a simplified ArchiMate model consisting of the four reference architectures and the related application components. This model can be found in figure 6.1. The complete model with the complete views can be found in figure 6.2. The model elements that should be related to each other have a higher opacity. The views are named 'Referentiecomponentenmodel (Top-27)', 'Applicaties en applicatieservices' and 'Applicatiecomponentenmodel'. This model is highly complicated, but it does include the same relationships as in the simplified model.

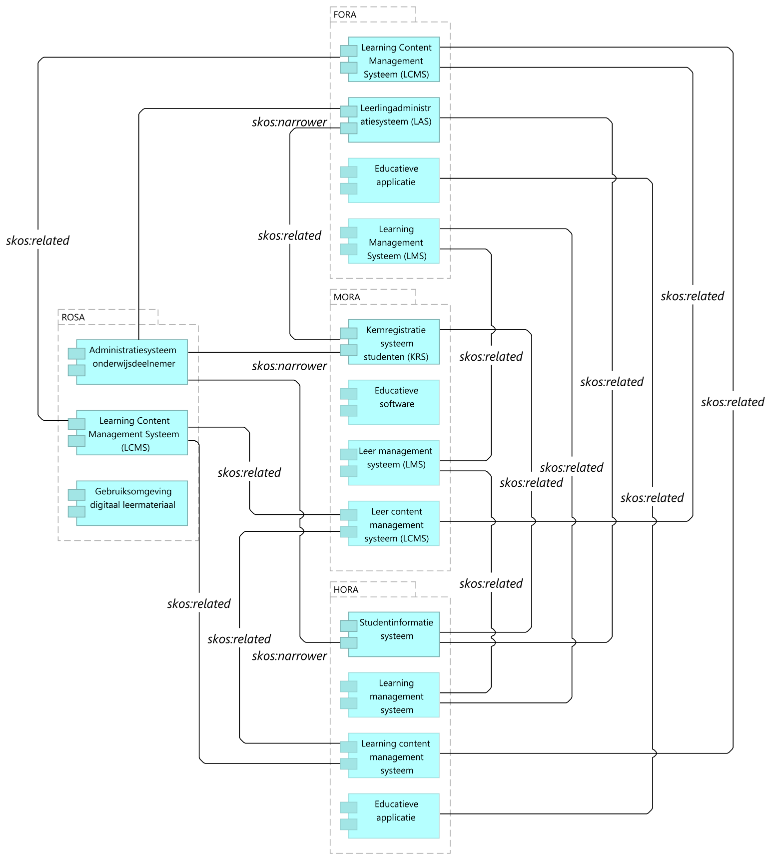


Figure 6.1: Relationships between ArchiMate Application Components

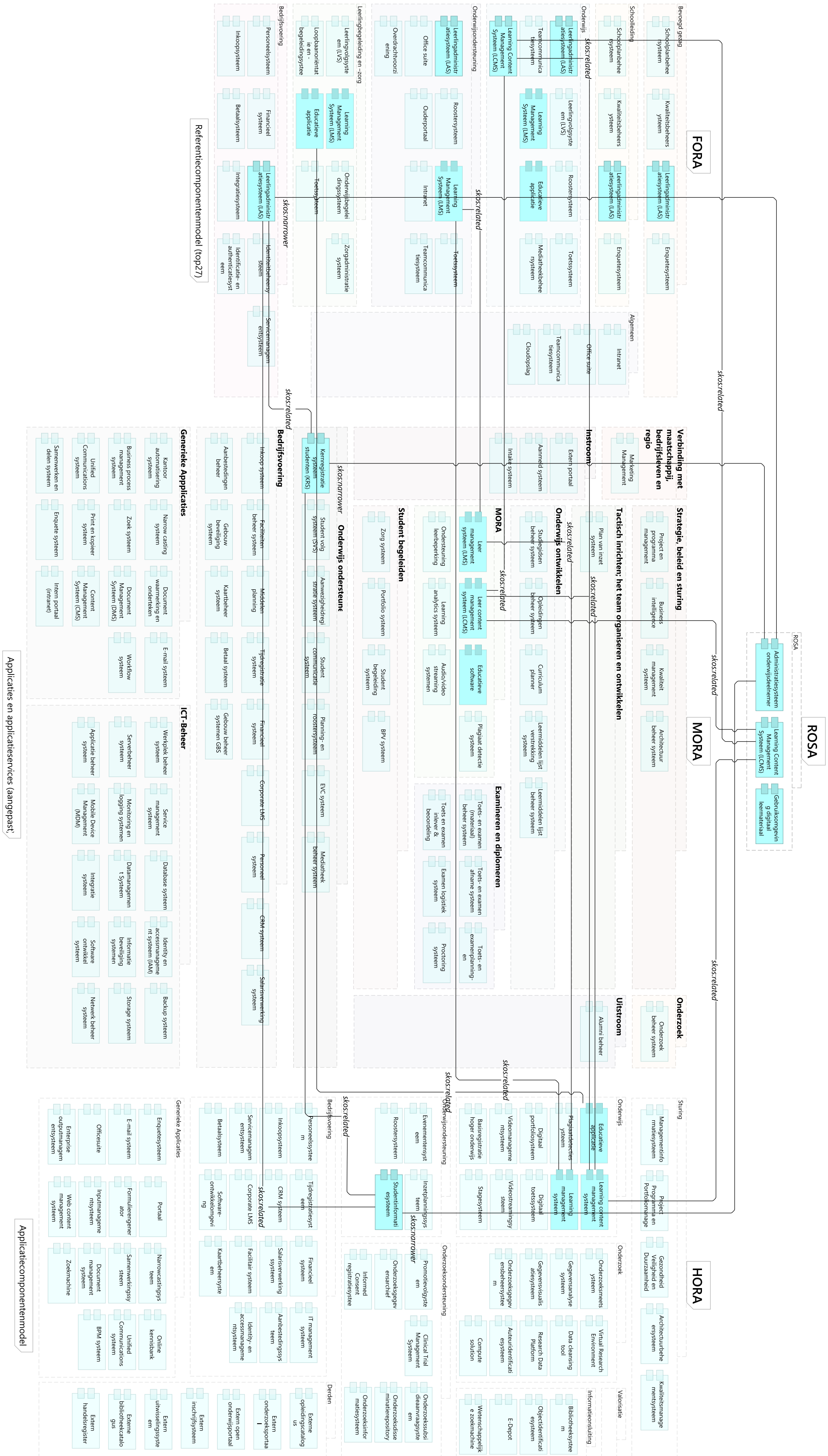


Figure 6.2: Educational sector relationships between views

Secondly, there have been looked at the business objects (in Dutch: informatieobjecten) of the reference architectures. One specific example has been chosen to indicate the need for these relationships. In the ROSA, the business object 'Onderwijsdeelnemer' is a generic term that can be further specified in the FORA, MORA and HORA. In the FORA this element is called a 'Leerling', in the MORA a 'Student' and in the HORA a 'Deelnemer'. All elements in the sector-specific educational reference architectures are 'narrower' terms than that of the ROSA. One can argue whether the term 'Deelnemer' is 'broader' than 'Onderwijsdeelnemer', however, the ROSA should function as a generic reference architecture, so there is chosen to use the relationship 'narrower'.

In figure 6.3, a simplified ArchiMate model consisting of the four reference architectures and their related business objects.

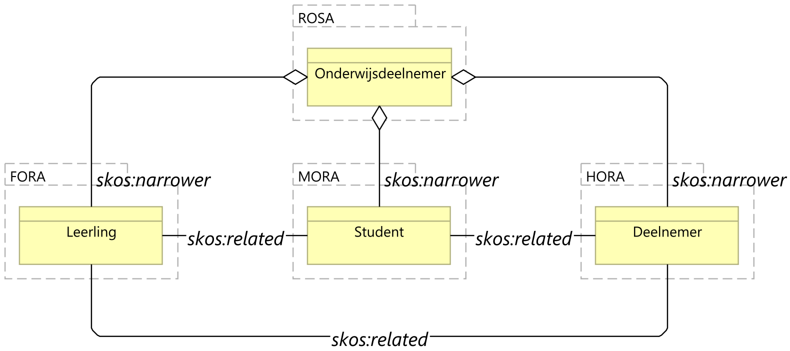


Figure 6.3: Relationships between ArchiMate Business Objects

Phase 5: Implementation of relationships

To implement the defined relationships, an RDF file is created. The alternative syntax used in this RDF file is TURTLE. First, the prefixes should be initiated that are used to define the elements and relationship types. All reference architectures can have a prefix, which is part of the URL of a wiki page where an ArchiMate element can be found. For example, the ArchiMate element 'Generieke / basis-applicatie' of the FORA can be retrieved by the URL `https://fora.wikixl.nl/index.php/FORA/id-f6d26447-fa36-4cbf8-5c48-8f251ef6817`. The prefix consists of the first part of the URL, which is in the case of the FORA this: `https://fora.wikixl.nl/index.php/FORA/`.

After that, the specific ArchiMate elements should be defined with the proper relationship type to another ArchiMate element. The two unique identifiers of the ArchiMate elements should be used to define the ArchiMate elements. In the case of the ROSA element "Administratiesysteem onderwijsdeelnemer", it gets three relationships 'narrower' with the FORA, MORA and HORA elements, which have names that are further specified. In the TURTLE file below one can see some of the relationships that are visualised in figure 6.1.

```
@prefix archimate: <http://bp4mc2.org/def/archimate#>.
@prefix skos: <http://www.w3.org/2004/02/skos/core#>.
@prefix ROSA: <http://rosa.wikixl.nl/index.php/>.
@prefix FORA: <http://fora.wikixl.nl/index.php/FORA/>.
@prefix MORA: <http://mora.mbodigitaal.nl/index.php/>.
@prefix HORA: <http://hora.surf.nl/index.php/>.

ROSA:Id-0a5b23bf-02aa-42d7-8ce6-fe1b736092ba a
    archimate:ApplicationComponent;
    skos:prefLabel "Administratiesysteem onderwijsdeelnemer"@nl ;
    skos:definition "Virtueel administratiesysteem van een onderwijsinstelling..."@nl ;
    skos:narrower FORA:id-c64a7a54-f38e-487e-8148-01bc3d9c92fd;
    skos:narrower MORA:Id-2b4dfd3e-cac0-94e8-8a37-ce491bf16a2d;
```

```
    skos:narrower HORA:Id-feb2d938-5c98-62e7-d5fd-5da245ad6486.

FORA:id-c64a7a54-f38e-487e-8148-01bc3d9c92fd
    a archimate:ApplicationComponent;
    skos:prefLabel "Leerlingadministratiesysteem (LAS)"@nl ;
    skos:definition "Digitaal leerlingadministratiesysteem van een onderwijsinstelling..."@nl ;
    skos:related MORA:Id-2b4dfd3e-cac0-94e8-8a37-ce491bf16a2d;
    skos:related HORA:Id-feb2d938-5c98-62e7-d5fd-5da245ad6486;
    skos:broader ROSA:Id-0a5b23bf-02aa-42d7-8ce6-fe1b736092ba.

MORA:Id-2b4dfd3e-cac0-94e8-8a37-ce491bf16a2d
    a archimate:ApplicationComponent;
    skos:prefLabel "Kernregistratie systeem studenten (KRS)"@nl ;
    skos:definition "Een systeem voor het beheren van gegevens van studenten zoals.."@nl ;
    skos:related FORA:id-c64a7a54-f38e-487e-8148-01bc3d9c92fd;
    skos:related HORA:Id-feb2d938-5c98-62e7-d5fd-5da245ad6486;
    skos:broader ROSA:Id-0a5b23bf-02aa-42d7-8ce6-fe1b736092ba.

HORA:Id-feb2d938-5c98-62e7-d5fd-5da245ad6486
    a archimate:ApplicationComponent;
    skos:prefLabel "Studentinformatiesysteem"@nl ;
    skos:definition "Een systeem dat het onderwijsaanbod en de belangrijkste gegevens..."@nl ;
    skos:related FORA:id-c64a7a54-f38e-487e-8148-01bc3d9c92fd;
    skos:related MORA:Id-2b4dfd3e-cac0-94e8-8a37-ce491bf16a2d;
    skos:broader ROSA:Id-0a5b23bf-02aa-42d7-8ce6-fe1b736092ba.
```

Phase 6: Publication of the data model on a triple store

After implementing the relationships in the RDF file, the file should be published on a triple store. For this case study, TriplyDB was used as a triple store, as it is free and easy to use. Within TriplyDB a new dataset is created, named "SRA". Within that dataset, the TURTLE file with all relationships was uploaded. Below in figure 6.4 one can find a screen capture of all application components that can be browsed through within the triple store. The triple store itself can be found here: `https://triplydb.com/remcoovervelde/SRA/`.

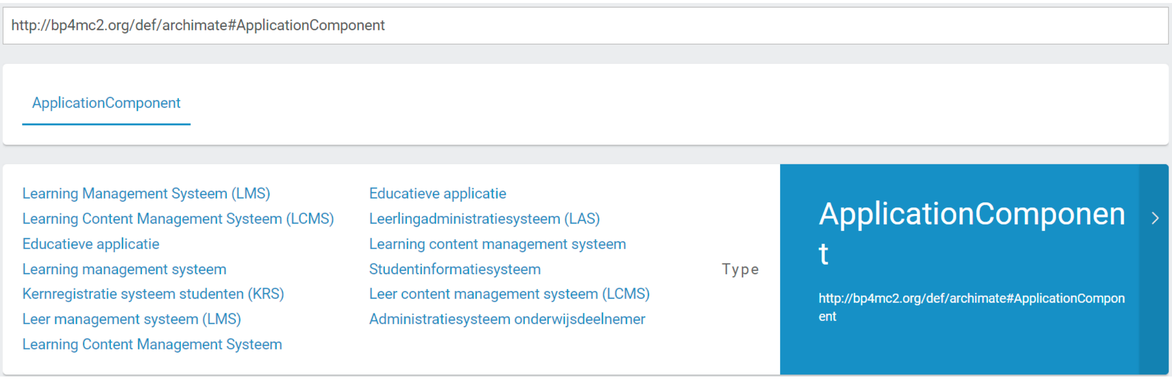


Figure 6.4: Snapshot of TriplyDB with all available application components

Phase 7: Query triple store

To query the linked data that is published on the triple store, an additional Virtuoso service is initiated. This service allows additional query paradigms to query the data. The service generates a SPARQL endpoint, which is: `https://api.triplydb.com/datasets/remcoovervelde/SRA/services/SRA/sparql`. To query the triple store from a semantic wiki page, in this case WikiXL, an extension called LinkedWiki from MediaWiki should be enabled. This extension allows the execution of SPARQL queries from a semantic wiki page.

To query the relevant information about the relationships of an ArchiMate element, a SPARQL query was written. Within the query, first, the needed prefixes are initiated. Thereafter, the label, relatedComponent and relationshipType are selected for the current ArchiMate element. This can be done by using the element ID of the ArchiMate element, which can be retrieved by the 'PAGENAME' of the ArchiMate element. This PAGENAME is a variable in Semantic MediaWiki that can be used to point to the URL of the current wiki page. Together with the prefix of the specific reference architecture, the ArchiMate element can be found in the triple store. The SPARQL query can be found below.

```
{{#sparql:
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX archimate: <http://bp4mc2.org/def/archimate#>
PREFIX skos: <http://www.w3.org/2004/02/skos/core#>
PREFIX FORA: <http://fora.wikixl.nl/index.php/FORA/>
PREFIX MORA: <http://mora.mbodigitaal.nl/index.php/>
PREFIX HORA: <http://hora.surf.nl/index.php/>
PREFIX ROSA: <http://rosa.wikixl.nl/index.php/>

SELECT ?label ?relatedComponent ?relationshipType
WHERE {
  {
    RefArch:{{PAGENAME}} skos:related ?relatedComponent.
    ?relatedComponent skos:prefLabel ?label.
    BIND ("Related" AS ?relationshipType)
  }
  UNION
  {
    RefArch:{{PAGENAME}} skos:narrower ?relatedComponent.
    ?relatedComponent skos:prefLabel ?label.
    BIND ("Narrower" AS ?relationshipType)
  }
  UNION
  {
    RefArch:{{PAGENAME}} skos:broader ?relatedComponent.
    ?relatedComponent skos:prefLabel ?label.
    BIND ("Broader" AS ?relationshipType)
  }
}
limit 20
|config=https://api.triplydb.com/datasets/remcoovervelde/SRA/services/SRA
|headers=Naam, Link, Relatietype
|class="table table-striped table-bordered table-sm dashboard-table sortable"
|footer=no
|log=2
}}
```

Phase 8: Inclusion of additional information in semantic wiki page

To include the query results in the WikiXL pages, templates formatting the WikiXL pages needed to be changed. These templates govern how for example the wiki pages of application components or business objects are structured and what the contents are of those pages. The SPARQL query that was written in phase 2 was included in eight templates corresponding to either a business object or application component of the four reference architectures.

When these templates were changed, the results of the SPARQL query were visible on the wiki pages. So, when looking up an ArchiMate element that has relationships with other ArchiMate elements, this is visible on the wiki page. Below one can find two examples of wiki pages of ArchiMate elements. In figure 6.5 one can see the ArchiMate element 'Onderwijsdeelnemer' in the ROSA, which has relationships with other ArchiMate elements in the FORA, MORA and HORA. In figure 6.6 one can see the ArchiMate element 'Learning Content Management Systeem (LCMS)' in the FORA, which has relationships with other ArchiMate elements in the ROSA, MORA and HORA.

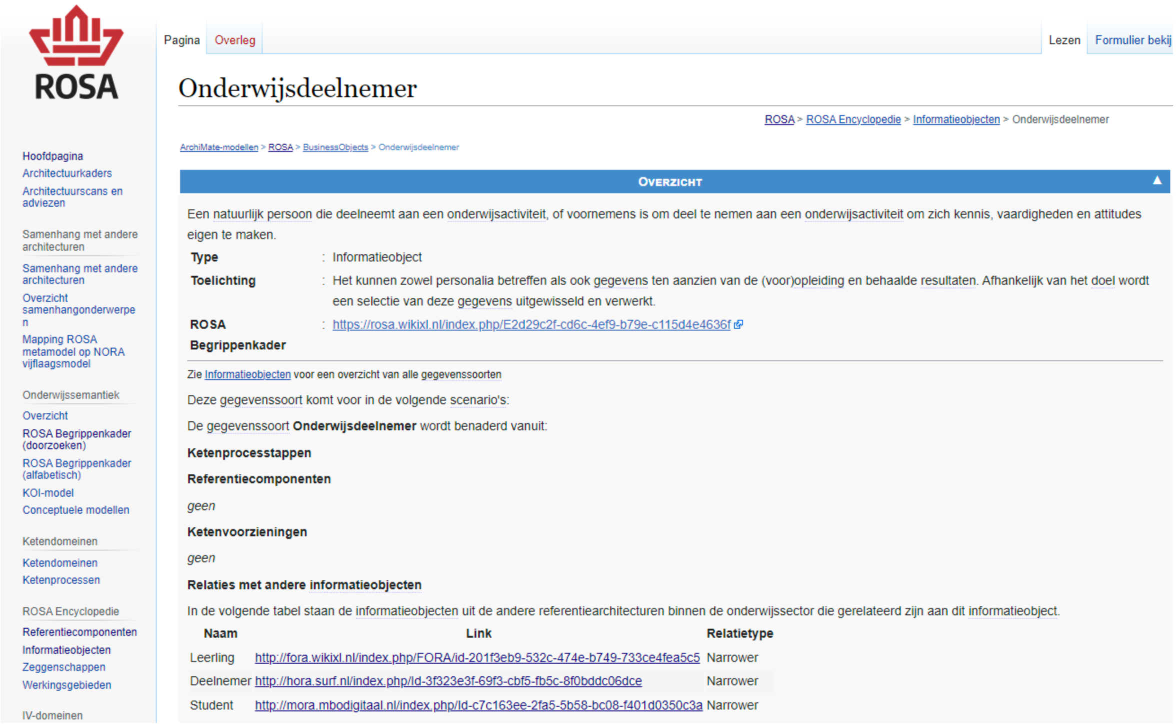
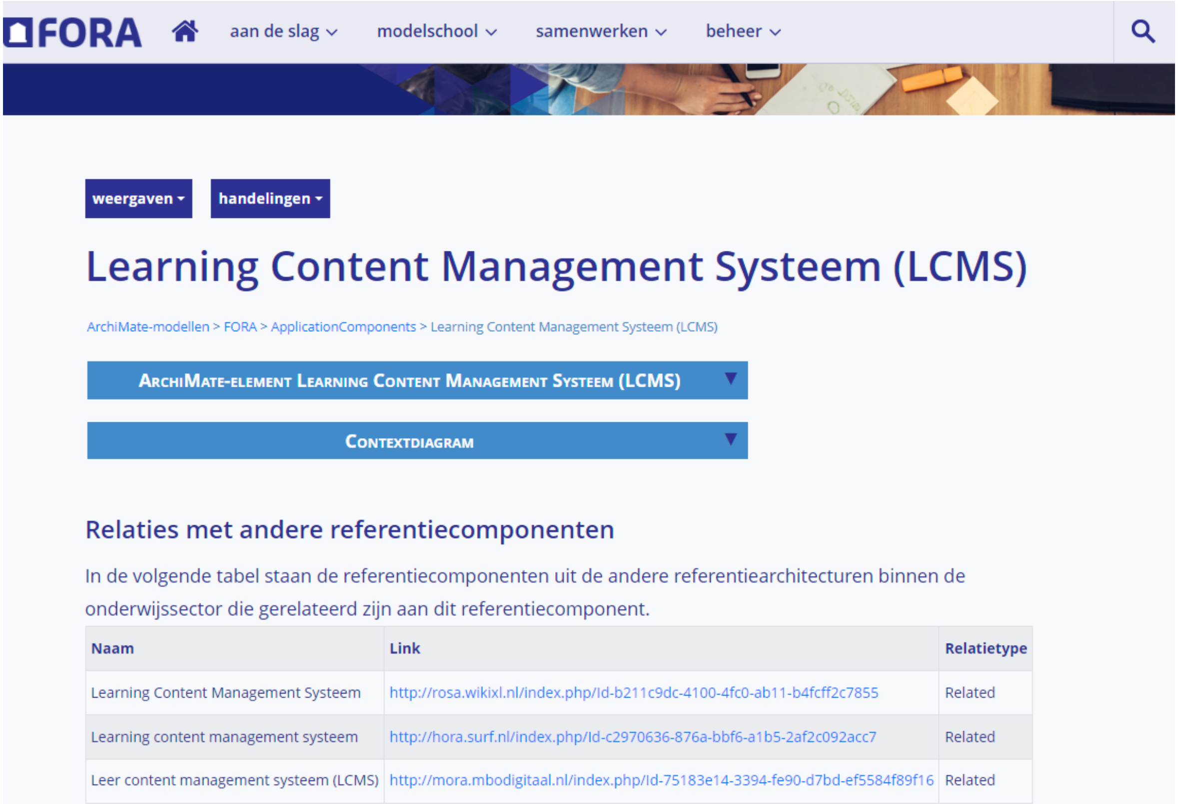


Figure 6.5: ArchiMate element 'Onderwijsdeelnemer' in ROSA with relationships to FORA, MORA and HORA



Naam	Link	Relatietype
Learning Content Management Systeem	http://rosa.wikixl.nl/index.php/Id-b211c9dc-4100-4fc0-ab11-b4fcff2c7855	Related
Learning content management systeem	http://hora.surf.nl/index.php/Id-c2970636-876a-bbf6-a1b5-2af2c092acc7	Related
Leer content management systeem (LCMS)	http://mora.mbodigitaal.nl/index.php/Id-75183e14-3394-fe90-d7bd-ef5584f89f16	Related

Figure 6.6: ArchiMate element 'Learning Content Management Systeem (LCMS)' in FORA with relationships to ROSA, MORA and HORA

6.2 Validation results

In this chapter, the designed method is validated using a case study. In this case study, some relationships between ArchiMate elements in educational reference architecture were defined and established using the designed method. The case study shows that using the method, a data model can be developed with relationships between ArchiMate elements. When this data model is published on a triple store, and queried by a semantic wiki (WikiXL) page, additional information can be retrieved about the relationships of that ArchiMate element. This information is useful for digital architects and other stakeholders, explained in section 4.6. Stakeholders do not have to analyse multiple reference architectures anymore, as they now have the knowledge of how specific components of reference architectures relate to each other. This improves the coherence between those reference architectures.

The case study demonstrates the usefulness of the method, allowing stakeholders to understand how ArchiMate elements in one reference architecture relate to those in another reference architecture. Several relationships are taken as examples. In figure 6.5, the ArchiMate element 'Onderwijsdeelnemer' from the ROSA can be found, illustrating its relationships with corresponding elements in the other three reference architectures. The implementation of these relationships highlights the method's usefulness by showing the additional information that stakeholders find valuable.

Furthermore, the validation results emphasise the importance of collaborative efforts, such as the collaboration between multiple stakeholders of multiple reference architectures. In this case study, advisory documents of the advisory group 'Coherence' are used to define the relationships between components of educational reference architectures. These relationships should be meaningful, so stakeholders of the different reference architectures should have discussed and agreed upon the meanings of these relationships.

The case study also illustrates that the approach is not universally applicable. The method cannot directly be applied to every reference architecture, as the WikiXL platforms needed some change in their internal functioning. One example of this is the retrieval of the element ID within the FORA, which is in the property of a WikiXL page of an ArchiMate element and not in the URL. Another example is the changes that need to be made to the WikiXL platform, as the LinkedWiki extension should be enabled and the templates of certain wiki pages need to be changed.

Furthermore, the case study shows that a digital architect following this method should perform many manual steps to realise the relationships between components of different reference architectures. So, it is time-consuming to manually define and establish the relationships.

Chapter 7

Discussion

This chapter aims to discuss the results and limitations of this research, as well as its execution process. First, a reflection is presented on the used research methodologies, evaluating their efficacy. After that, a reflection on the designed method is presented, followed by the limitations inherent in this research.

7.1 Reflection on the research methodologies

In this section, the research methodologies used for conducting this research are analysed and reflected upon.

7.1.1 Design Science Methodology

The foundation for the design and validation of the artefact of this research was rooted in the Design Science Methodology as introduced by Wieringa [1]. Implementing this methodology has led to a structured approach to design and validate the method. However, this research encountered a significant limitation: the inability to fully execute the Design Science Methodology due to its restricted scope. The research fell short of completing the treatment implementation phase, making practical validation unattainable. Instead, validation had to rely on simulations, in this research a case study. This overlooks certain real-world factors. Hence, caution had to be exercised in interpreting the insights obtained from the case study.

7.1.2 Systematic Literature Reviews

The theoretical knowledge gathered during the research topics phase was retrieved using (systematic) literature reviews. The systematic literature reviews adhered closely to the guidelines provided by Kitchenham [11]. However, the main threat to the validity of the results of the Systematic Literature Reviews is that there may be more relevant literature that has not been included. One reason for this could be that not all existing relevant papers were included in the searched digital libraries. Another reason could be that the search queries used might not have covered all relevant existing material. This threat was aimed to be mitigated by searching through four comprehensive and large digital libraries and using synonyms in the search query. These synonyms were primarily used for the word benefit, as the words improvement, advantage or contribution were also used by authors of research papers.

Moreover, a threat to the validity can be that the papers which are found might not address the research questions. To mitigate this threat, a lengthy, but well-structured and strict selection process was used. The selection process was aimed to be highly reproducible.

7.1.3 Focus group

At the start of the research, a focus group research was conducted. The focus group is an extended way of the interview method in which more in-depth data can be gathered. The focus group was conducted with four participants, all digital architects working in the Dutch public sector. To analyse the transcript of the focus group, the Focus Group Data Analysis Framework by Nili et al. [2] was used. This framework was thoroughly followed and in detail documented, so the validity of this analysis can barely be questioned. However, the fact that there was only one focus group held is a limitation of this research. Often, focus groups are held with multiple sets of participants. So, other focus groups should have been held with more participants. However, it was chosen to complement and validate the findings of the focus group with survey research.

7.1.4 Survey

The survey was conducted to complement and validate the findings of the focus group. In total, 40 digital architects completed the survey, which is a significant number. One limitation of the survey is that respondents are biased, as the findings of the focus group acted as a guideline for the survey and they got much background information on the type of research. The analysis of this survey was done using the Qualtrics survey tool and a spreadsheet containing all the answers. The Qualtrics survey tool offers a data analysis and reporting tool to gather (statistical) insights from the collected quantitative data. With these insights, the findings of the focus group were validated. The answers to the qualitative questions were analysed using a spreadsheet. These textual answers were manually analysed by the researcher to form general opinions of the architects. A limitation of this way of working is that the analysis of the qualitative data remains a process in the head of the researcher, which makes it a process that is not transparent.

7.1.5 Case study

The method was validated using a case study. This case study was conducted by the researcher itself, which indicates the first limitation of this research methodology. Although there have been made use of information from advisory documents, expert opinions and existing knowledge on the semantic wikis of reference architectures. Since I designed the method, there were no uncertainties on how to use the method. The biases that I had as a researcher were large, so the usability of the method could for instance not be validated. Furthermore, the method is only tested in one context; reference architectures within the educational sector published on a semantic wiki-based platform WikiXL. It is not known whether the method functions in another context, with other reference architectures and other semantic wikis.

7.1.6 Unstructured interviews

The interviews that were conducted throughout the research process were merely discussions with digital architects experienced with reference architectures within the Dutch public sector. These discussions or conversations have guided this research and the design of the method. However, there is a complete absence of transparency regarding these undocumented, unstructured interviews.

7.2 Reflection on the method

The validation of the designed method to improve coherence between reference architectures within the Dutch public sector has been conducted through one case study. So, the method was not in an iterative way designed. The method showed promising results in understanding the relationships between components of different reference architectures within the Dutch public sector. The method provides a structured approach including formal steps for analysing the reference architectures and identifying and defining relationships between components of reference architectures. After that, technical steps are provided for establishing relationships within an RDF-based data model, which can be published on a triple store and queried from a semantic wiki.

Using this method in the educational sector revealed its usefulness by showing the related ArchiMate elements of different reference architectures on the different semantic wikis. The stakeholders within the educational sector can benefit from the outcomes of this research, as they have now insights into the relationships of certain components of reference architectures with components in other reference architectures. Therefore, stakeholders can make informed decisions on how to use specific components of reference architectures.

While the method showcased considerable benefits, it is essential to acknowledge its limitations. The universal applicability of the method was found to be somewhat constrained, requiring modifications to the semantic wikis and the templates of wiki pages. Additionally, the method's effectiveness may vary depending on the specific nuances and complexities of other sectors or reference architectures beyond the educational domain. Furthermore, a single case study is used in which only the platform WikiXL is used as a semantic wiki. So, the method is not tested in combination with other semantic wiki-based platforms.

Moreover, the method requires a large effort from the digital architect using it. The proposed way of establishing relationships between ArchiMate elements in a data model requires manual work of the digital architect to write down all the relationships that are needed.

Furthermore, defining and establishing relationships between components of reference architectures is merely one aspect of improving coherence between reference architectures. Other aspects of coherence are for example aligning the meta-models of reference architectures and using the same terms and definitions for concepts. These aspects are not taken into account in this method.

7.3 Limitations of the research

The previous reflections on the applied research methodologies and the designed method already revealed a few limitations of this research. As mentioned before, the research could not fully implement the Design Science Methodology due to scope limitations. Furthermore, despite following rigorous guidelines for systematic literature reviews, the research acknowledges potential gaps in the coverage of relevant literature.

Moreover, the reliance on a single focus group with a limited number of participants poses limitations in capturing diverse perspectives and insights. Multiple focus groups with varied participants could have enriched the qualitative data and provided a more comprehensive understanding of the subject matter. Also, the survey conducted as part of the research may be susceptible to biases, as respondents were influenced by prior focus group findings. This influence could potentially skew the survey results, affecting the reliability and validity of the data collected.

Next, the researcher's involvement in conducting the case study introduces potential biases and limitations in objectivity, as there may be a lack of independent perspectives and evaluations. Additionally, reliance on advisory documents and expert opinions could influence the interpretation and findings of the case study. Furthermore, the absence of documentation for unstructured interviews conducted throughout the research process raises concerns regarding transparency and replicability.

Lastly, while the developed method showcased promising results within the educational sector, its generic applicability may be constrained. Modifications may be required for the semantic wikis of other reference architectures, and their effectiveness could vary depending on the specific nuances and complexities of other reference architectures beyond the educational domain. Furthermore, this method only highlights the realisation of relationships between components of reference architectures. This is merely one aspect of improving coherence between reference architectures. So, a larger effort is needed to improve coherence between reference architectures within the Dutch public sector.

Chapter 8

Conclusion

In this chapter, the main findings of this research are addressed. By answering the eight research questions first, the main research question can eventually be answered. The objective of this research is to provide an answer to the main research question posed at the start of this research:

RQ: *How can a method be designed to improve the coherence between the reference architectures within the Dutch public sector?*

The primary research question served as the foundation for this research, guiding the problem investigation phase towards a comprehensive understanding of the problem, and eventually to designing and validating an artefact to improve the problem context. Eight research questions were formulated to support and address specific perspectives of the main research question. The answers to each research question are presented and discussed in detail in the next section.

8.1 Research questions

RQ1 *How can organisations in the public sector benefit from Enterprise Architecture?*

The first part of the research aimed to get a thorough understanding of EA benefits for organisations in the public sector, by doing a state-of-the-art Systematic Literature Review (SLR). Based on the found and selected literature, 11 organisational benefits have been found of which four were empirically tested and seven were claimed and not empirically tested. Furthermore, two benefits of EA for projects are found, that were both empirically tested in the literature. These benefits are based on ten research papers that can be found in table 3.7.

The benefits that were empirically tested in one or more studies are in bold text. The organisational benefits include 'improve knowledge management' (1), **'improve communication' (2)**, **'improve organisational agility' (3)**, **'insight into organisational complexity' (4)**, **'reuse of components' (5)**, 'improve interoperability' (6), 'improve information quality' (7), 'improve Business-IT alignment' (8), 'reduction of duplication' (9), 'improve decision-making' (10) and 'cost reduction' (11). The project benefits that are found are **'deliver desired quality of project' (12)** and **'less project failure' (13)**. From the two project benefits, an affiliated organisational benefit 'improve project performance' emerged. To summarise the findings of this SLR, a theoretical model is developed based on the found studies that provide a clear overview of the (claimed) benefits of EA for organisations in the public sector. The theoretical model model can be found in figure 3.6.

RQ2 *How can reference architectures improve Enterprise Architecture practices?*

Second, the research aimed to find the benefits of reference architectures for EA practices by doing a state-of-the-art Systematic Literature Review. A reference architecture is a generic architecture for a class of systems that is used as a foundation for the design of concrete architectures from this class. A reference architecture includes a set of generic architecture principles, predefined models, reusable patterns and best practices.

There is a lack of empirical studies on this research topic, as the benefits of reference architectures for EA practices are barely studied. The found studies have an exploratory nature and often discuss use cases of reference architectures for EA practices. However, the measurable benefits of using these reference architectures have not been studied. One reason for this is that the benefits for organisations using Enterprise Architecture are also not extensively studied and often difficult to measure.

From the literature, three benefits of reference architectures for EA practices can be considered. First, reference architectures improve the communication between various EA stakeholders, by creating a common ground. Secondly, reference architectures guide the design, realisation, and maintenance of Enterprise Architectures, which reduces the time being used for developing Enterprise Architectures. Thirdly, by leveraging the reuse of knowledge and best practices, reference architectures improve the quality and consistency of EA deliverables. These benefits are based on eight research papers that can be found in table 3.10.

RQ3 *How is the architectural knowledge of reference architectures within the Dutch public sector organised and structured?*

The answer to this research question aims to explain how the architectural knowledge of reference architectures is currently organised and structured within the Dutch public sector. Architectural knowledge is increasingly regarded as an organisational asset that should be managed properly. It consists of architecture design as well as the design decisions, assumptions and the context of the architecture design.

The architectural knowledge of most of the reference architectures within the Dutch public sector is currently organised and structured on semantic wikis. A semantic wiki is an extension of a regular wiki. The regular wikis have some shortcomings, as the knowledge that is available on the wiki pages is in the form of unstructured (textual) information. This has no actual meaning. A semantic wiki adds an underlying knowledge model to a regular wiki, which describes the data the wiki contains.

Therefore, semantic wikis are used to organise the architectural knowledge of reference architectures. In the Dutch public sector, digital architects have used semantic wikis to publish sector-specific reference architecture knowledge with the intention that organisations within that sector reuse this information. Semantic wikis, particularly WikiXL, emerge as platforms for the publication of architectural knowledge. And from experience, it can be stated that semantic wikis have helped organise the semi-structured nature of architectural knowledge.

RQ4 *What is the current state of coherence between reference architectures within the Dutch public sector?*

There is a lack of coherence between reference architectures, based on the opinions of many digital architects. The complicated landscape and growing number of reference architectures within the Dutch public sector reveal multiple problems and a desire for improving coherence between those reference architectures.

Firstly, a definition of coherence is presented. This definition is firstly based on semantics, such as using the same architectural language and using the same terms for concepts. Secondly, the definition is based on the content, such as reusing common terms, reusing viewpoints, reusing information of existing reference architectures and explicitly referencing architecture components that are related to each other. Lastly, the definition is based on relationships between architecture principles and components. This research will focus on the last aspect of coherence.

Secondly, the desire for improved coherence is explained based on multiple drivers of stakeholders. These stakeholders are predominantly digital architects but also extending to other pivotal stakeholders. The drivers that were considered the most important are: (1) An intrinsic motivation to not reinvent the wheel, but reuse good examples, (2) Improving the understandability of terms within different reference architectures and (3) Leveraging each other's knowledge will improve the quality of reference architectures.

The desire for improved coherence also emerges from the problems that stakeholders experience of a lack of coherence. The following problems are considered the largest by the digital architects: (1) Information in different reference architectures that is common (largely the same) is not centrally accessible, (2) When multiple reference architectures are used to create a specific (Enterprise) architecture, they sometimes contradict each other and (3) Information in reference architectures sometimes does not explicitly refer to information in other reference architectures. While digital architects are the primary stakeholders of the problems, also other stakeholders were mentioned, such as information managers and software vendors.

The stakeholders, problems and drivers for improved coherence are visualised in an ArchiMate view that can be found in 4.6. The Dutch version of this view can be found in Appendix I.

In conclusion, there is no collective approach to how reference architectures can better cohere with each other. This highlights the need for a generic method that can be used to improve the coherence between reference architectures within the Dutch public sector. One aspect of improving coherence is by defining and establishing relationships between components of reference architectures. So, a method needed to be designed to define and establish these relationships.

RQ5 *What types of relationships are desired between the reference architectures within the Dutch public sector?*

The answer to this research question highlights the types of relationships desired between reference architectures within the Dutch public sector. One of these types is the 'reuse of' relationship. However, more examples are provided by digital architects during the focus group and survey research. Other examples are: 'is equal to', 'is not equal to', 'specifies further' and 'broader term'.

As the architectural knowledge of most of the reference architectures is currently modelled in the ArchiMate language and published on semantic wikis, relationships between these ArchiMate elements are needed. The desired relationship is one between multiple ArchiMate elements, each in a different reference architecture. This relationship is visualised in figure 4.7.

RQ6 *What are existing methods and techniques for defining and establishing relationships between different architectures?*

In the literature and from practice there was not found an existing method to define and establish relationships between different architectures. From experience in the Dutch public sector, there is a large desire for a standardised approach to improve the coherence between reference architectures. One aspect of this is the desire for a method to define and establish relationships between components of different reference architectures. This research attempts to design such a method. The method uses linked data principles and techniques to establish these relationships, as the architectural knowledge of reference architectures should break out of its isolated repositories.

RQ7 *How can a method be designed to define and establish relationships between reference architectures within the Dutch public sector?*

The complete answer to this research question is presented in section 5.3, in which the method of this research is designed. The method consists of eight phases that guide digital architects. This structured approach ensures that digital architects have a clear process, starting from analysing and understanding the reference architectures to including the additional information about relationships of an ArchiMate element in a semantic wiki. The method consists of technical and non-technical steps. In the initial four phases "Analysis of the reference architectures", "Preparation of the reference architectures", "Identification and analysis of implicit relationships" and "Selection of relationship types", the steps are non-technical. After that in phases five until eight, basic knowledge is needed about Linked Data principles and techniques, such as RDF, SKOS and SPARQL. Furthermore, a basic understanding is needed on the functioning of semantics wikis.

To ensure compatibility and effective integration, the method leverages the ArchiMate language, SKOS standard and Linked Data principles and techniques. These standards are widely used in the architecture community and Linked Data can be implemented in semantic wikis. By using the ArchiMate language, which is familiar to many digital architects, the method ensures ease of use.

RQ8 *Can the designed method effectively be used in practice, i.e. in the Dutch educational sector?*

To answer the last research question, there has been made use of a case study to validate the designed method in the educational sector. The case study confirms the method's effectiveness in improving coherence within educational reference architectures using relationships between ArchiMate elements. A concise prototype was developed consisting of a few relationships between ArchiMate elements of different educational reference architectures. Examples are given of ArchiMate elements with additional information that is visible on the WikiXL pages of these elements. The examples of 'Onderwijsdeelnemer' and 'Learning Content Management Systeem (LCMS)' of respectively the ROSA and FORA can be found in figure 6.5 and figure 6.6.

The case study also demonstrates that the method is not universally applicable. The method cannot directly be applied to every reference architecture, as the semantic wikis of reference architectures sometimes need modifications to show the additional information of related ArchiMate elements. Furthermore, the method requires large efforts from digital architects, as creating the RDF-based data model with relationships in it is a manual task. Also, WikiXL is the only semantic wiki that was used within the case study. Therefore, further research is needed to improve the method and validate it in different contexts, with different reference architectures and different semantic wikis.

8.2 Main research question

RQ *How can a method be designed to improve the coherence between the reference architectures within the Dutch public sector?*

To answer this main research question, a multifaceted approach was adopted. Initially, research was conducted by comprehensively understanding the benefits of Enterprise Architecture for organisations within the public sector. Furthermore, the benefits of using reference architectures for Enterprise Architecture practices were researched. Although empirical studies in this domain were limited, existing literature indicated that reference architectures could improve communication among stakeholders, guide architecture design processes, and improve the quality and consistency of EA deliverables.

The next step in the research was to delve into the use of semantic wikis, particularly WikiXL, to organise and structure architectural knowledge of reference architectures. Such platforms have been beneficial in practice in addressing the semi-structured nature of architectural knowledge, thereby improving the reusability of architectural knowledge of reference architectures.

However, the main problem of this research was the lack of coherence between reference architectures within the Dutch public sector. Digital architects experienced many problems of a lack of coherence. One aspect of improving this coherence is to define and establish meaningful relationships between components of reference architecture. Therefore, a method is designed to realise these relationships. This structured approach aims to guide digital architects in systematically defining and establishing relationships between ArchiMate elements of different reference architectures. The validation of this method was done by conducting a case study within the educational sector. While promising results were generated, further work is needed to improve the method.

The method focuses on the realisation of relationships between reference architectures. However, improved coherence between reference architectures can only be achieved by improving more aspects that are related to it. For example, meta-models of different reference architectures should be aligned with each other. Moreover, reference architectures should use the same terms and definitions for concepts that are used in the same way. Furthermore, common terms, viewpoints and architecture frameworks should be reused by different reference architectures. Also, explicit references are needed from information within reference architectures to information in other reference architectures.

In conclusion, this research provides a method to improve one aspect of coherence between reference architectures within the Dutch public sector. The method that is designed is a step-by-step guide that digital architects can follow to define and establish relationships between ArchiMate elements of different reference architectures, published on semantic wikis, within the Dutch public sector. When completing this method, the additional information about the established relationships is visible on the semantic wikis of the related reference architectures. The method or artefact of this research can be found in figure 5.1 (in Dutch in figure J.1). The method is documented and explained in section 5.3.

8.3 Future work

As indicated in the previous section, future work is needed to improve the coherence between reference architectures within the Dutch public sector. The method proposed in this research can be further researched and developed. The method should be tested in multiple contexts and used by multiple digital architects. When the feedback of a large group of digital architects is used to improve the method, the method will be increasingly used in practice. So, a support base is needed in the architecture community before the method will be used on a large scale.

Furthermore, this research focuses on defining and establishing relationships between components of reference architectures, however, this is merely one aspect of improving coherence. Also, the method requires large efforts from digital architects using the method. Much manual work is needed to establish the relationships in a data model. So, future research should look into the automation of establishing relationships, to reduce the manual efforts that are needed at this moment.

Appendices

In the appendices, one can find models, tables and additional contents that are excluded from the main text. In Appendix A one can find the BPMN processes of the two Systematic Literature Reviews. In Appendices B and C the shortlists of papers can be found of the first and second SLR respectively. In Appendix D the questions that were asked during the focus group can be found. Focus group data and the resulting data by using the FGDAF are presented in Appendix E. Moreover, in Appendix F the findings of the focus group are presented, written in Dutch, which were also given to digital architects in the survey research. In Appendix G, a Dutch summary is given of the results of the Research Topics study, which was also given to digital architects in the survey research. The survey questions are listed in Appendix H. In appendices I and J Dutch versions are presented of the validated ArchiMate motivation view 4.6 and the method J.1. Lastly, a Dutch summary of the thesis is presented in Appendix K.

Appendix A

BPMN processes of SLRs

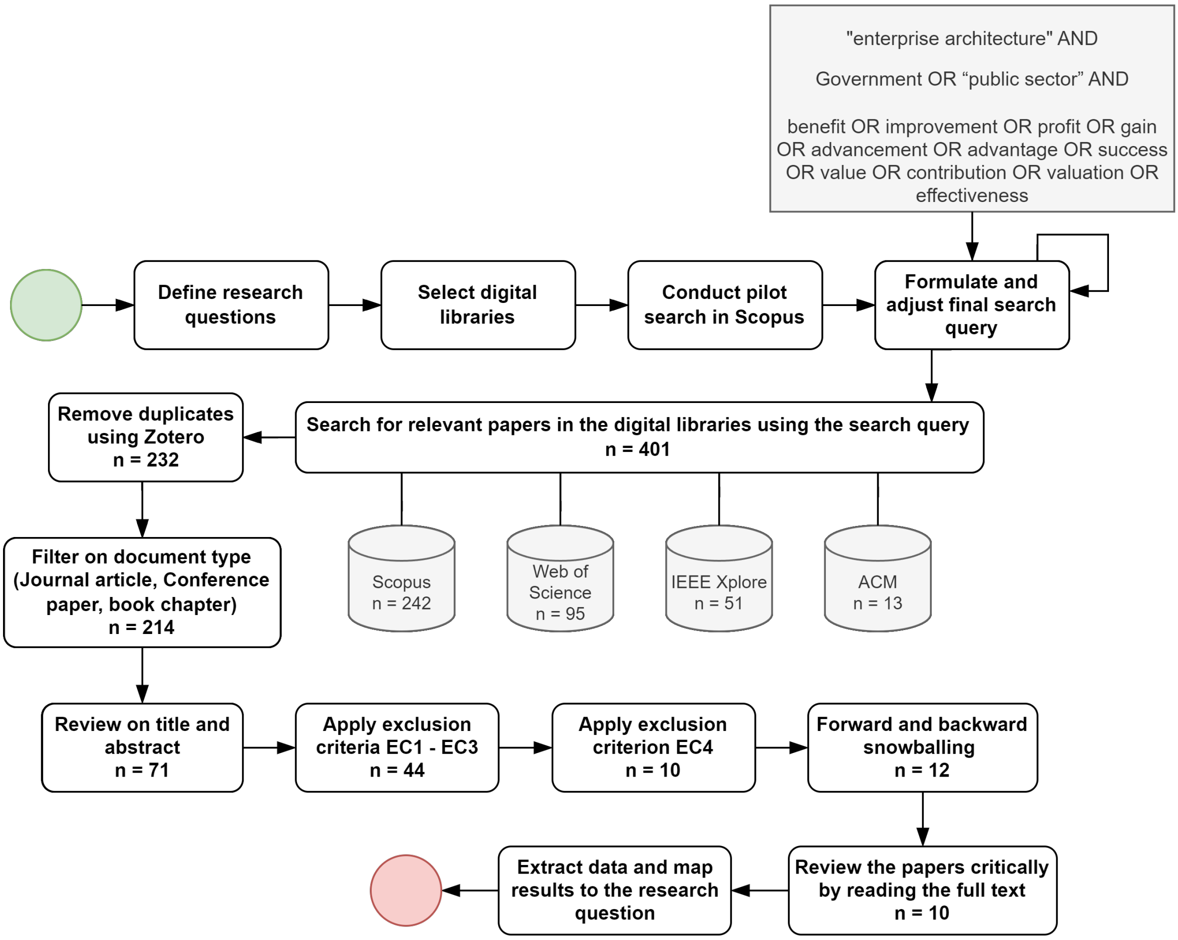


Figure A.1: Process of SLR1

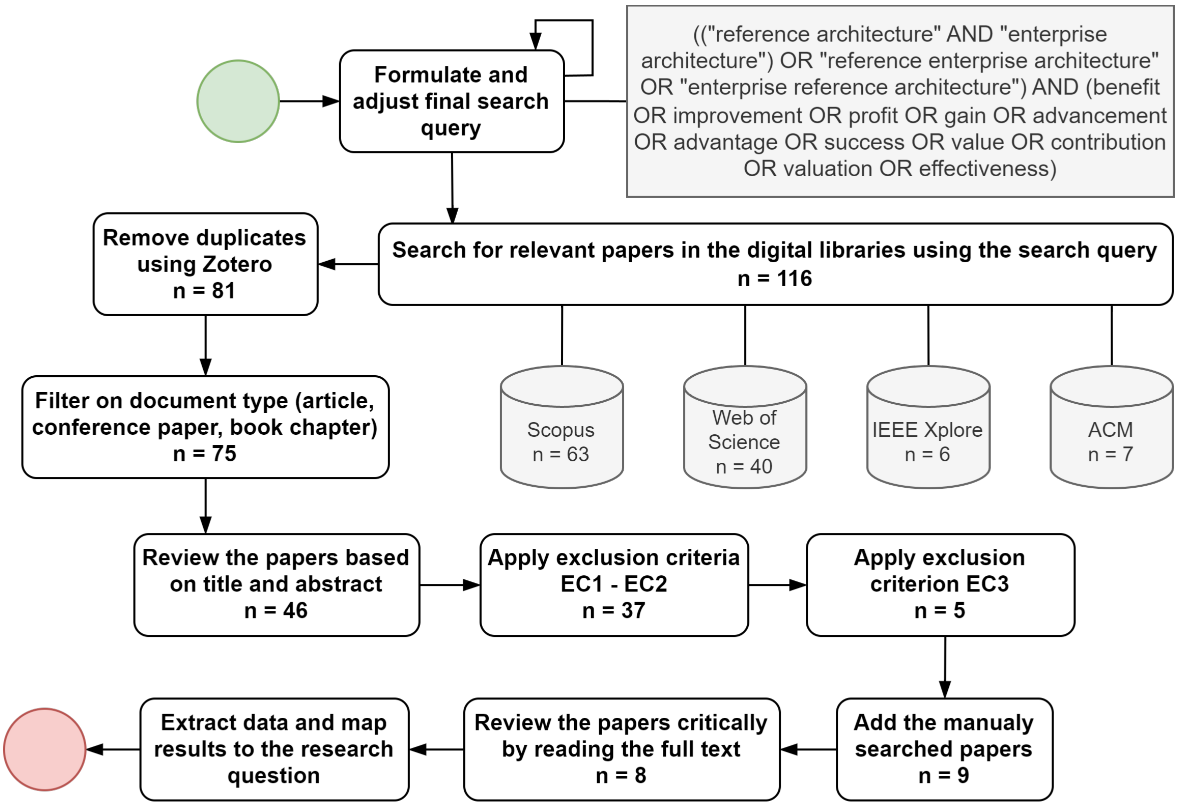


Figure A.2: Process of SLR2

Appendix B

Shortlist of papers of SLR1

No.	Title	Excluded?
1	Role of beacon architecture in mitigating enterprise architecture challenges of the public sector	yes
2	Measuring the benefits of enterprise architecture: Knowledge management maturity	no
3	Enterprise architecture and its role in solving business issues: Case study of the NSW department of lands	yes
4	A Framework for Evaluating Compliance of Public Service Development Programs with Government Enterprise Architecture	yes
5	A methodology for government transformation with enterprise architecture	yes
6	ICT-Project Failure in Public Administration: The Need to Include Risk Management in Enterprise Architectures	yes
7	Ambiguities in the early stages of public sector enterprise architecture implementation: Outlining complexities of interoperability	yes
8	Achieving Enterprise Architecture Benefits: What Makes the Difference?	no
9	National enterprise architecture framework: Case study of EA development experience in the Kingdom of Bahrain	yes
10	Can enterprise architectures reduce failure in development projects?	no
11	Improving Government Enterprise Architecture practice - Maturity factor analysis	yes
12	Enterprise architecture in countries with volatile governance: Negotiating challenges and crafting successes	yes
13	Architects' perceptions on EA use - An empirical study	yes
14	Government Architecture: Concepts, Use and Impact	no
15	Towards adoption of government enterprise architecture: The cases of Egypt and Syria	yes
16	Enterprise architecture as enabler of organizational agility - A municipality case study	no
17	Improving e-government performance through enterprise architecture	yes
18	Government enterprise architecture in practice	yes
19	Increasing the relevance of enterprise architecture through ”Crisitunities”' in U.S. state governments	no
20	Enterprise Architecture of Colombian Higher Education	yes
21	Empirical insights into the development of a service-oriented enterprise architecture	yes
22	Assessment of Enterprise Architecture Implementation Capability and Priority in Public Sector Agency	yes
23	Construction of enterprise architecture in discourses within the public sector	yes
24	The Decision-Making Context Influences the Role of the Enterprise Architect	no
25	Dynamics of Enterprise Architecture in the Korean Public Sector: Transformational Change vs. Transactional Change	yes
26	Enterprise architecture for e-Government	yes
27	Enterprise architecture institutionalization: A tale of two cases	yes
28	Preliminary Study of Malaysian Public Sector (MPS) Transformation Readiness through Enterprise Architecture (EA) establishment	yes
29	Method and practical guidelines for overcoming enterprise architecture adoption challenges	no
30	Enterprise architecture challenges: A case study of three Norwegian public sectors	yes
31	A systematic literature review: Critical Success Factors to Implement Enterprise Architecture	yes
32	Lean enterprise architecture method for value chain based development in public sector	yes
33	Effects of GWEA Implementation on ICT Standardisation Across SA Government Departments	yes
34	Dimensions for Scoping e-Government Enterprise Architecture Development Efforts	yes
35	A Proposal to a Framework for Governance of ICT Aiming At Smart Cities with a Focus on Enterprise Architecture	yes
36	Dynamic metamodel approach for government enterprise architecture model management	yes
37	Benefits of government enterprise architecture: Context of certain EA initiatives in India	no
38	Modelling the enterprise architecture implementation in the public sector using HOT-Fit framework	yes
39	Factors That Influence the Adoption of Enterprise Architecture by Public Sector Organizations: An Empirical Study	yes
40	Development and validation of enterprise architecture (EA) readiness assessment model	yes
41	The Adoption of Enterprise Architecture by Public Sector Organizations : Research in Brief	yes
42	Implicit Coordination and Enterprise Architecting Effectiveness	no
43	Roles and capabilities of enterprise architecture in big data analytics technology adoption and implementation	yes
44	Sustainable government enterprise architecture framework	yes
Total		**34**

Table B1: Shortlist of papers from SLR1 during application of EC4 - part 1 (step V)

No.	Author	Type	Year	Contribution of the paper
1	Bhagwat, A.	B	2008	Development of a new concept for mitigating EA challenges within the public sector.
2	Dyer, A.	B	2008	Development of a framework to measure the effectiveness of EA implementation by looking at the Knowledge Management perspective.
3	Harris, P.T.	C	2008	Analysis of EA and its applicability across government organizations. Focused on a single department from the government of Australia.
4	Liimatainen, K.	C	2008	Development of a framework for evaluating compliance of public service development programs with GEA.
5	Saha, P.	B	2008	Development of a methodology for government agency transformation based on EA.
6	Janssen, M.	C	2010	Analysis of the relationship between EA and risk management for ICT projects in the public sector.
7	Larsson, H.	C	2011	Analysis of the different interpretations of EA benefits and the effects of it on EA implementation.
8	van, Steenbergen, M.	C	2011	Analysis of the relationship between EA techniques being used and benefits that are perceived, as well as the influence of contextual factors.
9	AlSoufi, A.	B	2012	Development of an EA framework and the evaluation of it.
10	Janssen, M.	J	2012	Analysis of the relationship between project failure and the attention to EA or Risk Management. Extension of their paper from 2010.
11	Ojo, A.	C	2012	Identification of key factors for raising the maturity of Government Enterprise Architecture practice.
12	Zoughbi, S.	B	2012	Analysis of the relation between countries with a volatile governance and the implementation of EA.
13	Hiekkanen, K.	C	2013	Identification of perceptions on EA work in the Finnish public sector.
14	Janssen, M.	C	2013	Development of a conceptual model illustrating the relationships between Government Architecture concepts, its use, benefits and public value drivers.
15	Mohamed, M.A.	C	2013	Analysis of EA adoption in developing countries.
16	Carvalho, J.	C	2014	Analysis of the relationship between the development and use of EA and organizational agility. Case study in a large municipality in Portugal.
17	Hanafiah, M.A.	B	2014	Analysis of EA adoption in developing countries.
18	Lahtela, A.	C	2014	Analysis of the function of GEA and the challenges for implementing GEA at a Finnish government agency.
19	Bui, Q.N.	J	2015	Identification of four lessons learned during EA implemenation, based on three approaches/case studies in the U.S.
20	Llamosa-Villalba, R.	C	2015	Development and evaluation of the Colombian Higher Education framework.
21	Alwadain, A.	J	2016	Analysis of EA evolution in a government agency.
22	Bakar, N.A.	C	2016	Analysis of an assessment process of EA implementation capability and priority.
23	Lemmetti, J.	C	2016	Analysis of the different interpretations of EA benefits and the effects of it on EA implementation.
24	Van, den, Berg, M.	C	2016	Identification of four factors that determine the role of EA in IT decision-making.
25	Nam, K.	J	2016	Development of an EA success model (CSFs on three EA implementation stages) for the Korean public sector.
26	Agarwal, R.	C	2017	Development of an EA framework and the evaluation of it.
27	Dang, D.	C	2017	Analysis of the institutionalization process of EA in the Finnish public sector.
28	Hussein, S.S.	C	2017	Identification of 17 readiness factors for a succesful EA implementation in the Malaysian public sector.
29	Syynimaa, N.	C	2017	Development of an EA adoption methodology, with a large focus on EA benefits.
30	Ajer, A.K.	C	2018	Identification of three major challenges for EA projects in Norwegian public sector.
31	Ansyori, R.	C	2018	Literature review on examining critical succes factors of Enterprise Architecture implementations.
32	Hosiaisluoma, E.	C	2018	Development of a methodology for intertwining EA in organization's development work in a large city in Finland.
33	Makovhololo, M.L.	C	2018	Analysis of complexities regarding Government-wide EA in South-African government departments.
34	Nakakawa, A.	C	2018	Development of a methodology for scoping EA efforts in E-Government.
35	Tanaka, S.A.	C	2018	Development of a framework for governance of ICT aiming at smart cities with a focus on EA.
36	Abu, Bakar, N.A.	C	2019	Development of a dynamic EA metamodel for GEA.
37	Pandurangi, G.	J	2019	Literature review on the identification of EA benefits in Government and the proposal of a 4-pillar model (4PM) of EA value promotors.
38	Sallehudin, H.	J	2019	Development of a model with important factors influencing the EA implementation process.
39	Ahmad, N.A.	J	2020	Identification of factors that influence the adoption of EA.
40	Hussein, S.S.	J	2020	Development and evaluation of EA readiness assessment model.
41	Ahmad, N.A.	C	2020	Identification of factors that influence the adoption of EA.
42	Espinosa, J.A.	J	2021	Analysis of how implicit and explicit coordination influence architecting effectiveness.
43	Gong, Y.	J	2021	Analysis of the roles and capabilities of EA for Big Data Analytics adoption in a public sector organization.
44	Thirasakthana, M.	J	2021	Development of a framework for developing countries to support EA implementation.

Table B2: Shortlist of papers from SLR1 during application of EC4 - part 2 (step V)

Appendix C

Shortlist of papers of SLR2

No.	Title	Excluded?
1	Enterprise Integration - Business Processes Integrated Management: A proposal for a methodology to develop Enterprise Integration Programs	yes
2	Designing manufacturing systems: Contribution to the development of an Enterprise Engineering Methodology (EEM) within the frame of geram	yes
3	VERA: Virtual Enterprise Reference Architecture	no
4	An interorganizational knowledge-sharing security model with breach propagation detection	yes
5	A service-oriented reference architecture for organizing cross-company collaboration	yes
6	Industrialization strategies for cross-organizational information intensive services	yes
7	Managing systems of systems interoperability - federated soa and reference architectures	no
8	Mapping SOA artefacts onto an enterprise reference architecture framework	yes
9	An enterprise architecture approach towards environmental management	yes
10	Modeling digital preservation capabilities in enterprise architecture	no
11	Integrating environmental and information systems management: An enterprise architecture approach	yes
12	Adaptive architecture development for Smart Grids based on integrated building blocks	yes
13	A Reference Architecture for an Enterprise Knowledge Infrastructure	yes
14	Information systems for the governance of compliant service systems	yes
15	Evolving a core banking enterprise architecture: Leveraging business events exploitation	yes
16	Integrating Business Information Streams in a Core Banking Architecture: A Practical Experience	yes
17	Digital enterprise architecture-transformation for the internet of things	no
18	Enterprise architecture management forthe internet of things	yes
19	Architecting the enterprise towards enhanced innovation capability	yes
20	FIRST IN-DEPTH ANALYSIS OF ENTERPRISE ARCHITECTURES AND MODELS FOR HIGHER EDUCATION INSTITUTIONS	no
21	A critical review on reference architectures and models for higher education institutions	yes
22	EA management in the German public sector: An initial perspective on priorities	yes
23	An application design for reference enterprise architecture models	yes
24	Applying Enterprise Architecture for Digital Transformation of Electro Mobility towards Sustainable Transportation	yes
25	Life cycle engineering 4.0: A proposal to conceive manufacturing systems for industry 4.0 centred on the human factor (DfHFinI4.0)	yes
26	Positioning IT4IT in the face of classic Enterprise Architecture Frameworks A critical review	yes
27	Using enterprise architecture to model a reference architecture for industry 4.0	yes
28	Agile architecture for digital enterprises	yes
29	Utilizing an Enterprise Architecture Framework for Model-Based Industrial Systems Engineering	yes
30	Reference Architecture for Project, Program and Portfolio Governance	yes
31	A Reference Architecture for Enhanced Design of Software Ecosystems	yes
32	A Reference Architecture for On-Premises Chatbots in Banks and Public Institutions Guidance on Technologies, Information Security and Data Protection	yes
33	Adaptive enterprise architecture for the digital healthcare industry: A digital platform for drug development	yes
34	Towards a Reference Architecture for Demand-Oriented Public Transportation Services	yes
35	Blockchain Analytics Reference Architecture for FinTech-A Positioning Paper Advancing FinTech with Blockchain, Data Analytics, and Enterprise Architecture	yes
36	SECC Smart University Reference Architecture	yes
37	An Improved Purdue Enterprise Reference Architecture to Enhance Cybersecurity	yes
Total		**32**

Table C1: Shortlist of papers from SLR2 during application of EC3 - part 1 (step V)

No.	Author	Type	Year	Contribution of the paper
1	Ortiz, A.	J	1999	Development of a methodology for developing Enterprise Integration Programs in a business entity.
2	Chen, D.	C	2002	Development of a structured approach for designing a manufacturing system using the GRAI methodology, which is consistent with CIMOSA and PERA.
3	Vesterager, J.	C	2003	Analysis of the main components of the Virtual Enterprise Reference Architecture and examples of its use and potentials.
4	Soper, D.S.	J	2007	Development of an interorganizational knowledge-sharing security model that integrates the value chain reference model, the federated enterprise reference architecture, and multidimensional data warehouse technologies.
5	Schroth, C.	C	2008	Development of a service-oriented reference architecture for business media, that overcome the drawbacks of today's B2B software products and services.
6	Schroth, C.	C	2008	Implementation of a service-oriented reference architecture for business media at a Swiss public administration organization. Extended work on paper no. 9.
7	Chang, C.F.	C	2009	Development of a reference architecture framework that meet IKC2 challenges and a description of the linkage with EA and the framework, and how the framework guide the Singapore Armed Forces transformations.
8	Noran, O.	C	2009	Analysis of mapping SOA artefacts on a commonly used enterprise architecture framework.
9	Noran, O.	C	2010	Development of a synergy by integrating Environment Management as an aspect into the continuous EA initiative.
10	Becker, C.	C	2011	Development of an architectural approach that enables Business-IT alignment by accommodating the concerns of Digital Preservation in EA practices.
11	Noran, O.	C	2011	Analysis of integrating Environmental Management with EA (the Business and Information Systems)
12	Trefke, J.	C	2012	Development of the Smart Grid Architecture Model (SGAM) as well as the Enterprise Smart Grid Architecture Development (ESGAD) framework.
13	Fitzpatrick, D.	C	2013	Development of a reference architecture for enterprise knowledge infrastructures (RA-EKI). The reference architecture should support product managers in their product lifecycle value analyses.
14	Dubois, E.	C	2014	Development of a Process Reference Model to measure the quality of delivered IT services and explanation of how IS and EA can effectively support the deployment of such global governance model
15	San Miguel, B.	C	2014	Analysis of the integration of (real-time) information into an existing banking EA
16	San Miguel, B	C	2015	Analysis of the technical challenges of integrating real-time business event information into the EA of an existing bank
17	Zimmermann, A.	C	2015	Development of an extended service-oriented enterprise architecture reference model and ontology for an integrated approach of EA and IoT.
18	Zimmermann, A.	C	2015	The same paper as no. 17, only a different publication.
19	Louw, L.	J	2017	Literature review on requirements for building a more innovation-capable organization, and laying the foundation for an enterprise engineering approach for that.
20	Sanchez-Puchol, F	J	2018	Analysis of comparing 20 existing Enterprise Reference Architectures and Reference Models targeted to the Higher Education domain.
21	Sanchez-Puchol, F.	C	2018	The same paper as no. 20, only a different publication.
22	Sonnenberger, A.	C	2018	Identification of weaknesses of EA in the public sector in Germany. Recommendations were found to strengthen the existing structure and turning it into a coherent overall architecture for federal and state agencies in Germany.
23	Timm, F.	C	2018	Analysis on how reference enterprise architectures can help (financial) organizations save costs and improve the quality of their Regulatory Compliance Management (RCM) approaches
24	Anthony Jnr., B.	C	2020	Implementation of EA for digital transformations of E-mobility services. The Industrial Data Space Reference Architecture Model (IDS-RAM) is used to manage data integration to support cities implementing sustainable transportation services.
25	de Miranda, S.S.-F.	J	2020	Development of a framework for the conception of manufacturing systems as Cyber-physical socio-technical systems, with a life cyle engineering 4.0 perspective. PERA involved.
26	Hartmann, A.	C	2020	Analysis of comparing IT4IT with classic EA frameworks TOGAF and ARIS using evaluation criteria from the literature.
27	Paiva, M.	C	2020	Development of a reference architecture based on the Reference Architecture Model Industry 4.0 (RAMI4.0) and the ArchiMate language.
28	Anshina, M.	C	2021	Analysis of the need for a systematic architectural approach for digital enterprises. Agile methodologies and the Agreement-Driven Service Architecture (ADSA) model can help achieving the balance between flexibility and stability of an enterprise.
29	Binder, C.	C	2021	Analysis of an approach where TOGAF can be used to enable Model-Based System Engineering of manufacturing systems according to RAMI4.0.
30	Cordeiro, G.	C	2021	Development of a reference architecture for the comparison of PPP Governance models. The layered architecture combines roles and competences presented in ISO's and put the competences organized in the project management layers.
31	Gupta, S.K.	C	2021	Development of a reference architecture specifically for software ecosystems, concerning organizational, technical and business aspects of it.
32	Koch, C.	C	2021	Development of a reference architecture for developing and operating chatbots. The RA is based on a practitioner's perspective, with technical and methodological components as well as required technologies.
33	Masuda, Y.	J	2021	Development of a reference architecture for digital platforms related to the drug discovery and development process, based on the GDTC model and SCM of the EA framework named Adaptive Integrated Digital Architecture Framework (AIDAF).
34	Wurtz, M.-O.	C	2021	Analysis of the feasibility of extending public transportation reference architectures and development of such an extension.
35	Elsheikh, A.S.	C	2022	Development of a blockchain analytics reference architecture for the financial sector. The architecture is based on "Value-Driven Enterprise Architecture" and uses various techniques such as "TOGAF" and "Capability-Based Planning"
36	Hamza, Haitham S.	C	2022	Analysis of SECC's vision for smart universities, the proposed capabilities and the suggested reference architecture. The reference architecture developed is called Smart Universities Reference Architecture (SURA).
37	Xu, Wei	C	2023	Analysis of the history of the Purdue Enterprise Reference Architecture (PERA), analysis of the cybersecurity problems of it and proposal of an improved PERA to enhance cybersecurity

Table C2: Shortlist of papers from SLR2 during application of EC3 - part 2 (step V)

Appendix D

Questions of the focus group

No.	Question
1	Hoe wordt de samenhang tussen verschillende referentiearchitecturen op dit moment gedefinieerd binnen de publieke sector? En wat is jullie begrip van het concept “samenhang tussen referentiearchitecturen”?
2	Waarom willen we de referentiearchitecturen meer met elkaar laten samenhangen?
3	Wat zijn volgens jullie de belangrijkste voordelen die kunnen worden behaald door een verbeterde samenhang tussen referentiearchitecturen?
4	Zijn er bepaalde referentiearchitecturen, naast de NORA, die als leidend worden beschouwd binnen de NORA familie?
5	Hoe zou de mate van samenhang tussen twee referentiearchitecturen getoetst kunnen worden? Welke criteria zouden daarvoor nodig zijn?
6	Moet er een centrale organisatie verantwoordelijk worden voor het totale beheer van (samenhang van) referentiearchitecturen?
7	Hoe zou het delen van kennis tussen beheerders en gebruikers van verschillende referentiearchitecturen verbeterd kunnen worden?
8	Welke problemen en/of uitdagingen komen jullie in de praktijk tegen, door een gebrek aan samenhang tussen referentiearchitecturen? Zijn er concrete voorbeelden te noemen?
9	Wie ondervindt voornamelijk deze problemen? Zijn dat de architecten zelf of ook andere belanghebbenden
10	Kan er ingeschat worden hoeveel impact het gebrek aan samenhang tussen referentiearchitecturen heeft op organisaties in de publieke sector?

Table D.1: Questions part I of the focus group (02-06-2023)

No.	Question
1	Kunnen jullie concrete voorbeelden noemen van relaties tussen referentiearchitecturen?
2	Wat voor soorten relaties zijn het belangrijkste voor de bevordering van samenhang tussen referentiearchitecturen? Zijn dit complementaire relaties (aanvullend zijn op) of overkoepelende relaties (hergebruik van)?
3	Wat zijn de belangrijkste elementen van referentiearchitecturen die gerelateerd moeten worden aan elkaar? Zijn dit de architectuurprincipes of de architectuurmodellen?
4	Op welke manier zouden referentiearchitecturen met elkaar verbonden moeten worden? Is dit door binnen bestaande referentiearchitecturen te beschrijven hoe deze relateren aan andere referentiearchitecturen? Of zijn er nog andere opties?
5	Hoe worden op dit moment relaties tussen referentiearchitecturen beschreven? Wordt dit duidelijk in de architectuurmodellen of staat dit beschreven in tekst op de wiki's?
6	Zijn er op dit moment referentiearchitecturen die sterk gerelateerd zijn aan elkaar en dit ook beschrijven in hun referentiearchitecturen?

Table D.2: Questions part II of the focus group (02-06-2023)

No.	Description	Duration (in minutes)
1	Introduction of the research by presenting the (partly complete) conducted systematic literature reviews	10
2	Purpose of the focus group and explanation of the research method	5
3	Part I - State of coherence between reference architectures	70
4	Part II - Examples of desired explicit relationships between reference architectures	15

Table D.3: Planning of the focus group (02-06-2023)

Appendix E

The focus group data

Person	Data					
Moderator	To all participants: Waarom willen we de referentiearchitecturen meer met elkaar laten samenhangen?				To all participants: Ik hoor nu drie zaken. 1. Een gebrek aan samenhang zorgt voor problemen voor het maken van specifieke Enterprise Architecturen; 2. Domeinen hangen nou eenmaal samen, sommigen zorgen voor een dusdanige impliciete samenhang tussen referentiearchitecturen dat het nodig is om ze expliciet te laten samenhangen; 3. Hergebruik van componenten uit referentiearchitecturen is efficiënter"	
Participant 1			To P4: Een ander voorbeeld waarom domeinen overlappen is de visie vanuit de gehele onderwijssector. "Een onderwijsdeelnemer en een leven lang ontwikkelen". Daarbij, systemen moeten interoperabel zijn. Dus, de semantiek van systemen moet in die overlap zichtbaar zijn.		To moderator: Ja, inefficiënties worden zichtbaar op het gebied van sector-overstijgende processen	To moderator and all participants: Er moet meer herkenbaarheid zijn tussen referentiearchitecturen. Dit zorgt voor een verbeterde leercurve. Het kost namelijk veel moeite om van referentiearchitectuur naar referentiearchitectuur te stappen. Meer samenhang zal zorgen voor uitwisselbare architecten op projecten voor de Nederlandse publieke sector.
Participant 2			To P1: Er is een intrinsieke motivatie van veel architecten om niet alles opnieuw zelf uit te vinden, maar goede voorbeelden te hergebruiken. Het is heel inspirerend om te weten hoe de buren het doen. Dat moet vindbaar zijn, aangezien er al een keer goed over nagedacht is		To moderator: Ja, dat zijn drie belangrijke redenen. Maar er zijn er nog meer. Er ontstaan steeds meer referentiearchitecturen. Niet alle architecturen zijn referentiearchitecturen, maar ook vergezichten. Differentiatie zorgt er voor dat er nóg meer behoefte is om meer samenhang te hebben tussen componenten van architecturen. Concepten komen voor in meerdere architecturen. Processen lopen door meerdere referentiearchitecturen en moeten interoperabel zijn. Ketensamenwerking, waarbij meerdere partijen samenwerken op het gebied van informatie-uitwisseling en processen. Werkingsgebieden overlappen.	
Participant 3				To moderator and all participants: Er is een consensus in de architectuurwereld over meer samenhang. De beweging is bottom-up, dus vanuit specifiekere referentiearchitecturen naar generiekere referentiearchitecturen. En domeinen kennen veel overlap. Gemeenten en waterschappen bijvoorbeeld (GEMMA en WILMA). Maar ook het onderwijsverzuim in de GEMMA, FORA, MORA en HORA.		
Participant 4		To moderator and all participants: Domeinen overlappen en daarom moet informatie gezamenlijk te vinden zijn en elkaar niet tegenspreken! Als je een concrete (Enterprise) architectuur maakt, moet dat voor iedereen DE oplossing zijn.			To moderator: Er is een verbeterde kwaliteit van architectuur als je van elkaars kennis gebruik maakt. Momenteel missen referentiearchitecturen herleidbaarheid.	

Table E.1: Example format of focus group data for question 2 of part I (Step I of FGDAF)

Theme: Samenhang tussen referentiearchitecturen							
Category 1: Definitie van ’samenhang’			**Category 2: Huidige staat van samenhang**		**Category 3: Behoefte aan een verbeterde samenhang**		
Code 1: Semantiek	*Code 2: Inhoud*	*Code 3: Relaties*	*Code 4: Initiatieven*	*Code 5: Vorm*	*Code 6: Domein overlap*	*Code 7: Intrinsieke motivatie*	*Code 8: Technologie*
Samenhang op het gebied van semantiek is gericht op de volgende zaken: * Gebruiken en toepassen van dezelfde architectuurtaal, bv. ArchiMate; * Gebruiken van dezelfde begrippen voor concepten; * Het begrijpen van betekenissen van begrippen in relatie tot elkaar; * Gebruiken van dezelfde architectuurcomponenten.	Samenhang op het gebied van inhoud is gericht op de volgende zaken: * Views, viewpoints en architectuurmodellen: (Her-)gebruiken van viewpoints; * Architectuurkaders: (Her-)gebruiken van architectuurkaders (architectuurprincipes); * Standaarden: Gebruiken en toepassen van dezelfde standaarden, bv. TOGAF; * Positionering: Logisch positioneren van referentiearchitecturen t.o.v. andere referentiearchitecturen; * Traceerbaarheid: Verwijzingen tussen architectuurcomponenten.	Samenhang op het gebied van relaties is gericht op de volgende zaken: * Koppelingen tussen architectuurprincipes; * Koppelingen tussen architectuurmodelelementen.	Op dit moment ‘ontstaat’ samenhang voornamelijk door werkende initiatieven binnen referentiearchitecturen die uiteindelijk een eigen leven gaan leiden. De initiatieven hebben vaak een bottom-up-achtige vorm, waarbij een specifiekere referentiearchitectuur de relatie beschrijft met een abstractere referentiearchitectuur.	De samenhang, als die expliciet aanwezig is, is op dit moment vaak tekstueel beschreven en te vinden op kennismanagement-platformen als WikiXL en op andere websites en documenten waar referentiearchitecturen beschreven staan. Zo heeft de Referentie Onderwijs Sector Architectuur (ROSA) een pagina op haar WikiXL staan, waarbij de samenhang met andere architecturen is beschreven. Bij andere referentiearchitecturen ontbreekt het aan een specifieke pagina over de samenhang met andere referentiearchitecturen.	De belangrijkste reden voor een verbeterde samenhang is het feit dat domeinen simpelweg veel overlap hebben. Referentiearchitecturen gekoppeld aan deze domeinen moeten dus ook veel overlap bevatten. Dit is zichtbaar in (keten)processen die door meerdere referentiearchitecturen heen lopen en bijvoorbeeld concepten die in meerdere referentiearchitecturen voorkomen. De interoperabiliteit van processen kan worden bevorderd als processen op een gezamenlijke manier worden uitgelegd.	Een aantal zaken zal de kwaliteit van referentiearchitecturen ten goede komen: * Er is een intrinsieke motivatie van architecten om niet alles zelf opnieuw uit te vinden, maar goede voorbeelden te hergebruiken; * Als men van elkaars kennis gebruik maakt, zorg je voor een verbeterde kwaliteit van referentiearchitecturen; * Er zijn de laatste jaren steeds meer referentiearchitecturen ontstaan, momenteel kent de NORA familie 27 actuele referentiearchitecturen.	Er zijn tegenwoordig technologieën beschikbaar om informatie aan elkaar te koppelen. Linked Data is een manier om data aan elkaar te koppelen. Middels een ’subject’, ’predicate’ en een ’object’ kun je alle gewenste relaties tussen data elementen beschrijven.

Table E.2: Focus group data analysis results part I

Theme: Problemen door een gebrek aan samenhang en de gewenste relaties tussen referentiearchitecturen					
Category 1: Huidige problemen				**Category 2: Gewenste relaties**	
Code 1: Stakeholders	*Code 2: Traceerbaarheid*	*Code 3: Contradicties*	*Code 4: Efficiëntie*	*Code 5: Vorm*	*Code 6: Afspraken*
De volgende stakeholders zouden problemen ervaren van een gebrek aan samenhang tussen referentiearchitecturen: * Architecten en daardoor veel IT projecten; * Informatiemanagers; * Gebruikers van referentiearchitecturen in het algemeen; * Softwareleveranciers;	Inhoud van referentiearchitecturen is soms niet of nauwelijks traceerbaar. * Informatie van referentiearchitecturen is niet gezamenlijk te vinden * Componenten van referentiearchitecturen zijn niet of nauwelijks herleidbaar	Op bepaalde gebieden spreken referentiearchitecturen elkaar tegen, omdat deze niet in harmonie zijn opgesteld. Dergelijke contradicties bemoeilijken het om een specifiekere (Enterprise) architectuur op te stellen.	De volgende zaken verslechteren de efficiëntie van het opstellen van specifiekere architecturen, op basis van referentiearchitecturen. * Overnemen van componenten heeft geen prioriteit; * Overnemen van componenten is tijdrovend	Een relatie tussen referentiearchitecturen kan verschillende vormen hebben. Belangrijk is dat relaties expliciet worden vastgelegd. De relaties 'Aanvullend zijn op' en 'hergebruik van', gedefinieerd door de NORA, zijn allebei gewenste relaties. Voorbeelden van gewenste relaties zijn: * Expliciete verbindingen op inhoud: Doel is dat je de volgende vraag kunt stellen: "In welke referentiearchitecturen vind je componenten die te maken hebben met X?"; * Het (niet) overnemen van principes: Duiding geven aan waarom een principe wel of niet wordt overgenomen.	Om relaties tussen referentiearchitecturen vast te leggen zullen stakeholders in gesprek moeten gaan over het gebruik van begrippen, de semantiek van concepten/begrippen, de manier van modelleren, enz. Dit kan alleen als de volgende zaken geregeld worden: * Op management-niveau en bij de stakeholders zelf moet het belang van samenhang leven; * Faciliteren van vergaderingen tussen stakeholders.

Table E.3: Focus group data analysis results part II

Appendix F

The focus group findings

Introductie

Er wordt al enige tijd gezocht naar een verbeterde samenhang tussen referentiearchitecturen binnen de publieke sector. Referentiearchitecturen ondersteunen en geven richting voor het opstellen van Enterprise Architecturen van organisaties. Enterprise Architectuur (EA) is een veelgebruikt middel om samenhang binnen een organisatie te verzorgen. Het kan worden gebruikt om de structuur, bedrijfsprocessen, informatiesystemen en infrastructuur van een organisatie te ontwerpen en te realiseren [1]. Een succesvol gebruik van EA brengt veel voordelen met zich mee voor een publieke organisatie [2], waaronder het verbeteren van de wendbaarheid van de organisatie, verbeteren van de communicatie tussen stakeholders binnen de organisatie, verkrijgen van inzichten in de complexiteit van de organisatie en het verbeteren van de kwaliteit van IT-projecten en het verlagen van het mislukken van IT-projecten.

Het gebruik van referentiearchitecturen voor het opstellen van Enterprise Architecturen kent veel voordelen [2]. Ten eerste bevordert het de communicatie tussen EA stakeholders door een gezamenlijk uitgangspunt te hebben. Daarbij geven referentiearchitecturen begeleiding en sturing tijdens het ontwerp, realisatie en onderhoud van Enterprise Architecturen. Dit bespaart tijd. En als laatste zorgt hergebruik van kennis en zogenoemde 'best-practices' voor een verbeterde kwaliteit en consistentie van EA producten.

Om tot een verbeterde samenhang tussen referentiearchitecturen te komen, moet er eerst onderzocht worden wat de huidige staat van samenhang is en welke relaties tussen referentiearchitecturen wenselijk zijn. Om dit in kaart te brengen is een focusgroep sessie gehouden (02-06-2023) met verschillende architecten die betrokken zijn bij een set referentiearchitecturen. Deze sessie had vier deelnemers, allen adviseurs/architecten, met kennis en ervaring van de volgende referentiearchitecturen: NORA, GEMMA, WILMA, ROSA, FORA, MORA, HORA, CORA, VERA en VeRa. De bevindingen van deze kennissessie zijn hieronder te vinden.

Definitie van 'samenhang'

Samenhang tussen referentiearchitecturen raakt veel aspecten en dus is een eenduidige definitie van samenhang lastig te geven. Samenhang tussen referentiearchitecturen is gericht op in ieder geval de volgende zaken:

- Samenhang gebaseerd op semantiek
  - Gebruiken en toepassen van dezelfde architectuurtaal bv. ArchiMate
  - Gebruiken van dezelfde begrippen voor concepten
  - Gebruiken van dezelfde architectuurcomponenten
  - Het begrijpen van betekenissen van begrippen in relatie tot elkaar
- Samenhang gebaseerd op inhoud
  - Views, viewpoints en architectuurmodellen: (Her-)gebruiken van viewpoints
  - Architectuurkaders: (Her-)gebruiken van architectuurkaders (architectuurprincipes)
  - Standaarden: Gebruiken en toepassen van dezelfde standaarden bv. TOGAF
  - Positionering: Logisch positioneren van referentiearchitecturen t.o.v. andere re-ferentiearchitecturen
  - Traceerbaarheid: Verwijzingen tussen architectuurcomponenten

- Samenhang gebaseerd op relaties
  - Koppelingen tussen architectuurprincipes
  - Koppelingen tussen architectuurmodelelementen

Huidige staat van samenhang

Er is een gebrek aan samenhang tussen referentiearchitecturen, veel architecten en andere stakeholders zijn het daarover eens. Op dit moment 'ontstaat' samenhang voornamelijk door werkende initiatieven binnen referentiearchitecturen die uiteindelijk een eigen leven gaan leiden. De initiatieven hebben vaak een bottom-up-achtige vorm, waarbij een specifiekere referentiearchitectuur de relatie beschrijft met een abstractere referentiearchitectuur. De samenhang, als die expliciet aanwezig is, is op dit moment vaak tekstueel beschreven en te vinden op kennismanagementplatformen als WikiXL en op andere websites en documenten waar referentiearchitecturen beschreven staan. Zo heeft de Referentie Onderwijs Sector Architectuur (ROSA) een pagina op haar WikiXL platform staan, waarbij de samenhang met andere architecturen is beschreven. Bij andere referentiearchitecturen ontbreekt het aan een specifieke pagina over de samenhang met andere referentiearchitecturen.

Concluderend, er is geen gezamenlijke aanpak hoe referentiearchitecturen beter met elkaar kunnen samenhangen. Daarbij, beheerders van referentiearchitecturen dragen hun eigen verantwoordelijkheid over de inhoud en structuur van referentiearchitecturen. Dit bemoeilijkt de samenwerking in het bevorderen van samenhang, aangezien beheerders van referentiearchitecturen verschillende en niet altijd conformerende belangen hebben.

Behoefte aan een verbeterde samenhang

Binnen de architectuurwereld is er consensus over de behoefte aan een verbeterde samenhang tussen referentiearchitecturen. Hieronder staan een aantal redenen uitgelegd:

- De belangrijkste reden voor een verbeterde samenhang is het feit dat domeinen simpelweg veel overlap hebben. Referentiearchitecturen gekoppeld aan deze domeinen moeten dus ook veel overlap bevatten. Dit is zichtbaar in (keten)processen die door meerdere referentiearchitecturen heen lopen en bijvoorbeeld concepten die in meerdere referentiearchitecturen voorkomen. De interoperabiliteit van processen kan worden bevorderd als processen op een gezamenlijke manier worden uitgelegd.
- Er is een intrinsieke motivatie van architecten om niet alles zelf opnieuw uit te vinden, maar goede voorbeelden te hergebruiken;
- Er zijn de laatste jaren steeds meer referentiearchitecturen ontstaan, momenteel kent de NORA familie 27 actuele referentiearchitecturen [3];
- Als men van elkaars kennis gebruik maakt, zorg je voor een verbeterde kwaliteit van referentiearchitecturen;
- De technologie is beschikbaar om informatie aan elkaar te koppelen.

Huidige problemen

Het gebrek aan samenhang tussen referentiearchitecturen zorgt er voor dat er problemen ontstaan voor voornamelijk de architecten binnen de publieke sector. Praktische problemen waar zij tegenaan lopen staan hieronder uitgelegd:

- Informatie in referentiearchitecturen verwijst soms niet of nauwelijks expliciet naar informatie in andere referentiearchitecturen
- Als meerdere referentiearchitecturen gebruikt worden voor het opstellen van een specifieke (Enterprise)architectuur, spreken referentiearchitecturen elkaar soms tegen

- Informatie in verschillende referentiearchitecturen die gezamenlijk (grotendeels hetzelfde) is, is niet vanuit één plaats vindbaar
- Op dit moment ontstaat samenhang vooral door ad hoc samenwerkingen tussen architecten

Een ideaal beeld

Een verbeterde samenhang tussen referentiearchitecturen kan worden bereikt door expliciet relaties vast te leggen tussen componenten van referentiearchitecturen. Deze relaties kunnen verschillende vormen hebben. Het (niet) overnemen van principes is een voorbeeld van een dergelijke relatie die expliciet zou moeten worden gemaakt. De belangrijkste relaties zullen vastgelegd moeten worden tussen componenten van architectuurmodellen. Elementen uit ArchiMate architectuurmodellen zouden aan elkaar gekoppeld moeten worden, waardoor de informatie uit deze architectuurmodellen herleidbaar en traceerbaar worden. Door dit te implementeren kun je bijvoorbeeld de vraag stellen: ”In welke referentiearchitecturen komt het begrip ’Leerling’ voor?”

Referenties

[1] M. Lankhorst, M.-E. Iacob, and H. Jonkers, *Enterprise architecture at work: Modelling, communication, and analysis*. in Enterprise Architecture at Work: Modelling, Communication, and Analysis. Springer, 2005. doi: 10.1007/3-540-27505-3.
[2] Remco Martinus Overvelde, *Towards a methodology for enhancing the coherence between the reference architectures of the Dutch public sector: A literature study on the research topics*, Not published, 2023.
[3] ICTU, *NORA Familie*, Jan. 2023. https://www.noraonline.nl/wiki/NORA_Familie

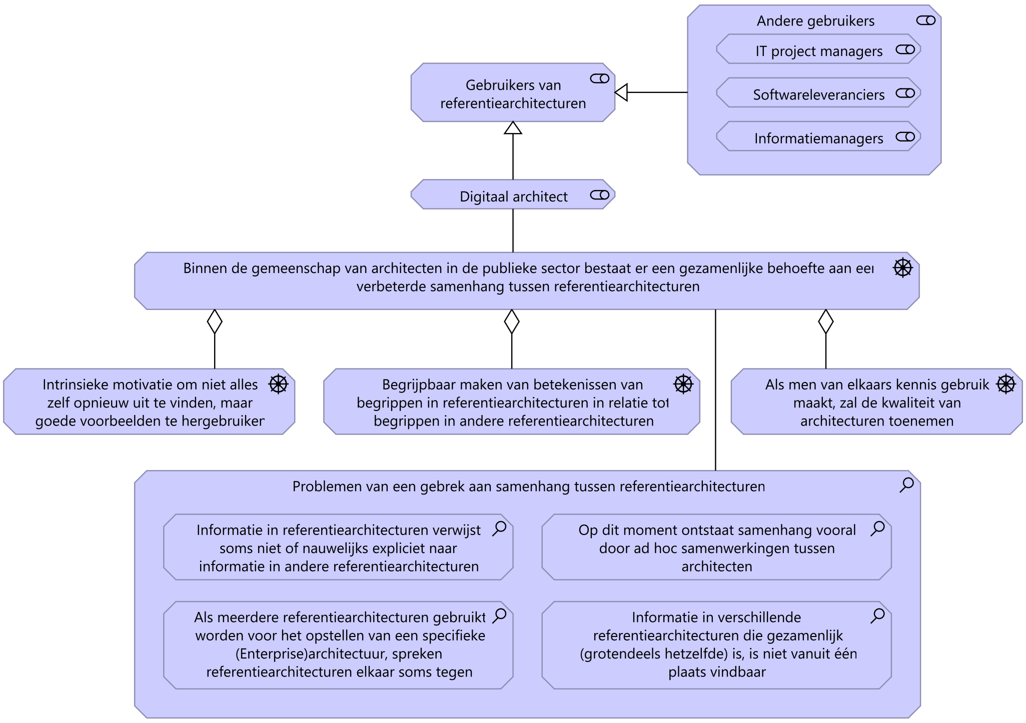


Figure F.1: Beknopte bevindingen van het focusgroep onderzoek (02-06-2023)

Appendix G

Dutch summary of the results of the two SLRs

Aan de start van het onderzoek heb ik twee systematische literatuurstudies gedaan naar de voordelen van Enterprise Architectuur voor organisaties in de publieke sector en de voordelen van referentiearchitecturen voor het opstellen van Enterprise architecturen.

Op de volgende pagina zal ik het onderzoek, inclusief de resultaten van de twee literatuurstudies, introduceren. Als u geen behoefte heeft om de resultaten van de literatuurstudies te lezen, sla dan deze pagina over.

Introductie van het onderzoek

Er wordt al enige tijd gezocht naar een verbeterde samenhang tussen referentiearchitecturen binnen de Nederlandse publieke sector. Referentiearchitecturen ondersteunen en geven richting voor het opstellen van Enterprise architecturen van organisaties. Enterprise Architectuur (EA) is een veelgebruikt middel om samenhang binnen een organisatie te verzorgen. Het kan worden gebruikt om de structuur, bedrijfsprocessen, informatiesystemen en infrastructuur van een organisatie te ontwerpen en te realiseren [1].

Literatuurstudie 1: De voordelen van EA voor organisaties in de publieke sector

Een succesvol gebruik van EA brengt veel voordelen met zich mee voor een publieke organisatie [2], waaronder het verbeteren van de wendbaarheid van de organisatie, verbeteren van de communicatie tussen stakeholders binnen de organisatie, verkrijgen van inzichten in de complexiteit van de organisatie en het verbeteren van de kwaliteit van IT-projecten en het verlagen van het mislukken van IT-projecten.

In onderstaand theoretisch model zijn de resultaten van de eerste literatuurstudie opgenomen, m.a.w. de voordelen van EA voor een organisatie in de publieke sector. De pijlen geven een positieve relatie weer. De voordelen zijn gebaseerd op een totaal van 10 studies, waarvan 8 empirisch bewijs hebben geleverd. Voordelen uit een studie met tenminste één studie met empirisch bewijs zijn groen gekleurd. De overige voordelen zijn enkel uitspraken uit studies (geel), afgeleide voordelen (paars) en een indicator voor het meten van organisatorische voordelen (blauw). De laatste is evenmin empirisch bewezen.

Literatuurstudie 2: De voordelen van het gebruik van referentiearchitecturen voor het opstellen van Enterprise architecturen.

Daarbij kent het gebruik van referentiearchitecturen voor het opstellen van Enterprise Architecturen veel voordelen [2]. Ten eerste bevordert het de communicatie tussen EA stakeholders door een gezamenlijk uitgangspunt te hebben. Daarbij geven referentiearchitecturen begeleiding en sturing tijdens het ontwerp, realisatie en onderhoud van Enterprise Architecturen. Dit bespaart tijd. En als laatste zorgt hergebruik van kennis en zogenoemde best-practices voor een verbeterde kwaliteit en consistentie van EA producten. Deze voordelen zijn gebaseerd op een totaal van 8 studies, waarvan slechts één studie empirisch bewijs bevat. Een andere conclusie van deze literatuurstudie is dan ook dat er een gebrek is aan empirisch gevalideerde studies in dit domein.

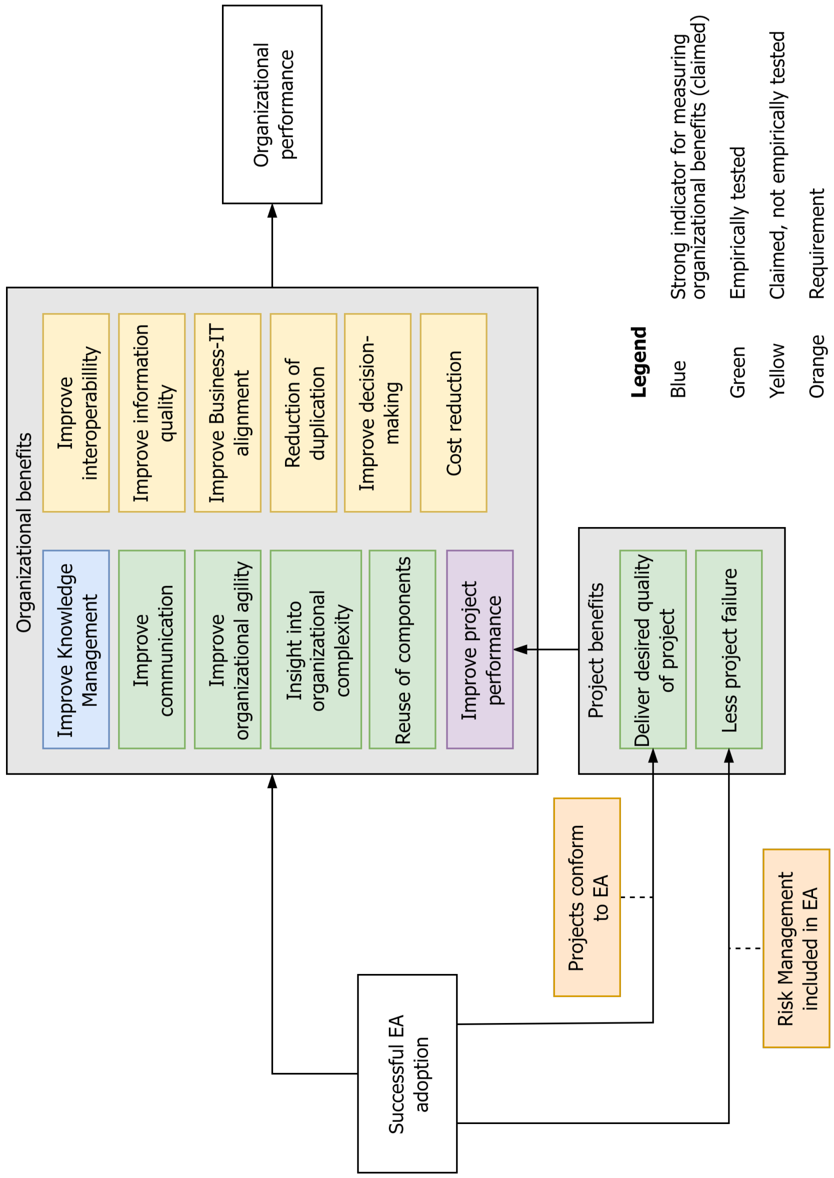


Figure G.1: Theoretical model on EA benefits for organisations in the public sector

Referenties

[1] M. Lankhorst, M.-E. Iacob, and H. Jonkers, Enterprise architecture at work: Modelling, communication, and analysis. in Enterprise Architecture at Work: Modelling, Communication, and Analysis. Springer, 2005. doi: 10.1007/3-540-27505-3.
[2] Remco Martinus Overvelde, “Towards a methodology for enhancing the coherence between the reference architectures of the Dutch public sector: A literature study on the research topics,” Not published, 2023.

Appendix H

Questions of the survey

No.	Question	Type of question
1	Bent u een digitaal architect* werkend binnen de Nederlandse publieke sector? *Met digitaal architect wordt bedoeld: enterprise architect, informatie architect, business architect, IT architect, solution architect, project architect, etc.	Multiple choice
2	Hoe ervaren bent u met het gebruik van referentiearchitecturen binnen de Nederlandse publieke sector?	Multiple choice
3	Heeft u een bijdrage geleverd aan één of meer van onderstaande referentiearchitecturen?	Multiple choice
4	Uitgaande van uw ervaringen. Hoeveel problemen ondervinden de benoemde gebruikers door een gebrek aan samenhang tussen referentiearchitecturen?	Matrix table
5	Zijn er vanuit uw ervaring andere stakeholders(personen en/of organisaties) die problemen ervaren door een gebrek aan samenhang tussen referentiearchitecturen?	Text entry
6	Beoordeel de drijfveren op hoe belangrijk ze voor u als digitaal architect zijn.	Matrix table
7	Licht uw antwoorden op de vorige vraag toe. Als u een drijfveer als (on)belangrijk beschouwd, waarom vindt u dat?	Form field
8	Welke drijfveren voor een verbeterde samenhang zijn er volgens u nog meer? Naast de reeds benoemde drijfveren, of indien de benoemde drijfveren als niet belangrijk worden beschouwd. Licht deze drijfveren toe.	Text entry
9	Beoordeel de problemen op hoe groot ze voor u als digitaal architect zijn.	Matrix table
10	Licht uw antwoorden op de vorige vraag toe. Als u een probleem als (zeer) groot/klein of als 'geen probleem' beschouwd, waarom vindt u dat?	Form field
11	Welke andere problemen ondervindt u, of kent u, door een gebrek aan samenhang tussen referentiearchitecturen binnen de Nederlandse publieke sector? Naast de reeds benoemde problemen, of indien de benoemde problemen niet als problemen worden beschouwd. Licht deze problemen toe.	Text entry
12	De voorbeelden die hierboven gegeven worden zijn voorbeelden van relaties tussen componenten van referentiearchitecturen, die expliciet gemaakt zouden moeten worden. Welke concrete voorbeelden van relaties tussen referentiearchitecturen kunt u nog meer noemen?	Text entry

Table H.1: Questions of the survey

Appendix I

Dutch version of the validated ArchiMate motivation view

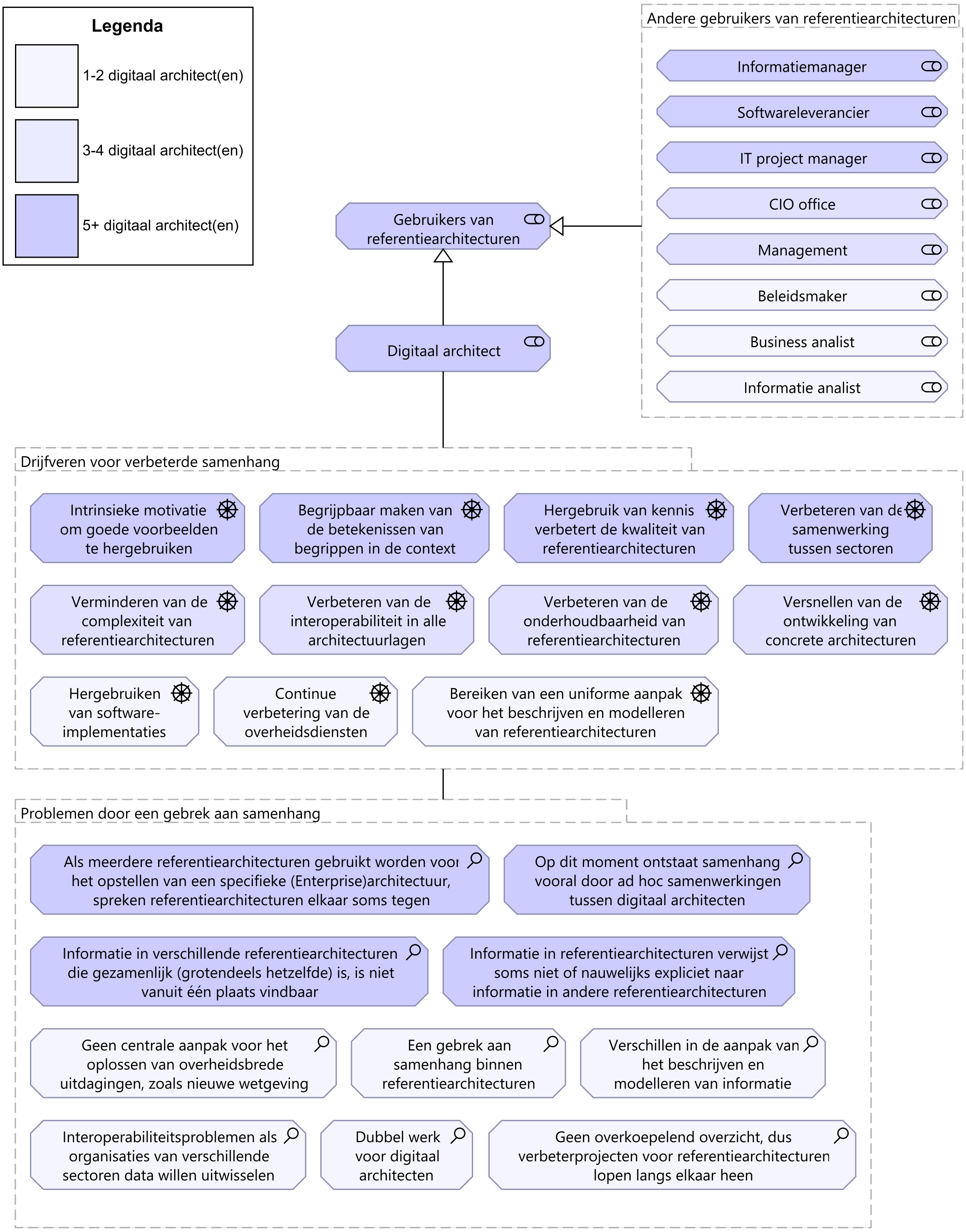


Figure I.1: Validated ArchiMate motivation view (in Dutch)

Appendix J

Dutch version of the designed method

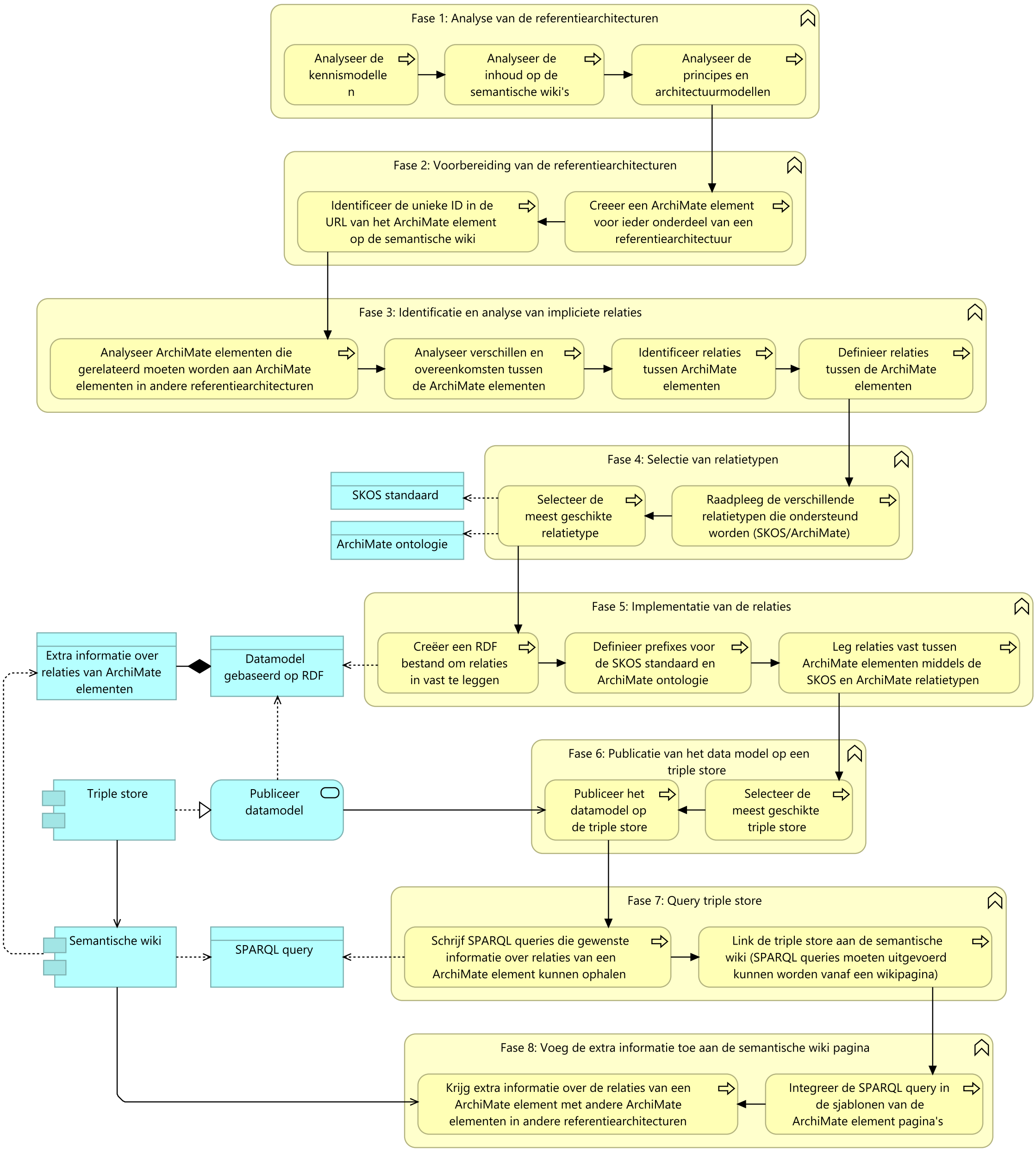


Figure J.1: Method (in Dutch)

Appendix K

Dutch summary of the thesis

Samenvatting: Op weg naar een methode om de samenhang tussen referentiearchitecturen binnen de Nederlandse publieke sector te verbeteren

Introductie

De Nederlandse publieke sector is verdeeld in verschillende domeinen. Voorbeelden hiervan zijn: Onderwijs en wetenschap, Gezondheid en zorg, Openbare orde en veiligheid, etc. Binnen deze domeinen bestaan zogeheten referentiearchitecturen. Dit zijn generieke architecturen voor een klasse van systemen, gebaseerd op best practices. Organisaties maken gebruik van de kennis uit referentiearchitecturen om concrete (Enterprise) architecturen op te stellen. Het aantal referentiearchitecturen is de laatste jaren hard gegroeid. Op dit moment zijn er 22 actieve referentiearchitecturen. Het merendeel van de referentiearchitecturen is gepubliceerd op het platform WikiXL, een Semantische Wiki waarin de architectuurkennis georganiseerd en gestructureerd is opgeslagen.

Probleemstelling

Referentiearchitecturen hebben veel raakvlakken met elkaar, aangezien domeinen en sectoren met elkaar overlappen. Er bestaan dus ook veel relaties tussen referentiearchitecturen. Echter, op dit moment zijn deze relaties niet expliciet gedefinieerd en vastgelegd. Deze expliciete relaties zijn nodig om tot een verbeterde samenhang tussen referentiearchitecturen te komen. Sinds de start van de NORA als eerste referentiearchitectuur is er een voortdurende wens vanuit de architectuurgemeenschap om tot een verbeterde samenhang te komen. Architecten spreken dan ook van een gebrek aan samenhang. Echter, een gezamenlijke aanpak om tot een verbeterde samenhang te komen bestaat niet. Onderzoek is daarom nodig naar een manier waarop de samenhang tussen referentiearchitecturen binnen de Nederlandse publieke sector verbeterd kan worden.

Onderzoeksdoel

Het doel van dit onderzoek is het ontwerpen van een methode die de samenhang tussen referentiearchitecturen verbetert. De onderzoeksvraag luidt dan ook:

RQ: "Hoe kan een methode worden ontworpen om de samenhang tussen referentiearchitecturen binnen de Nederlandse publieke sector te verbeteren?"

Om deze onderzoeksvraag te beantwoorden moeten eerst een aantal deelvragen beantwoord worden:

- **RQ1:** *"Wat zijn de voordelen van Enterprise architectuur voor organisaties in de publieke sector?"*
- **RQ2:** *"Wat zijn de voordelen van referentiearchitecturen voor Enterprise architectuur praktijken?"*
- **RQ3:** *"Hoe is de architectuurkennis van referentiearchitecturen binnen de Nederlandse publieke sector georganiseerd en gestructureerd?"*
- **RQ4:** *"Wat is de huidige staat van samenhang tussen referentiearchitecturen binnen de Nederlandse publieke sector?"*

- **RQ5:** *"Wat zijn de gewenste typen relaties tussen referentiearchitecturen binnen de Nederlandse publieke sector?"*
- **RQ6:** *"Wat zijn bestaande methoden en technieken voor het definiëren en vastleggen van relaties tussen verschillende architecturen?"*
- **RQ7:** *"Hoe kan een methode worden ontworpen om relaties te definiëren en vast te leggen tussen referentiearchitecturen binnen de Nederlandse publieke sector?"*
- **RQ8:** *"Kan de methode worden gebruikt om relaties te definiëren en vast te leggen tussen de referentiearchitecturen binnen de Nederlandse onderwijssector?"*

Onderzoeksmethode

Het onderzoek maakt gebruik van de Design Science Methodologie van Wieringa. Het onderzoek is verdeeld in drie fasen: 'Problem investigation', 'Treatment design' en 'Treatment validation'. In de eerste fase wordt ten eerste de context van het probleem onderzocht, waarna het probleem zelf wordt onderzocht. In de tweede fase wordt het artefact, de methode in het geval van dit onderzoek, ontworpen. En in de laatste fase wordt de methode gevalideerd, door hem toe te passen in de onderwijssector.

Theoretisch kader

Allereerst wordt de context van het probleem onderzocht. Door middel van een exploratief literatuuronderzoek zijn de concepten 'architectuur', 'enterprise architectuur' en 'referentiearchitectuur' onderzocht. Daarna zijn middels twee systematische literatuuronderzoeken de voordelen van Enterprise architectuur voor publieke organisaties en de voordelen van referentiearchitecturen voor Enterprise architectuur praktijken onderzocht. Vervolgens is onderzocht hoe semantische wiki's gebruikt kunnen worden voor het organiseren en structuren van architectuurkennis van referentiearchitecturen.

Voordelen van EA voor organisaties in de publieke sector

Op basis van 10 papers zijn in totaal 14 voordelen gevonden van Enterprise architectuur voor publieke organisaties, waarvan 11 organisatorische voordelen, 2 projectvoordelen en 1 afgeleid voordeel. Slechts 6 van de 14 voordelen zijn gebaseerd op empirisch onderzoek. De voordelen van Enterprise architectuur voor organisaties in de publieke sector zijn schematisch weergegeven in een theoretisch model, te vinden in figuur 3.6.

Voordelen van referentiearchitecturen voor EA praktijken

Er is weinig onderzoek gedaan naar de voordelen van referentiearchitecturen voor Enterprise architectuur praktijken. Toch zijn op basis van 8 papers de volgende 3 voordelen gevonden, die geclaimd worden door de auteurs:

1. Het verbeteren van de communicatie tussen EA stakeholders, door een gemeenschappelijke basis te vormen.
2. Referentiearchitecturen begeleiden het ontwerp, realisatie en onderhoud van Enterprise architecturen. Enterprise architecturen kunnen hierdoor sneller worden ontwikkeld.
3. Door hergebruik van kennis en best practices verbetert de kwaliteit en consistentie van EA artefacten.

Architectuurkennis en semantische wiki's

Referentiearchitecturen bestaan voornamelijk uit principes en architectuurmodellen. Die kennis moet georganiseerd en gestructureerd gepubliceerd worden. Uit de praktijk is gebleken dat semantische wiki's helpen met het organiseren en structureren van architectuurkennis. Zo is het WikiXL platform veelvuldig gebruikt voor het publiceren van architectuurkennis in de Nederlandse publieke sector.

Huidige staat van samenhang

De volgende stap in het onderzoek is het onderzoeken van de huidige staat van samenhang tussen referentiearchitecturen. Middels een focusgroep (n=4) en enquête (n=40) onderzoek zijn vragen over de huidige staat van samenhang beantwoord. Zo blijkt dat het overgrote merendeel van de architecten bevestigt dat er een gebrek aan samenhang is tussen referentiearchitecturen en dat verschillende stakeholders hierdoor problemen ervaren. Verder zijn de drijfveren voor een verbeterde samenhang en de gewenste relaties tussen referentiearchitecturen in kaart gebracht. In figuur I.1 zijn de stakeholders, drijfveren en problemen van (een gebrek aan) samenhang tussen referentiearchitecturen te vinden. Dit is een ArchiMate view bestaande uit motivatie-elementen.

Gewenste relaties tussen referentiearchitecturen

De gewenste relaties tussen referentiearchitecturen komen uit de focusgroep en het enquête onderzoek. Architecten bevestigen dat relaties tussen onderdelen van verschillende referentiearchitecturen expliciet gemaakt moeten worden. Echter, dit is slechts één aspect van het verbeteren van de samenhang tussen referentiearchitecturen. Naast het definiëren en vastleggen van relaties moeten bijvoorbeeld meta-modellen van referentiearchitecturen op elkaar worden afgestemd en begrippen en definities op dezelfde manier worden gebruikt.

Architecten noemen verschillende relatietypen die zij zouden willen zien, zoals: “hergebruik van”, “aanvullend op”, “is gelijk aan”, “specificeert nader”, etc. Om dit mogelijk te maken moeten alle onderdelen van referentiearchitecturen een eigen ArchiMate element hebben.

Concluderend: Relaties tussen ArchiMate elementen van verschillende referentiearchitecturen zijn nodig en Linked Data principes zouden hiervoor gebruikt kunnen worden. In figuur 4.8 is weergegeven om wat voor soort relaties het gaat.

Ontwerp van de methode

De ‘treatment design’ fase van het onderzoek bevat het ontwerp van de methode, het artefact van dit onderzoek. De methode moet er voor zorgen dat architecten relaties tussen ArchiMate elementen van verschillende referentiearchitecturen kunnen definiëren en vastleggen. Relatietypen die gebruikt kunnen worden komen uit de SKOS en ArchiMate standaarden. Een voorbeeld van een SKOS relatie is de ‘broader term’ en ‘narrower term’, waarbij generiekere en specifiekere begrippen kunnen worden gerelateerd aan elkaar.

Voordat de methode ontworpen kan worden moeten een aantal requirements worden opgesteld en een aantal keuzes worden gemaakt. Een aantal van de requirements zijn hieronder te zien:

- De methode moet begrijpelijk en bruikbaar zijn voor alle architecten met kennis van Linked Data technieken en principles en semantische wiki’s.
- De methode moet alle ArchiMate en SKOS relatietypen ondersteunen.
- De methode moet relaties definiëren en vastleggen tussen ArchiMate elementen van verschillende referentiearchitecturen.

De methode is een stappenplan bestaande uit formele en technische stappen. Een overzicht van de methode is gemodelleerd in ArchiMate, aangezien architecten hier bekend mee zijn. De methode bestaat uit 8 fasen, waarvan fase 1 t/m 4 bestaan uit formele stappen en fase 5 t/m 8 uit technische stappen. Het overzicht is te zien in figuur J.1.

De methode zorgt ervoor dat relaties tussen ArchiMate elementen van verschillende referentiearchitecturen gedefinieerd kunnen worden en vervolgens vastgelegd. De methode ontwikkelt een datamodel waarin de relaties zijn vastgelegd. Dit datamodel kan vervolgens gepubliceerd worden op een triple store, waarna deze triple store kan worden bevraagd vanuit een semantische wiki. De methode zorgt er uiteindelijk voor dat stakeholders meer informatie te zien krijgen over de relaties van een

ArchiMate element met ArchiMate elementen uit andere referentiearchitecturen. Een implementatie van de methode is in figuur 5.2 te zien.

Validatie van de methode

Op dit moment is de adviesgroep 'Samenhang Onderwijsarchitecturen' bezig om de sector- en referentiearchitecturen binnen de onderwijssector beter op elkaar te laten aansluiten. Daarom lijkt de onderwijssector met de referentiearchitecturen FORA, MORA, HORA en ROSA een geschikte context om de methode te valideren. Om dit te doen is een case study door de onderzoeker uitgevoerd waarin de methode is gebruikt om een aantal relaties tussen onderdelen van referentiearchitecturen vast te leggen. Met andere woorden:

- Relaties tussen ArchiMate elementen zijn gedefinieerd en vastgelegd in een datamodel (TURTLE bestand)
- Het datamodel is gepubliceerd op TriplyDB (Triple store)
- De extra informatie over relaties van ArchiMate elementen is zichtbaar op het WikiXL platform, een semantische wiki

Een voorbeeld van te relateren informatieobjecten uit de verschillende referentiearchitecturen is in figuur 6.3 te zien.

De relaties zijn zichtbaar op het WikiXL platform van de verschillende referentiearchitecturen. In figuur 6.5 is te zien hoe een 'Onderwijsdeelnemer' in de ROSA gerelateerd is aan 'Leerling', 'Deelnemer' en 'Student' in respectievelijk de referentiearchitecturen FORA, HORA en MORA.

De methode kent echter ook zijn nadelen. Op dit moment is nog veel handmatig werk van een digitaal architect nodig om de relaties vast te leggen in een data model. Daarbij is het definiëren en vastleggen van relaties slechts één aspect van het verbeteren van de samenhang tussen referentiearchitecturen. Meer aspecten zullen verbeterd moeten worden om tot een verbeterde samenhang te komen.

Conclusie

Uiteindelijk heeft dit onderzoek geleid tot het vinden van **14** voordelen van EA voor organisaties in de publieke sector. Ook blijkt dat er weinig onderzoek naar de voordelen van referentiearchitecturen voor Enterprise Architectuur is gedaan. Toch zijn er **drie** voordelen gevonden.

Vervolgens is de **huidige staat** van **Samenhang** tussen referentiearchitecturen in kaart gebracht, waarbij architecten bevestigen dat er een **gebrek** aan samenhang tussen referentiearchitecturen is en dat dit problematisch is. Om tot een verbeterde samenhang te komen moeten **relaties** tussen referentiearchitecturen worden **gedefinieerd** en **vastgelegd**. Dit is één aspect van het verbeteren van de samenhang. Hiervoor is een eerste versie van een **methode** opgeleverd en gevalideerd in de **onderwijssector**. De methode zorgt voor extra **informatie** die zichtbaar is in een semantische wiki over de relaties van een ArchiMate element met ArchiMate elementen in andere referentiearchitecturen. Deze informatie zorgt ervoor dat gebruikers van referentiearchitecturen beter inzichtelijk hebben hoe referentiearchitecturen aan elkaar gerelateerd zijn.

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