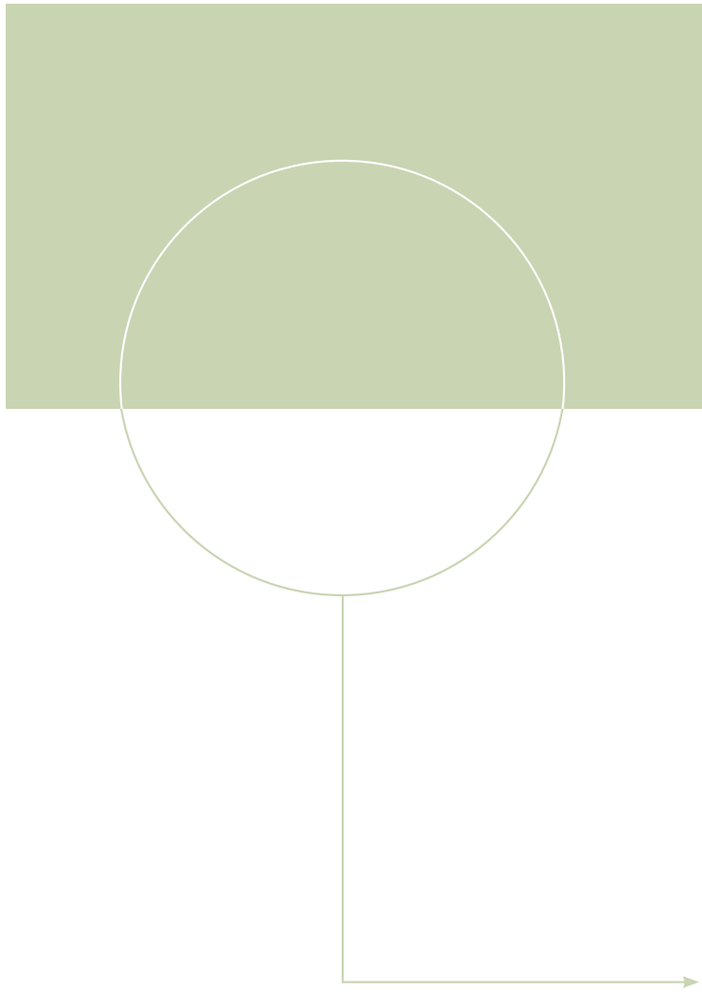

Master's thesis

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Enterprise architecture to support learning in and across cities

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Enterprise architecture to support learning in and across cities

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2021/06/22

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Abstract

Smart city development efforts have met hindrances when trying to replicate solutions in other cities. This thesis studies the more general approach of learning and knowledge transfer from the development effort, across cities. It specifically looks at the role of Enterprise Architecture to facilitate learning and knowledge transfer in smart city projects. A literature review and a survey have been conducted to answer the questions of how Enterprise Architecture currently supports learning and how it can be improved in that regard. Further, it applies its findings on The Enterprise Architecture framework used in the +CityxChange project and evaluates the proposed changes with an expert evaluation. It concludes that the complexity and terminology used in the Enterprise Architecture framework are limiting factors for its use in learning.

Sammendrag

Smart by utbyggings prosjekt har møt hindinger når de prøver å gjenskape løsninger i andre byer. Denne oppgaven studerer den mer generelle tilnærmingen av å lære og videreføre kunskap fra utbyggings prosjektene, på tvers av byer. Den ser mer spesifikt på rollen til Virksomhets-arkitektur for å fremme læring og kunskaps videreføring i smart by prosjekt. En Literatur analyse og en spørre undersøkelse ble utført for å svare på spørsmålene om hvordan Virksomhets-arkitektur blir brukt for å hjelpe med læring og hvordan det kan blir forbedret for det formålet. I tilleg brukes funnene på Virksomhets-arkitektur rammeverket som blir brukt i +Cityx-Change prosjektet og evaluerer de foreslåtte endringene med en ekspert evaluering. Oppgaven konkluderer at kompleksitet og terminologien brukt i Virksomhets-arkitektur rammeverket er begrensende faktorer for dens bruk innenfor læring.

Contents

Figures

Tables

Code Listings

Acronyms

TOGAF ADM TOGAF Architecture Development Method. 12, 13, 43, 44

API Accessible Programming Interface. 12, 36, 37, 42

EA Enterprise Architecture. 1–3, 5, 7, 9–23, 25, 26, 31–34, 36, 37, 39, 42–45, 47, 48

EAF Enterprise Architecture Framework. 1–3, 5, 7, 11, 14–23, 25, 26, 29, 31, 34, 35, 39, 41, 43, 44, 47

EMaaS Electric Mobility as a Service. 7, 37

ICT Information and Communications Technology. xix, 2, 5, 7, 11, 12, 23, 25, 43, 44

IT Information technology. 2, 11

KA Knowledge Architecture. 10, 11, 14

KM Knowledge management. 10, 11

KPI Key Performance Indicator. 1, 34, 37, 41

MOM Message-oriented middleware. 12

MVC Model View Controller. 12

NSD Norwegian Centre for Research Data. 17

NTNU Norwegian University of Science and Technology. 17

OCL Object Constraint Language. 11, 14

SCIS EU Smart Cities Information System. 1

TAM Technology Acceptance Model [1]. 17, 19

TOGAF The Open Group Architecture Framework. xvii, 5, 12, 13, 23, 26, 36, 37, 39, 41, 43, 44

UI User Interface. 12

UML Unified Modeling Language. 11, 14, 37

URI Uniform Resource Identifier. 36, 37

URL Uniform Resource Locator. 36

Glossary

ICT ecosystem An ICT system and the systems it interacts with.. 5, 7, 25

boundary object Objects that contain information used by multiple communities that might be interpreted differently from one community to another. 9–11, 19, 26, 31, 34, 43, 44

The Open Group A global consortium creating open technology standards.. 36

Chapter 1

Introduction

This chapter will introduce the problems this thesis addresses, their context and how they will be addressed.

1.1 Overview

Smart city is a concept that has gained traction in resent years. This can be seen through projects such as +CityxChange [2], Triangulum [3], EU Smart Cities Information System (SCIS) and their connection to EU H2020. Cities that intend to be smart must allow for continuous innovation and sustainable use of resources while supporting a high quality of life for its citizens. Enterprise Architecture (EA) has been used to support this [4–6] development by using or proposing different Enterprise Architecture Frameworks (EAFs) and modelling the development context and to act as a framework for standardising development efforts.
There are multiple definitions of smart cities, [7] defines smart cities as "A system that enhances human and social capital wisely using and interacting with natural and economic resources via technology-based solutions and innovation to address public issues and efficiently achieve sustainable development and a high quality of life on the basis of a multi-stakeholder, municipally based partnership."[7, p. 164]. It mentions that innovation is an important part of the definition and that the goals of smart cities are equally sustainability, quality of life and efficiency. For the purpose of this thesis, a smart city can be seen as any city that continuously innovates or improves based on a set of sustainable goals or Key Performance Indicators (KPIs) inline with the general public's best interest and obtain the necessary data to evaluate and meet its goals.
+CityxChange and Triangulum are European lighthouse projects with so called lighthouse cities that should innovate and provide solutions that follower cities can implement themselves, by replicating or using solutions from the lighthouse cities as inspiration for their own smart city planning projects.
Replication of smart city solutions is difficult [8]. [8] mentions 6 factors from smart city and community projects that may prevent replication. These factors are loosely that replication has little interest from stakeholders in lighthouse cit-

ies, focus on current efficiency limits opportunities for innovation, cities consider themselves too unique for existing solutions, non financial benefits can be hard to gauge, existing regulations and vested interests and politicians may refrain from implementing concrete measures. It also mentions that smart cities will require citizens to change their behaviour to some degree, thereby meeting resistance from the general public.

1.2 Problem statement

Although replication has been researched, how cities learn from each other and the role of EA in facilitating learning in a smart city project or initiative has very little research. The author of this thesis considers this to be a critical problem in current smart city projects, especially lighthouse projects. The goal of their projects is to innovate and learn from each other, but there are no best practices for this. As smart cities contain complex interconnected ICT systems and multiple stakeholders with contradicting motives, there should be documentation in place to ensure a common vision and understanding of the problems. Without this documentation it will be harder to gauge the effectiveness of the projects and trace misconceptions or faults. This thesis consider EA as the most fitting approach to documentation for this problem. Although EA has mostly been part of Information technology (IT) or computer science, its main focus is on humans or maximising human efficiency [9]. The problem is knowing what EA needs to capture to facilitate learning and how the information should be displayed. As the EA will have to display a comprehensive abstraction of complex system, it will have to be limited to show relevant information while hiding irrelevant information.

1.3 Research questions

This thesis aims to answer these research questions:

RQ1: How is EA currently being used to enhance learning in smart city projects?

RQ2: How can cities benefit from EA documentation of working smart city solutions?

RQ3: How can EA be used to enhance transfer of knowledge from lighthouse cities to follower cities?

RQ4: What should EAF capture to enhance learning in lighthouse projects?

1.4 Research aim

The research aims to evaluate the potential of EA as it relates to the facilitation of innovation, discussions, communication and learning in and from smart city projects. It will also assess which parts of EA facilitate learning or can be extended

to do so. The research aims to use its finding to propose an EAF that can enhance learning within smart city projects.

1.5 Research objective

The objectives of this study are to:

- **RO1:** Gain a better understanding of how the current state of EA facilitates learning and how the proposed smart city EAFs diverge.
- **RO2:** Understand which aspects of EA is perceived to be of use and enhance learning in smart city projects.
- **RO3:** Understand how EA can transfer and retain knowledge within an organisation and shared with other organisations.
- **RO4:** Provide recommendations for improvement to the EAF used in +CityxChange.

1.6 Thesis structure

The next chapter covers a literature review to establish the current state of the research on the topic. In chapter 3 the methodology for the research is documented. Chapter 4 presents a survey conducted with +CityxChange. Chapter 5 looks at the EAF used in +CityxChange. In chapter 6 a model based on the findings is proposed. This model is evaluated in chapter 7. Then, in chapter 8 the results are presented and discussed. Finally the conclusion of the thesis is presented in chapter 9, followed by references and appendices.

Chapter 2

Literature review

This section summarises the previous work that cover the same or a similar topic and explores potential research gaps. It also illustrates the current state of the art in smart city EA.
The structure of the chapter is shown in figure 2.1.

2.1 Research context

This literature review was conducted to better understand the state of EA in smart city projects or similar projects and understand the current research gaps related to EA as a tool for learning. It was initiated as a result of work related to +CityxChange where researchers found that their EAF might be improved by considering how enterprises learn. Their work is in part documented in [2]. The EAF shown in figure 2.2 was proposed in +CityxChange along with the development process shown in figure 2.3 and will be used in this thesis as a base to be improved in relation to learning. The EAF was created for representing ICT ecosystems involving multiple stakeholders. Their use of ICT ecosystem builds on [11] that describes ICT ecosystems as "encompasses the policies, strategies, processes, information, technologies, applications and stakeholders that together make up a technology environment for a country, government or an enterprise. Most importantly, an ICT ecosystem includes people - diverse individuals who create, buy, sell, regulate, manage and use technology." [11, p. 3]. +CityxChange builds on this description "+CityxChange encompasses not only the data, applications and technologies, but also the policies, regulations, processes, and stakeholders that together constitute the larger technology environment for implementing +CityxChange solutions in each of the cities." [12, p. 117].
The horizontal layers in figure 2.2 can be referred to as the technology stack. It adds upon terminology used in TOGAF. Data is considered to be an important aspect of the EAF as many services and stakeholders rely on data in general and open data in particular. Physical infrastructure is important as smart city development projects often involve physical assets such as electrical grids or measurement devices. The context layer contains the drivers for the services being developed.

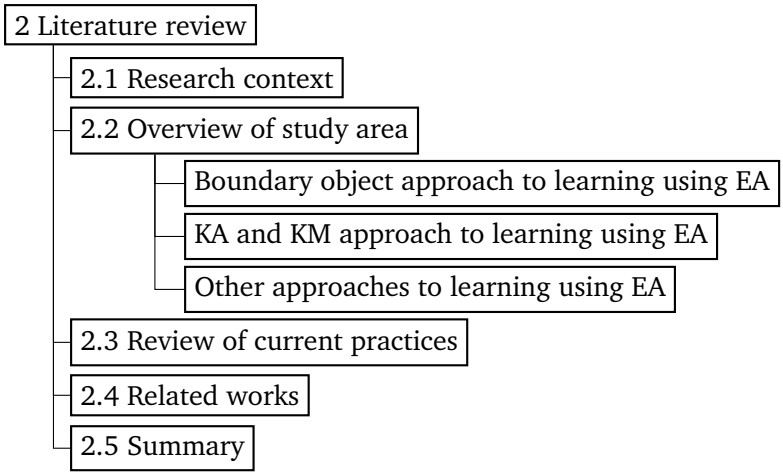

Figure 2.1: Structure of Literature review chapter

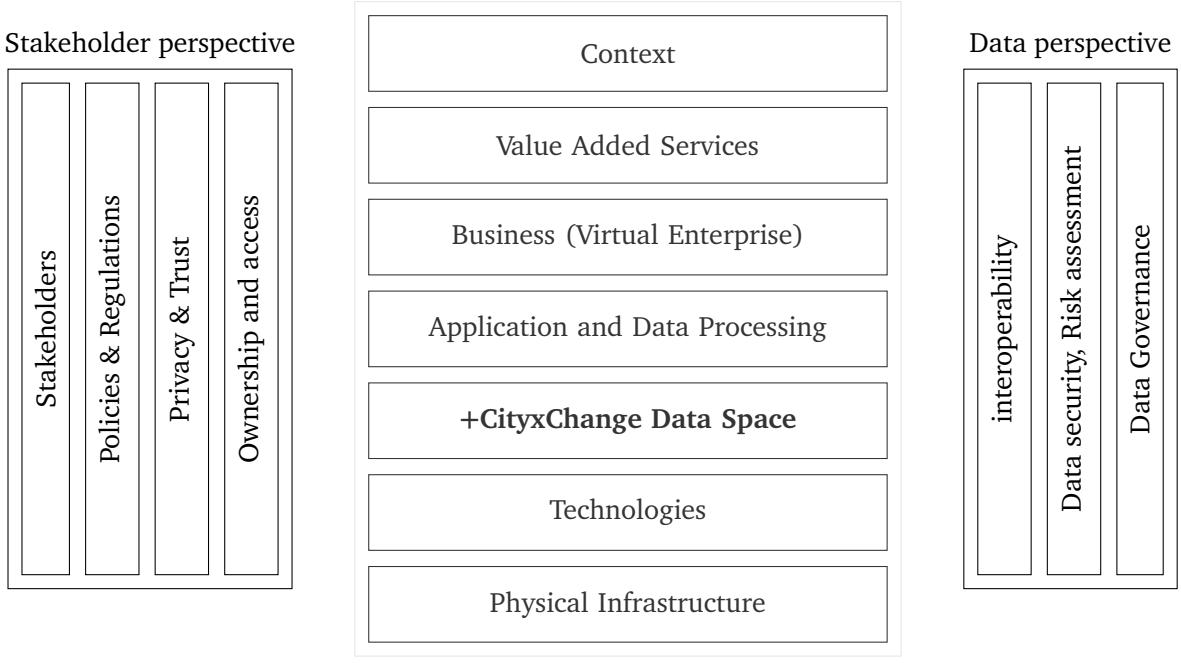

Figure 2.2: EAF used in +CityxChange adapted from [10]

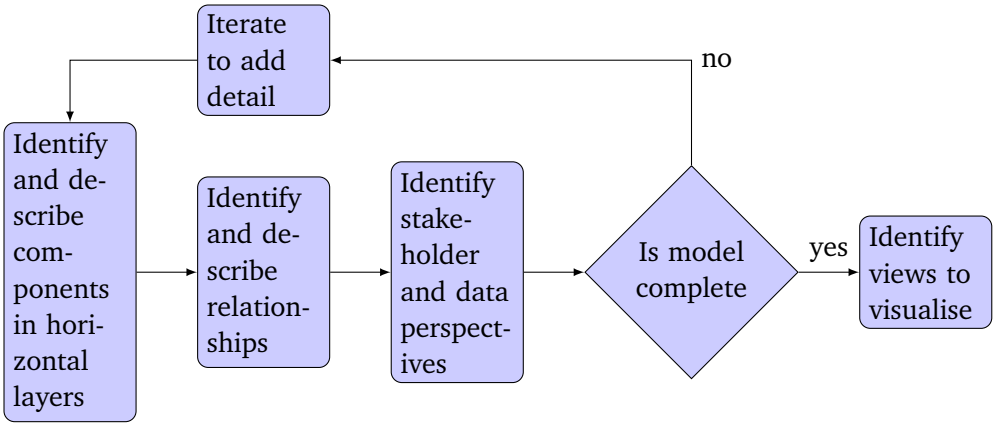

Figure 2.3: Development process of EA models using the +CityxChange EAF, adapted from [10] figure 5.1

These drivers unify the partners involved in the project. The vertical layers describe components that go across the horizontal layers and might be connected to several layers simultaneously. These are often values that effect the system as a whole and not individual components.
[2] gives some guiding principles on how the EAF could be used, but leaves out specifics so as to allow for greater flexibility for EA architects. Figure 2.3 shows the proposed development process.
Figure 2.4 shows an example ICT ecosystem or EA model made using the +CityxChange EAF. It only shows the horizontal layers of the system being developed and not the stakeholder perspective or data perspective. The EA relates to an Electric Mobility as a Service (EMaaS) system. It captures a multi stakeholder project with six identified partners involved in development. These are shown in the business layer. It also shows that the services rely heavily on physical infrastructures and data. Although the +CityxChange EAF in figure 2.2, the development process in figure 2.3 and the resulting EA model in figure 2.4 were not evaluated on learning, it was developed based on literature on EA and smart cities and is believed to cover important aspects of smart city development well.

2.2 Overview of study area

The field of EA has matured since the arrival of the Zachman framework [13] widely regarded as the origin of EA as a concept. There exist models to evaluate and compare EA [14] as well as a comprehensive industry for creating and maintaining EA in organisations [9]. Learning within organisations has also been covered in research, but not with unified concepts.

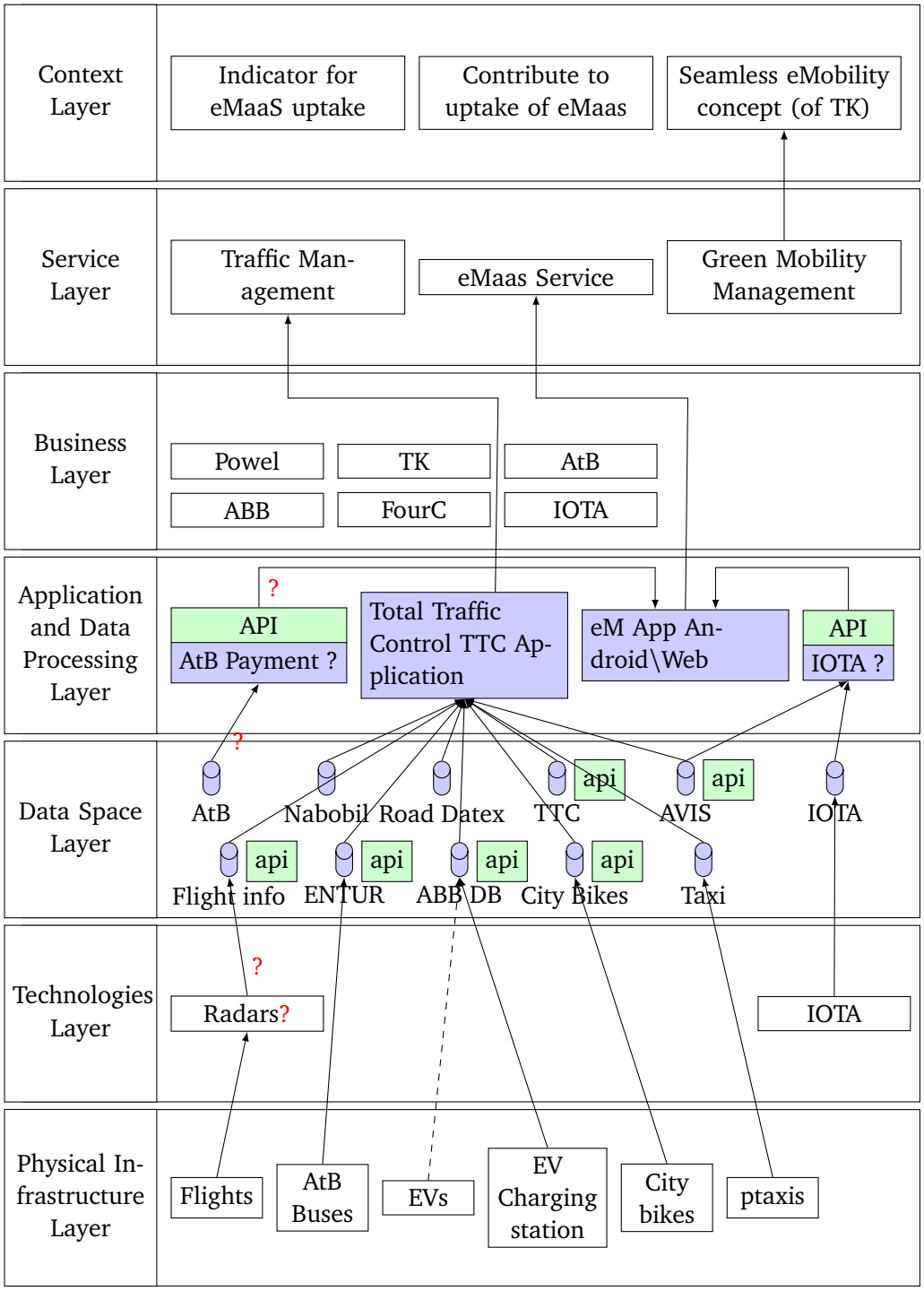

Figure 2.4: Example of EA model created using the +CityxChange architecture, adapted from figure 5.4 in [10]

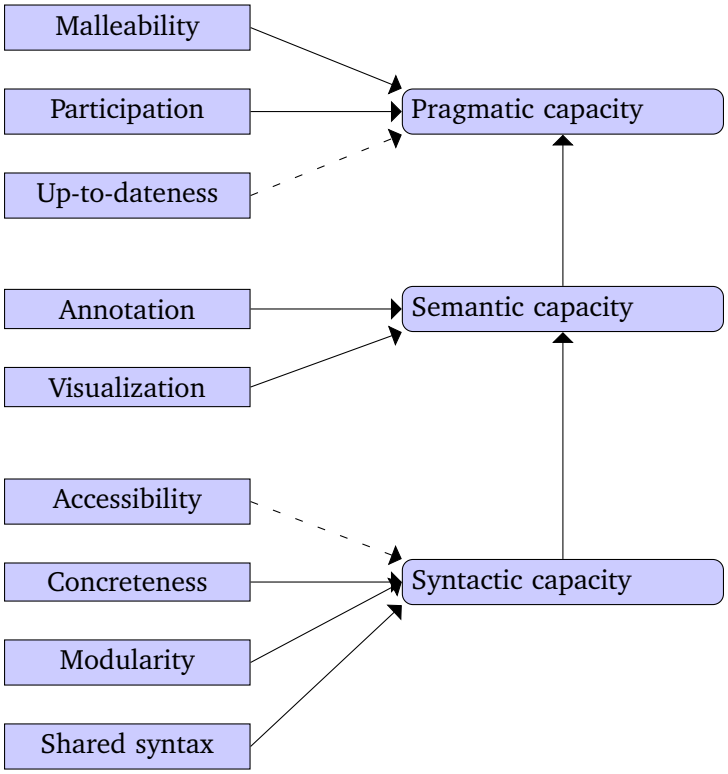

Figure 2.5: Knowledge boundary properties and how they affect capacity. Adapted from [16]

2.2.1 Boundary object approach to learning using EA

In [15] boundary objects are described as "[boundary objects] form the boundaries between groups through flexibility and shared structure—they are the stuff of action" [15, p. 603] where boundaries refer to shared spaces or objects. The article mentions that the concept was originally made to analyse cooperative work. The boundary objects is where communication happens between group or the method used for communication. The article end with explaining that as the boundary objects are meant for simplifying analysis, their definition is tied to scope and scale. boundary objects are tied to scope as they must be relevant for the context that is being analysed, and they are tied to scale as the objects must be important enough to warrent analysis. [16] looked at EA models for learning using boundary object perspective. boundary objects might be documentation such as EA that contain information and can be interpreted differently by individuals based on their background or occupation within an organisation. The research aims to find the properties of EA models that enable syntactic, semantic or pragmatic capacity for boundary objects. knowledge is transferred between groups or individuals using boundary objects and knowledge is translated. Its literature review found 11 boundary object properties; modularity, Abstraction, concreteness,

Property	short Explanation
Malleability	Supports changes by all communities using the boundary object.
Participation	The relevant communities participate in the creation and maintenance of the boundary object.
Up-to-dateness	The boundary object is updated and communities are informed.
Annotation	Individual communities can add additional information for local use.
Visualization	The boundary object has a physical representation.
Accessibility	The boundary object is known about and accessible to the communities.
Concreteness	The boundary object contains information relevant for the specific communities.
Modularity	Parts of the boundary object can be viewed in seclusion from the rest while maintaining correctness.
Shared syntax	A common understanding exist for interpretation of the boundary object.

Table 2.1: A short explanation of Boundary object properties from [16]

shared syntax, malleability, visualization, annotation, versioning, accessibility, up-to-dateness, stability and participation. They hypothesised that accessibility, concreteness, modularity and shared syntax increase syntactic capacity of boundary objects. while annotation and visualization increase semantic capacity and malleability, participation and up-to-dateness increase pragmatic capacity. syntactic capacity increases semantic capacity which in turn increase pragmatic capacity. Their theory is that for the ability to learn one needs the capacity of boundary objects and capabilities. Figure 2.5 shows the relationship between properties and capacities. The findings did not support the hypothesis of causation from availability and up-to-dateness to syntactic capacity, but postulate that it is a requirement for learning. The conclusion is that boundary objects should be connected to the domain concretely and that the visualisation should be efficient to enhance learning.
Table 2.1 shows a short explanation of the properties.

2.2.2 KA and KM approach to learning using EA

[17] looks at EA through the lens of Knowledge Architecture (KA) and Knowledge management (KM) specifically within large scale organisations. They note

that EA changed from a classic perspective, focusing on domain specific systems to large-scale architecting with focus on abstract, meta-level systems with more intensive communication infrastructures. This shift required more complex architectures. KA is formed by knowledge reservoirs and knowledge flows and is seen as a component of enterprise assets similarly to boundary objects. The research views KA as "incorporates the manner of creating knowledge, its application and learning within enterprises."[17, p. 4] The elements of KA are people, processes, behaviours, technology and content. They conducted a literature review on KA and found that KA did not sufficiently address large-scale architecting, did not have suitable methodology and did not have a supervising framework. The research proposes a KA methodology and framework to alleviate these problems. They base their KA framework on zachman's EAF as it is seen as an accepted standard that is both malleable formal and robust. In their framework the focus is on the planner perspective, owner perspective and designer perspective, while the other perspectives are seem as outside the scope of KA. Their methodology is based on CommonKADS, a methodology commonly used for engineering in KM where the goal of KM is to create models for knowledge recounting that can either be in the context category, concept category or artefact category. The researchers used "leadership, culture and structure, processes, explicit knowledge, implicit knowledge, knowledge hubs and centers, market leverage, measures, personnel skills and technological infrastructure"[17, p. 17] as the metrics to evaluate their framework.

2.2.3 Other approaches to learning using EA

[18] conducted a literature review on theoretical approaches for creating and evaluating organisational structures impact on motivation and learning. They found that most approaches were insufficient for an evaluation framework and advocated for theories with a holistic approach to organisation modelling. They selected Mintzberg [19] for their research. They used it with Unified Modeling Language (UML) and Object Constraint Language (OCL) to create an evaluation model.

2.3 Review of current practices

The use of ICT architecture and EA in smart cities varies greatly. There is currently no best practices for determining what EA to use or ICT architecture patterns to use. [4] looked at important properties of smart cities that would be architecturally significant and important for deciding ICT infrastructure. It also looked at the current business aspects of the IT support infrastructure. It conducted a questionnaire comprising of questions regarding architecture, data sources, management, funding and project objectives. It found that organisational structure, business processes, information systems and infrastructure were the most important dimensions for EA. The research conclude that the ICT architecture should be generic with a focus on interoperability and that performance was not

a critical concern. They suggest the ICT architecture to use a layered architecture and Model View Controller (MVC) pattern with Accessible Programming Interface (API) facade and messaging architecture. However [20] concluded from their research that no ICT architecture would be generalizable enough to benefit new smart city projects. They ascertain that TOGAF Architecture Development Method (TOGAF ADM) is a good approach to smart city development and that smart cities can be viewed as enterprises. This is supported by [21] which focused on the business aspect of EA. They found that the abstract architectures proposed did not fulfil the business requirements and also recommend TOGAF ADM. [20] separated the TOGAF ADM into three parts; Why, what and how, then looked at how the literature related to those separations. TOGAF ADM was found to sufficiently cover the smart city issues in the literature. The issues discussed in the paper did not cover learning or knowledge transfer, so it is uncertain if TOGAF ADM would be sufficient when focused on learning.

2.4 Related work

Authors	article	Purpose	context and categorisation	Model
Kakarontzas, George - Anthopoulos, Leonidas - Chatzakou, Despoina -Vakali, Athena	A Conceptual Enterprise Architecture Framework for Smart Cities - A Survey Based Approach	Propose generic ICT architecture	• Context: EADIC - (Developing an Enterprise Architecture for Digital Cities) • Categories: ICT architecture and Smart Cities	ICT architecture: host organisation of an application has a User Interface (UI) MVC layer with synchronous API calls to Business logic layer that communicates with local data storage and Message-oriented middleware (MOM) server. The MOM server talks to otter applications and integrates with the municipality. The UI is accessed by a browser.

Hämäläinen, Mervi	A Framework for a Smart City Design: Digital Transformation in the Helsinki Smart City	"Shed light on the elements that are relevant for robust digital transformation" [22, p. 65] by presenting a design framework	• Context: Helsinki Smart City • Categories: Smart Cities and Design framework	Evaluation framework: 11 values that have values from 0 to 3. The 11 include four dimensions; Smart city strategy, Technology - Digital technologies, Governance - orchestration and Stakeholders, and 7 sub-values; capabilities, data, technology experimentation, security and privacy, vertical and horizontal scope, funding and metrics, and stakeholder values.
Abraham, Ralf - Aier, Stephan - Winter, Robert	Crossing the line: overcoming knowledge boundaries in enterprise transformation	Understanding properties of EA that allow shared understanding during enterprise transformations	• Context: Enterprise transformation research • Categories: EA, Knowledge boundaries and Enterprise transformation	See 2.5
Mamkaitis, Aleksas - Bezbradica, Marija - Helfert, Markus	Urban Enterprise: a review of Smart City frameworks from an Enterprise Architecture perspective	Understand EA in smart cities	• Context: Smart city research • Categories: Smart Cities, EA and TOGAF	Suggests using TOGAF ADM
Pourzolfaghar, Zohreh - Bezbradica, Marija - Helfert, Markus	Types of IT architectures in smart cities–a review from a business model and enterprise architecture perspective	Evaluate architectures based on business perspective	• Context: EA business Layer research • Categories: EA, Business perspective and Smart city	Suggests using TOGAF ADM

Varaee, Touraj - Habibi, Jafar - Mohaghar, Ali	Presenting an Approach for Conducting Knowledge Architecture within Large-Scale Organizations	Finding a valid methodology and framework for KA within large scale organisations.	• Context: Large scale organisations research • Categories: EA, Knowledge and KA	KA framework: Rectangular cuboid (7 by 6 by 6) based on zachman
L. LouwI, - H.E. EssmannII - N.D. du PreezI - C.S.L. Schutte	Architecting the enterprise towards enhanced innovation capability	Proposing a EAF to support innovation	• Context: Enterprise research • Categories: EA and Innovation capabilities	EAF: consisiting of strategue intent, value chain and process, information, human resources, physical assets, organisational, performance, financial and governance architecture. It is viewed as influenced by suppliers partners customers and external influences.
Närman, Pia - Johnson, Pontus - Gingnell, Liv	Using enterprise architecture to analyse how organisational structure impact motivationand learning	Proposing an evaluation framework of motivation and learning based on EA	• Context: Organisational structures research • Categories: EA, motivation and learning	Evaluation model: based on UML and OCL

Table 2.2: Related work relevant for this thesis

Some of the related literature used in this paper is summarised in table 2.2.

2.5 summary

There is substantial research on smart city and how it relates to EA, but little is documented on how cities learn from EA.

Chapter 3

Methodology

This section covers the approach taken to answer the research questions and the different research methods used in this work to ensure quality.

3.1 Research methodology

3.1.1 Research flow

Figure 3.1 shows a visualisation of how the identified problems in the literature motivated the research objectives, how the objectives were reached through the research process and how the thesis documents the process and results.
The research started with an initial literature review in order to identify gaps or problems in the literature. The results of the review informed the research objectives. The literature review was continued after the objectives were identified and progressed alongside with the other research activities. The other research activities that were done was a survey, model proposition and expert evaluation. The survey was conducted to better understand the use of EA in a smart city project context, how the +CityxChange EAF in particular contributed to the project and how it and EA in general related to +CityxChange's learning efforts. The survey was implemented using an online questionnaire. The data gathered from the survey was used with the data from the literature review in order to identify the requirements and to propose a model consisting of an EAF, a development process and EA elements. An EA element is considered as a visual representation of an uninstantiated entity that can be used in an EA model. When the element is instantiated it becomes a component. The model was evaluated with an expert evaluation, using semi-structured interviews.

3.1.2 Literature Review approach

- **Query construction:** Literature was queried using the search engines at google scholar, web of science, Scopus and Oria. The search terms used included: "Enterprise Architecture" AND "smart cities", Learning from "En-

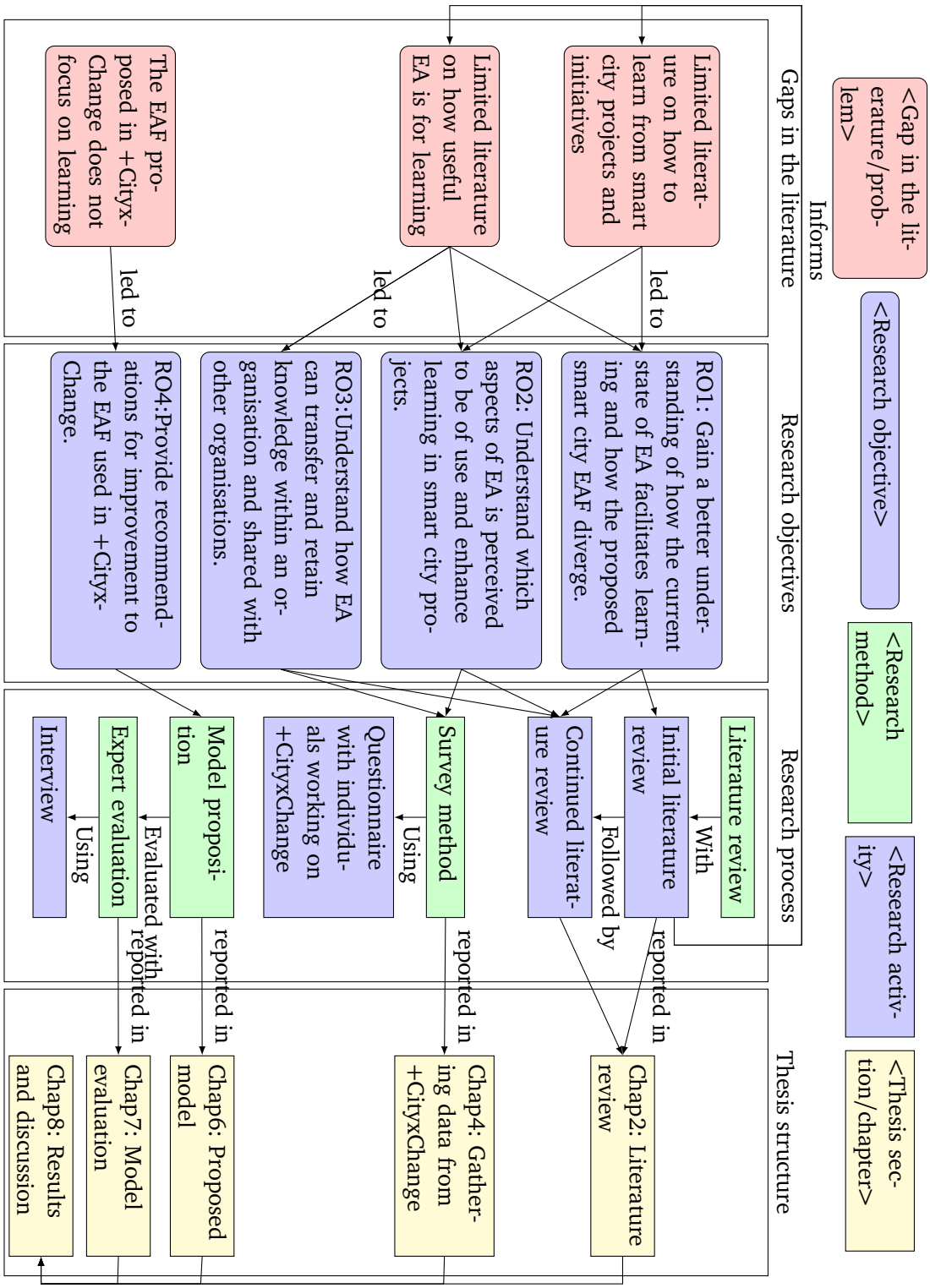

Figure 3.1: How research was conducted and documented in this thesis.

ID	Question
Q01	Is the research aim clearly stated?
Q02	Is the research method clearly stated?
Q03	Is the research context clear?
Q04	Is the research grounded in theory?
Q05	are the results clearly presented?
Q06	Is validity of research discussed?
Q07	Does it discuss use of Enterprise architecture?
Q08	Does it discuss knowledge management, innovation, knowledge transfer or learning without artificial intelligence or machine learning?
Q09	Does it discuss smart city, smart city services or construction planning?
Q10	Uses a technology acceptance model or similar.

Table 3.1: Literature screening questions and relevance questions.

terprise Architecture models", cities as learning innovation ecosystems, and knowledge transfer across cities. Additional literature was gathered based on references and authors.

- **Screening:** Relevance and quality was assessed to exclude articles given by the query. The questions used to assess quality and relevance are listed in table 3.1.

3.1.3 Survey approach

- **Data collection method:** A questionnaire was used to gather data. The questions were based on the initial literature review discussed in chapter 2 and based on the Technology Acceptance Model [1] (TAM) to indicate potential of the EAF proposed in +CityxChange. The questionnaire was made primarily for this thesis, but also to be used for a delivery within +CityxChange project [10]. As a result not all questions of the questionnaire were deemed relevant for this thesis. The questionnaire consisted of 6 parts; information about the questionnaire and consent to use and publish data, demographic on participants, view of EA in general, view of EAF used in +CityxChange, view of how EA in general and the EAF in particular relates to knowledge transfer and a final section for free-text answers with the opportunity to give feedback that the participants felt were missing or required clarification. In total there were 47 questions and the questions were given via nettskjema.no due to an existing data processing agreement with Norwegian University of Science and Technology (NTNU). Permission to process personal data was granted by the Norwegian Centre for Research Data (NSD) and all participant consented to the use of relevant data.
- **Population/sampling:** The questionnaire was given online to 42 participants

with a connection to +CityxChange. The criteria for receiving the questionnaire was a familiarity with the EAF used in +CityxChange. Of the 42 asked participants 13 participated. A question within the questionnaire asked for their familiarity with the EAF on which one participant indicated that they were not familiar with the EAF. Although this indicate that this person did not fit the criteria for receiving and answering the questionnaire, the answers were still included in the analysis.

- **Data analysis:** Due to the limited number of answers, a qualitative approach were used for most questions including all free-text questions. Percentages and graphics were calculated and created by nettskjema.

3.1.4 Model proposition approach

The model proposition followed a designed and creation process with five steps

- **Awareness:** The needs of the model were gathered through the literature review and questionnaire.
- **Suggestion:** A potential solution to the needs were suggested.
- **Development:** A model implementing the suggestions were developed.
- **Evaluation:** The model was evaluated with expert evaluation
- **Conclusion:** The results were analysed and reported in this thesis.

3.1.5 Expert evaluation approach

Themes	Questions	Motivation
Role of EA	First off, I would like to know a bit about how you view EA as a whole. So, What do you consider to be the job of EA?	Lead off with a question the participant is likely to already have an opinion on.
		Understand whether or not the proposed model is aligned with the needs of the participant.
Participation, Malleability, annotation and shared syntax	Who do you think has a use for the EA models?	Understand the usage context.
		Understand if the EAF is aligned with the users needs.
	Do you think the suggested EAF allow them (groups of users) to adequate model their perspective of the EA? (Why, why not?)	Understand if it supports the different usage contexts
		Understand if there are perspectives with misssing elements.
	Do you think that any part of the EAF could be interpreted differently by some of the users? (Why, why not?)	Understand if the users would have a common understanding of the resulting model.

		Understand if the syntax or terminology has contradictory meanings within between different communities.
Visualization, Accessibility	Do you think the EAF would give an efficient representation of the EA? (why, why not)	Understand whether or not the visualization is easy to interpret and important components can quickly be identified.
	Do you think the EAF will be understood by non-practitioners of EA? (why, why not)	Understand if the complexity is too high or if it creates problems when using the model to introduce the EA to new personnel.
+CityxChange, concreteness	Do you think the EAF is adequate for +CityxChange projects? (why, why not)	Understand if the needs of +CityxChange is aligned with the EAF.
	Is there anything you think is unnecessary in the EAF? (why, why not)	Understand whether or not the EAF is to broad or can be simplified without negative effects.
Modularity	Would the EAF allow specific problems to be viewed separately from the entire EA while maintaining correctness or validity? (why, why not)	Understand if the EAF supports modularity.
		Understand if the different users of the model can work on what is relevant to them without unnecessary interference.
Technology acceptance	Do you think the EAF would be usefull for +CityxChange or smart city development?	Understand "perceived usefulness" as it relates to TAM and +CityxChange and the smart city development projects.
	Do you think the EAF would be easy to use?	Understand "perceived ease of use" as it relates to TAM.
	Would you use this yourself or recommend it to others?	Understand "intent to use" as it relates to TAM.

Table 3.2: Interview questions for expert evaluation of proposed EAF

- **Data collection method:** A semi structured interview was used for the evaluation. The interview consisted of six themes; "Role of EA", "Participation, Malleability, annotation and shared syntax", "Visualization, Accessibility", "+CityxChange, concreteness", "Modularity", "Technology acceptance". The themes and relevant questions are listed in table 3.2. The themes are based on the boundary object discussed in [16] and TAM. 12 questions were prepared before the interview and used to guide the interview. 30 minutes were

allocated to each interview as the participants were busy and requested that it be kept short. Not all questions were asked during every interview due to the time constraint and nature of semi structured interviews. The themes were still covered. The interviewees were given a short introduction to the proposed model consisting of the proposed EAF, development process and EA elements, but were not given definitions of the layers or use case for the elements, unless explicitly requested. This was done to determine if the terminology used was appropriate and intuitive. Intuitiveness was one of the problems identified through the questionnaire and seen as important for the evaluation.

- **Population/sampling:** Three participants were selected and interviewed separately. All three were selected based on their knowledge of either the +CityxChange EAF or learning within smart city projects. The qualities of the participants that were important for the sampling process were:
    - Participant 1: Experienced with EA and one of the architects behind the EAF used in +CityxChange.
    - Participant 2: Familiar with EA for smart cities and a contributor to the EAF used in +CityxChange.
    - Participant 3: Not familiar with EA, but experienced with urban planning and learning across cities.

Chapter 4

Gathering data from +CityxChange

This section introduces a survey conducted to understand the the needs of the +CityxChange EAF.

4.1 Motivation behind the survey

A survey was found to be the best approach to understanding the role of EA in smart city projects and how it relates to learning. +CityxChange was chosen as a project where the survey could be undertaken. As an ongoing lighthouse project involving two lighthouse cities and five follower cities, it is believed to be representative of smart city projects. The main motivation of the survey was to gain insights from the +CityxChange employees that had used the +CityxChange EAF. Their understanding could be used to improve EA in regards to learning in smart city projects. The survey was made to understand the context where the EA was used, who were using it, what their attitudes towards it were and what could be done to improve it. The secondary motivation was for this information to be used to improve the +CityxChange EAF to support learning across cities. The full questionnaire can be found in apendix A.

4.2 Survey Results

4.2.1 Demographic

The demographics section asked for gender, age represented organisation and role within organisation. Overall the demographic information is inline with what was expected in the field of EA and computer science. The roles reported varied, but could be summed up as researchers, developers, engineers and managerial roles.

Figure 4.1 and 4.2 show the participants experience with EA and smart city pro-

How much experience do you have with Enterprise Architecture *

Answer	Number of	Percentage
No experience	4	30.8%
Less than 1 year	5	38.5%
1 - 3 years	3	23.1%
4 - 5 years	1	7.7%
6 or more years	0	0%

Figure 4.1: Questionnaire demographic on EA experience

How much experience do you have with Smart City related projects? *

Answer	Number of	Percentage
No experience	1	7.7%
Less than 1 year	0	0%
1 - 3 years	10	76.9%
4 - 5 years	2	15.4%
6 or more years	0	0%

Figure 4.2: Questionnaire demographic on smart city experience

jects respectively. It shows that a significant percentage of participants have little experience with EA. This makes it hard to trust some of the data in regards to quality of the EAF and EA model, but also shows the level of expertise of the users. It is clear that the models must be understood by those with little experience with EA. The participants had more experience with smart city projects. This makes the domain specific questions more trustworthy.

4.2.2 Ease of use and usefulness

The questionnaire results indicate that EA in general and the +CityxChange EAF in particular are seen as useful in the +CityxChange project, but the EAF is not easy to understand.

4.2.3 How it relates to knowledge transfer

The questionnaire results indicate that the EAF could be useful for both retaining and sharing knowledge.

4.2.4 Free-text answers

Due to the nature of these questions, no statistical analysis was conducted. It is still seen that valuable information could be drawn from them. The answers indicate that the organisations vary greatly in how they approach knowledge retention and transfer and all of them use multiple approaches. The methods used include both

formal and informal methods. Only one answer indicated that their organisation was considering changes or additional methods to retain or transfer knowledge within their organisation. This could indicate that most find their current methods satisfactory.
Most answers indicated that their organisation did not use any other EA approaches than the +CityxChange EAF. One answer mentioned using TOGAF while another mentioned an intention to use in the future, but that it was not relevant for +CityxChange. This could indicate that the +CityxChange EAF covers its domain well and that modifying the EAF for hybrid approaches is not of high importance.
The answers indicated that it was difficult to use without a background in EA and that additional value could be gained from lowering the difficulty to a point were non practitioners could understand it. This could indicate that either the detail is too high, that the presentation is difficult to understand or the inherent complexity is problematic. The terminology used in the EAF should be reconsidered or clarified.
The last specific question of the questionnaire was in regards to which problems the individual thought should be solved by EA. The answers varied a lot with no discernible pattern. It is believed that the question was too broad, but the answers still brought forth a few sentiments that should be considered. A compilation of the answers would be; frameworks and tools for defining and implementing software architecture, aspects of data, regulatory compliance, knowledge retention, digital transformation, ICT system replication, high level view, cross organisational cooperation, complex systems and sharing of architectural knowledge.

4.3 Extracted EA Requirements

based on the questionnaire and literature, a few requirements were made for the EAF and resulting EA models.

- The EAF must be understandable based on the architecture alone for non technical personnel.
- The EA models must be easy to understand for people with some experience with the EAF without thorough understanding of the scenario it describes.
- The EAF model must be improved with common knowledge retention, sharing and transfer activities in mind.
- The EAF model must be improved with supplementary technologies in mind.
- Describe which views could be useful for different supplementary activities.

Chapter 5

+CityxChange EAF evaluation

This chapter presents an evaluation of the +CityxChange based on the literature review and information gathered from +CityxChange.

5.1 Evaluation based on data gathered from +CityxChange

The evaluation presented in this section is informed by the survey presented in chapter 4 and meeting notes. The meeting notes were taken during meetings between EA architect and key personnel with an overview of the +CityxChange. The meetings were conducted to give feedback and correct deviations between EA models created using the +CityxChange EAF and their ICT ecosystem.

+ Its focus is relevant for the information that needs to be transferred.
+ Goals and interests can be shown.
+ Separate view can be used to mask information that is not important to individuals.
+ External factors are considered.
+ The representation covers the necessary parts of the system for development.

- It is too complicated for beginners.
- The framework presentation can be confusing.
- The terminology can be confusing.
- The term "Business" has been criticised as being inappropriate when citizen welfare is a core motivator.
- It is not designed with specific knowledge retention or knowledge sharing activities or methods in mind.
- The focus is on the ICT system modelling and not on the human aspect.

5.2 Evaluation based on Boundary objects perspective from literature

The evaluation presented here is based on the boundary objects properties described in [16];

- **Accessibility:** The questionnaire indicate that complexity made it inappropriate as a communication channel with other communities than those experienced with EA.
- **Concreteness:** The questionnaire indicated that there was no information missing from the model that was desired by the respondents.
- **Modularity:** The models layered architecture allow for high modularity.
- **Shared syntax:** Multiple respondents to the questionnaire requested revisiting the terminology, indicating that the syntax is flawed.
- **Annotation:** The model does not specifically encourage nor discourage annotation.
- **Visualization:** The current use of the model uses standard notations for TOGAF. The representation of the EAF itself has been noted as confusing.
- **Malleability:** The complexity of the EAF might prevent changes of the models without help of an EA architect.
- **Participation:** The meetings used to inform the model involved multiple communities, but the complexity of the EAF might prevent direct change by the communities.
- **Up-to-Dateness:** The EAF does not specifically encourage nor discourage continuous change.

5.3 Evaluation based on Innovation perspective from literature

The evaluation presented here is based on the innovation capabilities described in [23].

Sub architecture	Layer	Innovation capability
Horizontal layers		Proactive initiatives for identifying opportunities.
		Procedures to manage and realise ideas.
		Testing, screening and prioritising opportunities and ideas.
		Ideas are quickly defined and prototyped.
		Practices and procedures for developing and implementing ideas.
		Practices to network and facilitate collaboration between internal teams.

		Procedures for identifying and exploring latent opportunities.
		Core competencies are identified
		Human resources are managed to ensure sufficient core competencies for operational needs.
		Core innovation competencies are identified.
		Human resources are managed to ensure sufficient core competencies for research and development.
		Procedures to ensure needed competencies are considered during the hiring process.
		Procedures for communication has been identified and implemented.
		Organisational resource needs are being monitored.
		Sufficient resources are allocated to innovation.
		Investment and prioritisation of innovation.
		Organisational values and policies encourage innovation.
		Change management procedures have been defined and deployed.
		Initiatives for motivating, rewarding, and celebrating success.
		Align existing personnel's skills with their role.
		Creating cross-functional and multidisciplinary teams.
		Flexible organisational and human allocation structures.
		Organisational structures that encourage organisation wide communication.
		The organisational structure enables efficient decision-making.
		Innovation metrics have been identified and defined.
		Benchmarkings has been established to compare innovation metrics with successful organisations.
		Goals are aligned with innovation objectives.
		Innovation activities are appropriately prioritised with allocated resources.
		Identifying and planning for important decisions.
		Innovation process and activities are grounded in theory.
		Innovation committee has been established or roles have been identified and assigned responsibility for key innovation related choices.

		Identifying, documenting and implementing best-practices for innovation.
		Identified strategy for knowledge acquisition.
		Identified strategy for acquiring knowledge related technologies.
		Strategy and innovation objectives are continuously improved and communicated.
		Align project management with type(s) of innovation.
		Innovation process competencies have been identified, acquired and developed.
		Frameworks for contextualising, categorising and analysing data.
	Services	**Non**
	Business	**Non**
	Application	**Non**
	Data Space	Procedures for continuously understanding the needs of the end user.
		Managing tacit knowledge.
		Procedures for capturing, and retrieving data.
		Practices for exploring existing and new fields of research.
		Metrics are monitored to identify process and management improvements.
		Procedures for identifying, summarising, highlighting, and extracting relevant information.
	Technologies	Core technologies are identified, managed, and maintained to ensure that project and operational needs are continuously fulfilled.
		Procedures for proactively identifying, developing, and acquiring required technologies.
		Tools to facilitate the information flow have been identified and implemented.
		Tools for identifying, summarising, highlighting, and/or extracting relevant information.
		Procedures for developing and elaborating concepts.
		Tools and technology for storing and maintaining data.
	Infrastructure	Physical resources are allocated to the portfolio of projects, based on prioritisation and in balance with operational requirements.
Stakeholder perspective	Stakeholders	Involving end user at various stages throughout the innovation process

		Involving suppliers at various stages throughout the innovation process.
		Involving other stakeholders (partners, alliances, etc.) in the innovation process.
	Policies	Procedures for ensuring supplier competency and that technology supports innovation type(s).
		Practices to communicate and collaborate with external parties.
	Privacy and Trust	**Non**
	Ownership	Planning and coordinating the innovation portfolio.
Data Perspective	Interoperability	Opportunities and concepts are aligned and with required technology, competencies, processes, systems, etc.
	Data security, Risk	Procedures to reduce project uncertainty and identify, manage, and mitigate risk.
	Data Governance	Managing and balancing the innovation portfolio.
		Managing intellectual property.
		Establish intellectual property management and sharing policy.
Development process	Identify component	Opportunities and ideas are coordinated and viewed in context with required technology, competencies, processes, systems, etc.
	Identify relationships	**Non**
	Identify stakeholder	**Non**
	Validation	**Non**
	Iteration	**Non**
	Identify views	**Non**

Table 5.1: A mapping of the innovation capabilities discussed in [23] table 1, to the +CityExchange EAF with changes to fit smart city development

Table 5.1 shows an attempt at mapping the innovation capabilities to the +CityxChange EAF. Not all capabilities had a clear connection to each layer, therefore they were altered slightly and mapped to the best fit. Some of the capabilities could fit into multiple layers, showing that there might be an unintended overlap between the layers. Other capabilities did not fit well into any layer and where added to the closest layer based on terminology. This was often the case with capabilities surrounding procedures. Some of these procedures had clear ties to data, but did not fit into the data perspective or data layer while other related to policies. Many of the procedures that did not have a clear mapping was added to the context layer as that seemed to be the best fit.
The mapping indicates that procedures are an important aspect of enterprises and innovation or learning, and are not explicitly covered by the EAF. The mapping also indicate that the context layer is overworked.

Chapter 6

Proposed model

This section describes the proposed enhancements to the +CityxChange EAF to promote learning across cities in smart city development projects.

6.1 Developed model

When developing the new model, as many issues as possible, from the original, should be solved. But there is a trade-off between complexity and coverage. Complexity should be low to encourage use by non-experts while coverage should be high to allow use in multiple situations and for correct usage.

6.1.1 Enhancements of the development process

The development process of an EA has been altered, as shown in figure 6.1, to allow for consideration of elements that are relevant to learning. It is meant as a guide and not meant to be used as a hard requirement. More specifically; three steps have been added.

- **Consider users**: Added due to learning and EA being concepts that are intrinsically linked to human efficiency and behaviour.
- **Knowledge identification**: Added as it is believed that the EA model by itself will not be able to sufficiently cover everything each individual needs for learning, but can still guide the individual towards important information. It also forces the EA architects to consider how knowledge is created within the system.
- **Resource identification**: Added due to resources being a concept that is repeatedly mentioned in the literature. Both when it comes to innovation and within smart city development due to the multi stakeholder context.

Mindset	Relevant boundary object properties
Why is the model needed?	concreteness

Who is the model for?	concreteness, malleability, participation
What is relevant for the models users?	concreteness, malleability, participation
What is needed to make decisions?	concreteness
How does the EA look to outsiders?	concreteness
Where can users find more information?	concreteness, (indirect) accessibility
What documentation needs to be updated on changes?	Up-to-dateness
Who and what is communicated?	concreteness
Which protocols or processes do they use?	concreteness
Which techniques are used to share/retain knowledge?	concreteness
How is communication documented?	concreteness
Who has an interest in the systems completion?	concreteness, malleability, participation
Who participates in development?	concreteness, malleability, participation
Do groups interpret the system differently?	shared syntax, annotation, modularity
Do groups have different terminology?	shared syntax
Are there things that are likely to be misinterpreted?	shared syntax
Can unnecessary information be hidden?	modularity, visualization
Have human resources been allocated?	concreteness
Have financial resources been allocated?	concreteness, visualization
Are there missing resources?	concreteness, visualization
Could resources improve the system?	concreteness, visualization

Table 6.1: A mapping of the mindsets to relevant Boundary object properties

Figure 6.1 also adds questions one can have in mind while developing the EA model. The questions are called mindsets and are meant to make the intention behind the EA model clearer to the architect and make them consider knowledge flows. A mindset in this context is a perspective or set of ideas that can influence decisions. This semi-structured approach is used as the concept of "learning" is hard to define or achieve in a rigid environment. The mindsets are a result of

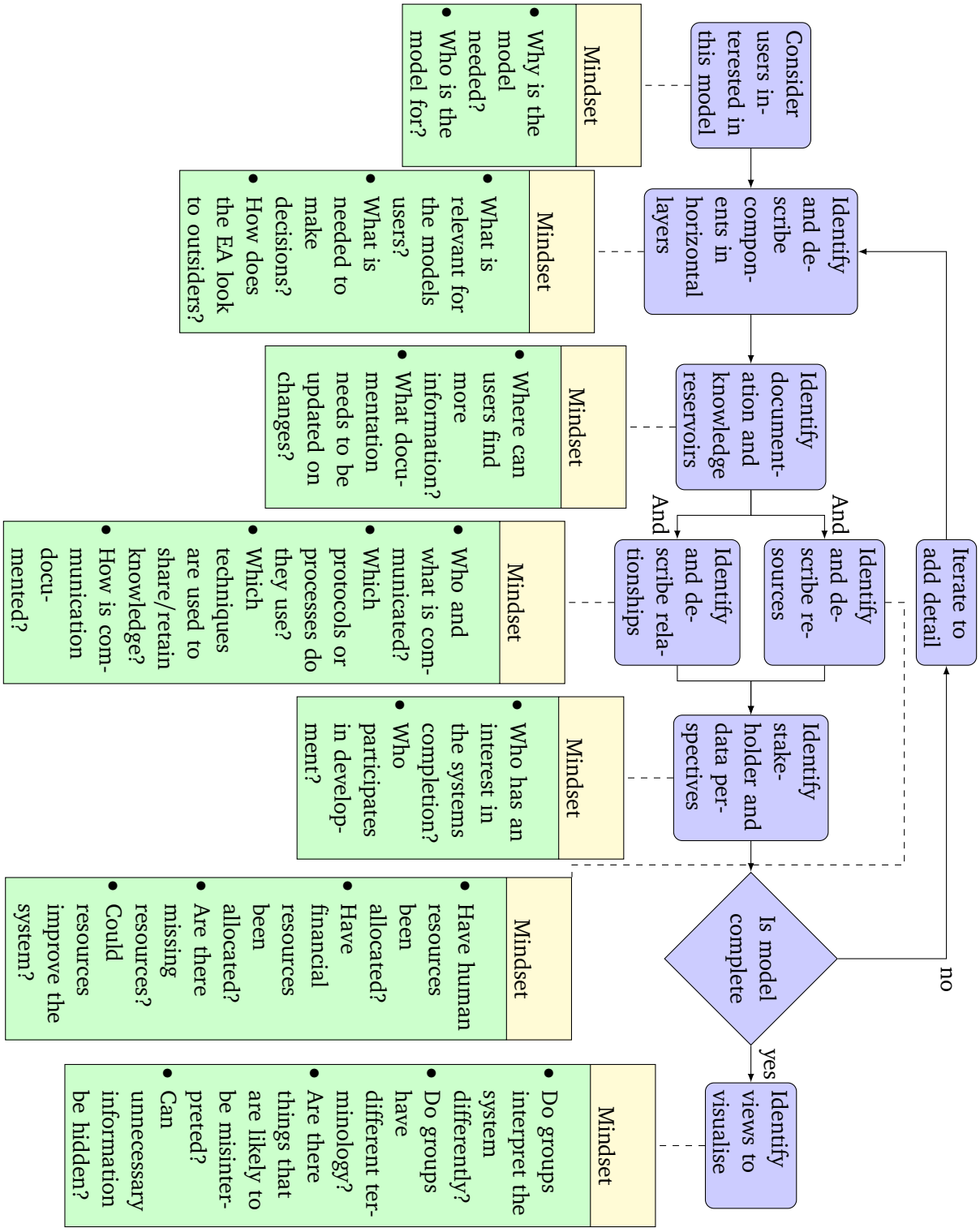

Figure 6.1: Development process of an EA using the proposed model.

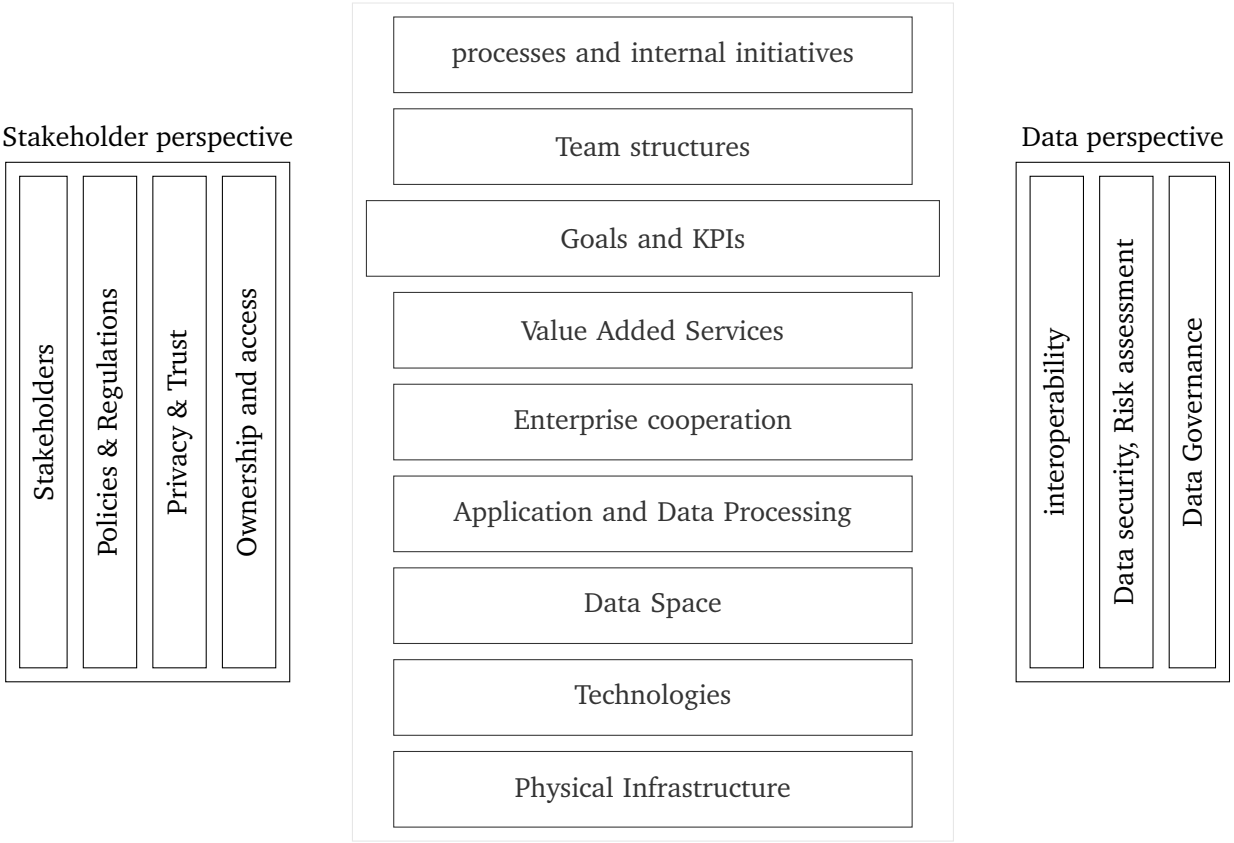

Figure 6.2: Proposed EAF based on the +CityxChange EAF

viewing the EA model as a boundary object, It does not use the specific terminology within the diagram, as it is not expected that the EA architects are familiar with the concept. Table 6.1 shows how the terminology applies to the mindsets.

6.1.2 Enhancements of the EAF

As shown in figure 6.2 and 6.3 the EAF has been expanded and more architectural elements have been added. Although this could intuitively increase complexity, the intent is that a further segmentation of the domain and greater specificity with better concreteness, shared syntax and visualization, can make the model more intuitive and allow more relevant views for individuals.
The original context layer has been expanded to three layers; "goals and KPIs", "Team structures" and "processes and internal initiatives". The "goals and KPIs" layer is intended to be used like the context layer was used in the original. It contains the core motivations behind the system(s) being developing. Figure 6.2 shows this layer being accentuated. This is because it is considered to be vital for decision making. "Team structures" and "Processes and internal initiatives" were placed above, not because of higher significance, but because they are further re-

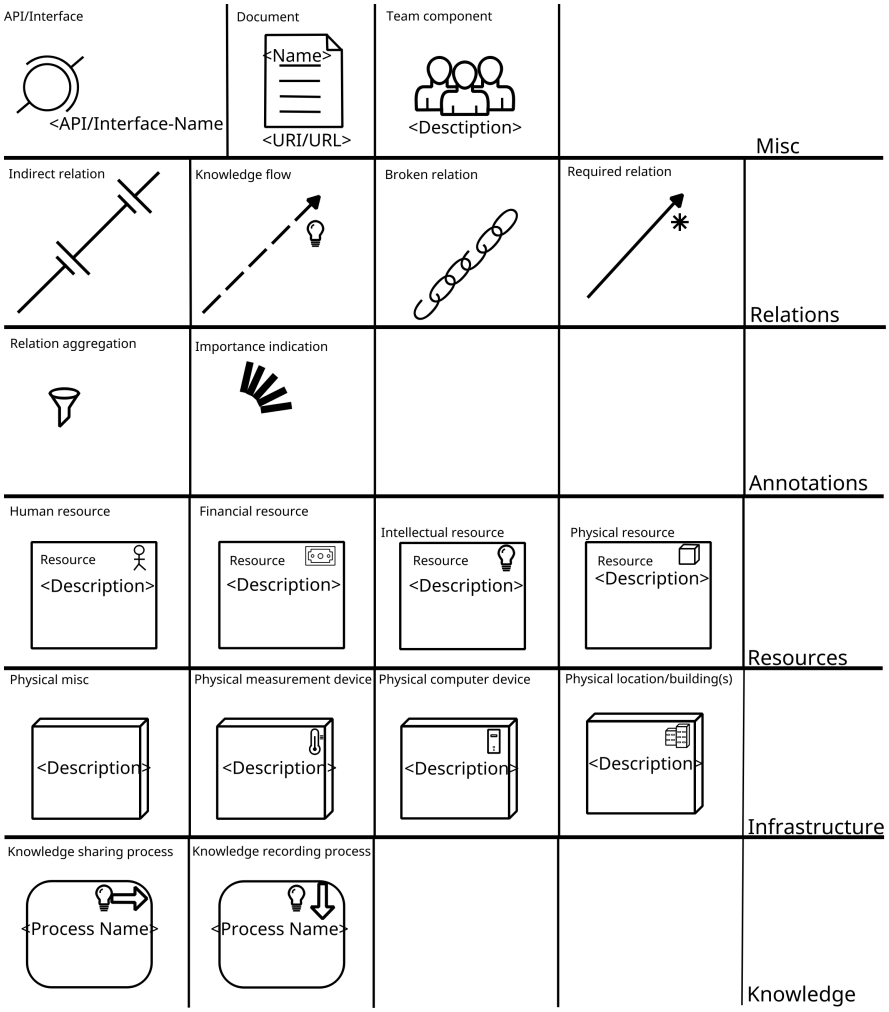

Figure 6.3: Proposed elements for making EA models from proposed EAF

moved from the application and physical infrastructure layers. The added "Team structures" layer is for documenting internal teams working on development. It is intended to help understand how knowledge flows between people and groups. It is different from the layer in the origin EAF called "Business (Virtual Enterprise)" and called "Enterprise collaboration" in the proposed EAF in that the collaboration layer contains companies or stakeholders involved in the development rather than internal structures that might be specific to each stakeholder. "Processes and internal initiatives" is the final layer that has been changed from the original. It is meant to capture more of the knowledge flows by adding processes that are initiated and heavily governed by peoples, such as daily meetings and workshops.

6.1.3 Addition EA elements

Figure 6.3 shows the proposed elements that can be used to create the EA models. It is meant to supplement or enhance the elements in TOGAF. TOGAF was used as a base due to its current use within +CityxChange and recommendation by multiple relevant articles [20, 21]. Some of the elements, such as aggregation and indirect connections, have been added to allow views to partially be created logically from a base EA model allowing further hiding of irrelevant information. while other elements are meant to include knowledge related components or better represent the smart city context.

- **Api/interface** element is an alteration of the TOGAF interface elements. It has been changed so that it is more clearly differentiated from the other elements. This was done as the APIs were a topic mentioned repeatedly in +CityxChange meetings and are seen as important parts of the EA.
- **Document** element is a more general version of TOGAF artefact that also has a Uniform Resource Locator (URL)/Uniform Resource Identifier (URI). This URL/URI was added to improve the accessibility of the document.The Open Group defines an artefact as "a physical piece of data that is used or produced in a software development process, or by deployment and operation of a system."[24]. The proposed document is not tied to the software, but can be things like meeting notes.
- **Team component** was added because humans are the core of any knowledge related activity.
- **Indirect relation** was added to allow hiding of connected elements in certain views without hiding the connections between the other elements.
- **Knowledge flow** shows how knowledge flows in the EA and was added to make knowledge information more specific.
- **Broken relation** shows that a connection is expected or preferred, but not implemented. This was added to visualise potential areas for improvement or innovation.
- **Required relation** shows that a connection can not be removed without significant work. This was added to allow separate communities to give additional information about what is necessary from their perspective.
- **Relation aggregation** was added as the multi stakeholder context often require many to one connections and a way to remove clutter could improve visualisation. It might also be beneficial for views where components with several connections are hidden.
- **Importance indicator** is meant to attach to other components to indicate that the user of the EA model might want to consider that component. It can be relevant to add this to specific views as importance is dependent on perspective.
- **Resources** elements expand the TOGAF resource element with four more specific version and a new notation. The versions are human financial, intellectual and physical resources respectively. These were added based on

their importance for innovation capabilities.

- **Physical entities** were added as the smart city concept often revolve around physical infrastructure such as chargers for EMaaS, sensors for data gathering and smart grids. The TOGAF node element is changed into a physical misc element for generic physical components and specific elements were added for measurement, computation devices and locations.
- **Knowledge processes** were added to show how the knowledge flows within the EA, how it is shared and how it is recorded.

Some of the unchanged elements from TOGAF that are seen as important are; the influence relation, the stakeholder and goals/KPI related elements, principle element and note.

Grouping	Element	Description/attribute
Misc	API or interface	Used to indicate API or interfaces.
		Attribute: API name.
		Attribute: API ID for lookup.
		Attribute: File link or URI.
	Document	Used to represent documentation or artefact stored outside the current EA model.
		Can be used refer to other EA components, UML diagram, organisational charts, system specifications, resource allocations, etc.
		Attribute: File name.
		Attribute: File description.
		Attribute: File link or URI.
		Attribute: File access description (if link or URI is not applicable).
		Attribute: File type or comprehension.
	Organisational component	Used to represent a team, group or other organisational structure.
Relations	Indirect relation	Used to show an indirect relationship that should be known.
	Knowledge flow	Used to show how knowledge flows or is created.
	Broken relation	Used to show that a relation is expected, but not implemented or functional.

	Required relation	Used to show that a relationship can not be removed.
Annotation	Relation aggregation	Used to simplify visualisation of many to one or many to many relationships.
	Importance indicator	Used to show that a component or relation is important for development or decision making.
		Attribute: Justification
Resources	Resource misc	Used to represent a resource, when no other element can be more descriptive.
		Attribute: Resource type.
		Attribute: Resource quantity.
		Attribute: Resource description.
		Attribute: Resource justification.
	Human Resource	Used to represent a human resource.
		Attribute: Resource quantity.
		Attribute: Resource description.
		Attribute: Resource justification.
	Intellectual Resource	Used to represent a knowledge based resource.
		Attribute: Resource quantity.
		Attribute: Resource description.
		Attribute: Resource justification.
	Physical Resource	Used to represent a resource with physical properties.
		Attribute: Resource quantity.
		Attribute: Resource description.
		Attribute: Resource justification.
Infrastructure	Physical misc	Used to represent a physical entity when no other element is more descriptive.
		Attribute: Type.
		Attribute: Description.

	Physical measurement device	Used to represent data-gathering devices.
		Attribute: Data type.
		Attribute: Description.
	Physical computation device	Used to represent computing devices, servers or similar.
		Attribute: Capability.
		Attribute: Description.
	Physical location/building	Used to represent important locations or buildings.
Knowledge	Knowledge sharing process	Used to represent activities such as meetings, workshops etc that share knowledge between individuals or groups.
		Attribute: Process name.
		Attribute: Knowledge description.
	Knowledge recording process	Used to represent activities such as document writing, meeting recording etc that result in tacit knowledge being converted to explicit knowledge.
		Attribute: Process name.
		Attribute: Knowledge description.

Table 6.2: Suggested elements represented in the EA model and optional attributes of those.

Table 6.2 shows a more detailed view of the suggested elements. It adds attributes on some elements that might not be visible on the component, but can be added in a digital representation and viewed when a component is selected.

6.2 Summary

This chapter presented an enhanced EAF along with a EA development process and EA elements that can be used to represent an EA that could support the transfer of learning across cities. The model builds on the +CityxChange EAF and TOGAF, and is intended to promote learning in a smart city context.

Chapter 7

Model evaluation

7.1 Purpose of evaluation

An evaluation of the proposed model was performed to find out if the proposed changes were beneficial for smart city projects and could enhanced learning.

7.2 Interview findings

Participant 1 was positive to how the elements and development process related to the EAF, but had concerns about the EAF itself. The participant mentioned that the distinction between "Enterprise cooperation" layer and "Team structures" was not clear and that the motivation for adding "Team structures" was not clear either. "Team structures" and "internal processes" seemed to be ill fit for multi stakeholder systems such as +CityxChange and did not inherently seem to be related to theories found in TOGAF or similar frameworks. It seems that these two layers were trying to model the system on a different level then the other layers and could cause conflicts. An example that could cause conflict were if the "Goals and KPIs" layer contained a goal, then it would be hard to note if the goal was connected to the internal teams in the layers above or the "Enterprise cooperation" layer. It was also unclear if the context layer was sufficiently covered by the three layers the proposed model replaced it with. Participant 3 also mentioned the importance of the context layer as it relates to learning. Participant 3 mentioned that "Goals and KPIs" seemed to be for quantitative aspects, but lacked the qualitative aspects of context.
"Team structures" was mentioned by participant 1 as not being particularly important, that the important parts for +CityxChange were responsibilities and decisions. Participant 2 also mentioned that they did not see the motivation behind "Team structures" and elaborated on how it clashed with the over aching goals of the EAF to model the cooperation between the partners and stakeholders while allowing the individual partners to steer their own development process. Participant 2 mentioned that if "Team structure" and "Processes and internal initiatives" were

added, then they were more likely to be vertical layers similarly to "Stakeholder perspective". The layers could still be relevant but seemed to be misplaced. Participant 3 viewed "Team structures" as what they would consider "Institutional aspects". Although participant 2 and 3 both had issues with the layer, they also mentioned that it was important in some cases.
Participant 3 went into more detail on "Processes and internal initiatives". It was considered to be very important for learning, but also very complicated with many factors. They expect that the EA model would have to overlook important aspects of learning related processes. Participant 3 also mentioned that peoples cultures or backgrounds would have a significant effect on processes and learning.
In regards to the suggested development process, participant 2 was mostly positive, but found the concept of "mindset" to be easily misunderstood. The idea behind it was still good, but other terminology should be considered. The specific questions listed in the mindsets were relevant, but seemed more relevant for evaluating existing architectures or understanding the motivation behind the components included in a finished model. Participant 3 mentioned that several steps and vocabulary was overlapping. As an example, it would be difficult to separate users of the model from stakeholders. This would also be a problem when developing the EA model as it is usually developed by reading documentation and interviewing users or stakeholders. It was not clear from the development process who to communicate with and how they affect your mindset.
Participant 2 went into more detail than participant 1 when evaluating the proposed elements. Altering the interface element as suggested was not recommended, but they requested adding variants or notations to specify more details about APIs. For instance, there might be an API that will exist in the future, an anonymous API or request format. The "indirect relationship" was seen as problematic, as everything would in some way be indirectly connected and the graphical parts seemed like a poor visualisation of indirect relationships. It was also recommended to change the "broken relationship" visualisation as the more intricate notation made it seem like a stronger connection rather than broken. Adding more relationship notations was still seen as a good idea. Participant 2 thought the idea behind the resource elements were good, but only relevant at too high a detail for an EA that was meant for a higher level view. Participant 3 also mentioned that the resulting model would likely be too complicated to be useful for most people. For the physical elements participant 2 requested that the "physical location/building" should allow for nesting while the "measurement device" should be a collection of devices and should have a different notation. A thermometer was not seen as appropriate for the "measurement device". Participant 2 mentioned that the knowledge elements would probably not be relevant because they would need to model at too fine a detail.

Chapter 8

Results and discussion

This section describes the results of the research and discusses how it relates to earlier work. It also covers shortcomings and possible sources for errors.

8.1 Findings for RQ1: How is EA currently being used to enhance learning in smart city projects?

The literature review found that most EA used in ICT city planning does not specifically consider learning to a great extent. The literature is conflicted on whether or not EA in smart city projects should be used to allow replication or should focus on flexibility. The literature suggests either ICT architectures when advocating replication or existing EAFs when advocating flexibility. Most of the research using existing EAFs suggests using TOGAF ADM and a few suggests using zachman. Although most literature does not specifically relate to learning, it does suggest that TOGAF ADM and other EAFs cover important aspects of it. In particular the business aspects from the different EAFs are seen as important. The survey indicate that the EAF used in +CityxChange has high relevance to the project which is considered to be a key factor in boundary objects. The complexity of the +CityxChange EAF is a significant hindrance for learning. The research in this thesis could not determine if this was a result of the EAF itself or inherent to TOGAF ADM that it builds on or EA in general. The suggested changes in the proposed model were unable to lower complexity or show any significant improvement in learning.

8.2 Findings for RQ2: How can cities benefit from EA documentation of working smart city solutions?

The literature is split on whether or not replication is achievable, but it is clear that EA is part of the solution. Literature on boundary objects shows that boundary objects such as EA models can be useful for learning as long as the information is

closely related to the domain of interest where the learning takes place. The proposed model suggested adding information on internal teams, knowledge flows and knowledge processes, notation to simplify visualisation and more elements specifically for smart city development. The evaluation found that the proposed model did not improve the +CityxChange EAF. This thesis can not conclusively determine how the model could be improved, but it is believed that the core problems of the proposed model is the attempt at modelling knowledge at a teams level and not at the enterprise level. The literature on learning and innovation, and the model evaluation indicate that processes for learning are complex and require detailed descriptions to be useful. It is unclear if modelling learning on the enterprise level would have a significant benefit. Without the modelling of knowledge processes and flows, the +CityxChange EAF is still a valid boundary object that could be useful for smart city projects. The survey responses indicated that both EA and the +CityxChange EAF were seen as useful, but respondents were more positive towards EA than the EAF. This does not prove that the EAF is more or less useful than TOGAF ADM, zachman or any other framework, but it does indicate that the use of EA in +CityxChange could improve.

8.3 Findings for RQ3: How can EA be used to enhance transfer of knowledge from lighthouse cities to follower cities?

The survey shows that the organisations involved vary greatly. This is also reflected in the literature and mentioned as a core challenge of replication of smart city projects. This thesis will therefore argue for using a flexible EAF instead of focusing on replicating ICT architectures. The limited experience with EA also creates a problem, as it can not guarantee a shared syntax between the communities. The evaluation of the proposed model indicate that it increased complexity and should therefore not be used. The +CityxChange EAF or TOGAF ADM should be used instead. If the +CityxChange could be made less complex without any significant side effects, then that would be ideal. This thesis can not determine how to do that as the proposed changes did not help.

8.4 Findings for RQ4: What should EAF capture to enhance learning in lighthouse projects?

From the perspective of boundary objects, what needs to be captured must relate specifically to what is being learnt. The survey and evaluation indicate that the EA should give a high level view, hence the EA should capture key factors for decision making at a high level. The context layer should be a focus, as it is seen as the motivation for the EA and ICT should be present as it adds concreteness. The proposed model tried to model knowledge flow, but the evaluation found

that this is not appropriate. It is still believed that knowledge flow should be a consideration for the EA architect and management. This thesis can not determine more specifically what needs to be captured as the proposed changes were not seen as beneficial.

Chapter 9

Conclusion, limitations and future work

This chapter summarises the thesis and presents lessons learned, implication of the findings and future work.

9.1 Summary

The motivation for this thesis was to better understand the role of EA and how it relates to learning and knowledge transfer in smart city projects. The literature was reviewed and a survey was conducted with +CityxChange. This was used to inform a model based on the +CityxChange EAF and later evaluated with the use of expert evaluation. The proposed model was found to not have a positive impact on learning, but does show that more research is needed to understand how EA relates to learning.

9.2 Contribution / implications of study

This thesis contributes to the current EA research by identifying a need for a better understanding of how EA is used in knowledge processes and how knowledge processes should effect EA models. The research has identified that the complexity and terminology used in EA and smart city projects is a limiting factor for its usefulness and that supplementing EA models with information on knowledge flow can increase complexity in a detrimental way.

9.3 limitations

Time constraints limited the research in this thesis. A follow up questionnaire and iterative model development were planned, but not conducted. A follow up questionnaire would have allowed for more specific questions relating more closely to

the research questions and objectives. The original questionnaire results indicated that the current situation had problems and allowed hypothesis to be formed, but without a follow up questionnaire these hypothesis could not be tested thoroughly. Iterative model development could have responded to the evaluation and allowed for alternative representation of knowledge processes and responded to the issues found. Without this its unclear if faults are with the model or inherent to adding knowledge processes to EA.
The limitations discussed have resulted in the findings being described more like an outline than specific criteria for EA. This outline is however in line with the literature that advocate for flexibility in smart city related EA.

9.4 Future works

Further research should be conducted to better understand how EA relates to learning. It should look at how EA could be used in existing knowledge sharing activities and documentation processes such as workshops, scrum meetings, pitch meetings and interviews. alternatively it should look at how knowledge flows and processes could be represented in a helpful way for management. It should also look at how organisational cultures differ in lighthouse city projects and how that impacts EA.

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Appendix A

Questionnaire for +CityxChange

Enterprise architecture: its role in +CityxChange

Request for participation to provide feedback on the +CityxChange Enterprise Architecture Framework

This is a question to you about participation in in a research project. Here we give you information about the aim of the project and what participation means for you.

Aim
The aim of this questionnaire is to obtain feedback on the Enterprise Architecture Framework (EAF) used in +CityxChange (+CxC). The questionnaire has three main parts: (i) Demographic information on respondents; (ii) feedback on the usefulness of the EAF and use case models; and (iii) how the EAF could be enhanced to support knowledge transfer within and across cities.

This work is conducted as a part of a Master's project at the Department of Computer Science, at NTNU. The feedback on the +CxC EAF may be included as a part of the deliverable D1.2 Report on the Architecture for the ICT Ecosystem for the +CxC project.

The respondents to this questionnaire should have seen a presentation or used the +CxC EAF for modelling use cases.

Who is responsible for the research project?
NTNU IDI is responsible for the data processing in this project.

Why are you being asked to participate?
You are associated with the +CityxChange project and have been exposed to the +CxC EAF

Prospective respondents were purposely selected and invited to partake in the survey since they have prior knowledge on enterprise architecture or/and are familiar with the developed EAF used in +CxC project. Accordingly, the email address of the selected respondents were gotten either from the +CxC project master list or from the respondents organisational website.

What does it mean for you to participate?
Participation is through an electronic questionnaire. The questions are primarily about your opinion of how Enterprise Architecture relates to your work and the usefulness of the +CxC EAF. The questions are a combination of multiple choice, likert-scale and free-text.

Participation is optional
It is optional to participate in the project. If you decide to participate, then you can opt out at any point and withdraw your consent without giving any reason. All your personal data will then be deleted. There are no negative consequences for you if you do not wish to participate or opt out later.

Your privacy – How we use or process your data

We will only use the data for purposes explained here. We process your data confidentially and in line with regulations.

- Those that will have access to the data are: The student working on the thesis, the supervisor and the co-supervisor.
- The data will only be accessible to those mentioned above, deleted once the project completes and any published research will anonymize the data.
- The questionnaire is conducted with nettskjema. You can get more information on that here: https://www.uio.no/tjenester/it/adm-app/nettskjema/mer-om/

Any research publication will not give personally identifiable information

Your rights

As long as you can be identified by the data, you will have the right to:
- Insight into what data we collect about you and retrieve said data.
- Correct the data about you.
- Delete the data about you
- Complain about the use of data to "Datatilsynet"

What gives us the right to process personal data about you?
We process data based on your consent.

On request from NTNU IDI, NSD – Norsk senter for forskningsdata AS evaluated the processing of personal data in this project grounded in regulations.

How can i learn more?
If you have questions in regards to the studies, or wish to exercise your rights, contact:
- NTNU IDI sobah.a.petersen@ntnu.no.
- Data protection office at NTNU: Thomas Helgesen, thomas.helgesen@ntnu.no

If you have questions to NSD's evaulation of the project; contact:
- NSD – Norsk senter for forskningsdata AS via email (personverntjenester@nsd.no) or phone: 55 58 21 17.

Regards,

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Consent for participation in the study: I have received and understood information about the project to provide feedback on the +CityxChange Enterprise Architecture Framework. *

- [ ] I give consent

Demographic Information

To understand where the feedback is coming from, we need to understand your position in your organisation and your familiarity with the Enterprise Architecture approach.

Gender? *

- ○ Male
- ○ Female
- ○ Other gender identity
- ○ Prefer not to answer

Age? *

- <20 years
- 20 - 30 years
- 31 - 40 years
- 41 - 50 years
- 51 - 60 years
- Over 61

What type of organisation do you represent? *

- University
- Research organisation
- City council or municipality
- Private organisation
- Public organisation
- Other

If you answered other in the question above, please specify here.

What type of services does your organisation primarily provide? *

- Energy related
- Data related
- Innovation related
- ICT Infrastructure related
- Transport/mobility related
- Other

If your answer to the question above was "Other", please indicate the type(s) of service(s) provided by your organisation.

What is your primary role within your organisation? *

How much experience do you have with Enterprise Architecture *

- ○ No experience
- ○ Less than 1 year
- ○ 1 - 3 years
- ○ 4 - 5 years
- ○ 6 or more years

How much experience do you have with Smart City related projects? *

- ○ No experience
- ○ Less than 1 year
- ○ 1 - 3 years
- ○ 4 - 5 years
- ○ 6 or more years

Enterprise Architecture Approach

Indicate your level of agreement with the following statements about EA in general

	Strongly dis-agree	Disagree	Neither agree nor disagree	Agree	Strongly agree	Not appli-cable
Enterprise architecture is relevant for my work. *	○	○	○	○	○	○
Enterprise architecture is relevant for the +CxC project. *	○	○	○	○	○	○

Are you familiar with the +CxC Enterprise Architecture Framework (+CxC EAF)? *

- ○ I have seen a presenation of it
- ○ I have used it
- ○ I have provided feedback on the EAF
- ○ I have provided input and/or feedback to one or more models based on the EAF
- ○ I am not familiar with it
- ○ Other

Indicate your level of agreement with the following statements about the +CxC EAF

	Strongly dis-agree	Disagree	Neither agree nor disagree	Agree	Strongly agree	Not appli-cable
The framework is useful for my work. *	○	○	○	○	○	○
The framework is useful for CxC. *	○	○	○	○	○	○
The framework is easy to under-stand. *	○	○	○	○	○	○
The framework is easy to use. *	○	○	○	○	○	○
I will recommend the framework to colleagues in my organisation. *	○	○	○	○	○	○
I will use the framework for my work in the future. *	○	○	○	○	○	○

Use Case Scenarios described using the +CxC EAF

Indicate your level of agreement with the following statements about the use case scenario models described using the +CxC EAF

	Strongly dis-agree	Disagree	Neither agree nor disagree	Agree	Strongly agree	Not appli-cable
The use case models are useful for my work. *	○	○	○	○	○	○

The use case models are useful for the +CxC project. *	○	○	○	○	○	○
The use case models are easy to understand. *	○	○	○	○	○	○
I find it easy to describe a scenario using the use case models. *	○	○	○	○	○	○
The use case models have helped me clarify details about our use case. *	○	○	○	○	○	○
I will use the use case models for my work in the future. *	○	○	○	○	○	○
I will recommend the use case models to colleagues in my organisation. *	○	○	○	○	○	○

Enterprise architecture and knowledge transfer

Indicate your level of agreement with the following statements about how the +CxC EAF could help

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree	Not applicable
It could help in discussions with colleagues and/or collaboration partners within my organisation. *	○	○	○	○	○	○
It could help when explaining use cases and solution architectures to colleagues. *	○	○	○	○	○	○
It could help with capturing knowledge. *	○	○	○	○	○	○
It could help with sharing knowledge within my organisation and/or project partners. *	○	○	○	○	○	○
It could help when sharing knowledge across cities. *	○	○	○	○	○	○

It could help with reusing knowledge. *	○	○	○	○	○	○

Indicate your level of agreement on if +CxC EAF could support various types of activities

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree	Not applicable
It could support participatory design activities. *	○	○	○	○	○	○
It could support collaborative activities. *	○	○	○	○	○	○
It could support reflection about use cases. *	○	○	○	○	○	○
It could support identifying potential value added services. *	○	○	○	○	○	○
It could support creative activities such as brainstorming. *	○	○	○	○	○	○
It could support shared understanding to support decision making. *	○	○	○	○	○	○

Are there additional information that you would like to capture using the +CxC EAF?

What techniques does your organisation use to document knowledge that individuals have learnt during a project? e.g. interviews, observations or writing documentation.

What techniques does your organisation use to share knowledge? e.g. collaboration, training or meetings.

Apart from the +CxC EAF, does your organisation use Enterprise Architecture for other means? If so, how does it relate to this framework and can they be combined?

Which problems do you think enterprise architecture can or should attempt to solve?

If you have any other feedback or comments, please add them here.