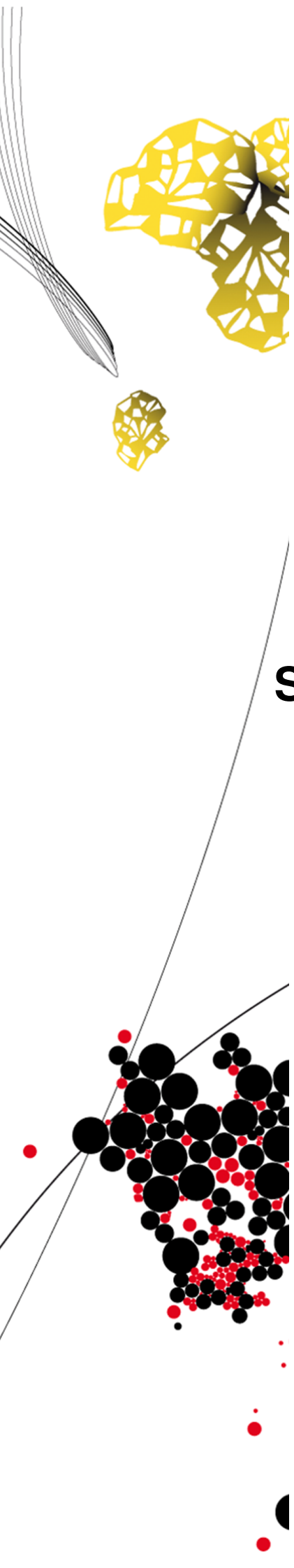

UNIVERSITY OF TWENTE.

**Faculty of Electrical Engineering,
Mathematics & Computer Science**

Enterprise Architecture Patterns: Supporting Sustainable Development

Roberto Rafael Garcia-Escallon

M.Sc. Thesis
June 2020

Supervisors:
dr. ir. A. I. Aldea
prof. dr. ir. M. Van Sinderen

IEBIS
Faculty of Electrical Engineering,
Mathematics and Computer Science
University of Twente
P.O. Box 217
7500 AE Enschede
The Netherlands

Summary

Context

The Enterprise Architecture practice enables and steers change in organizations. In that role it has been widely accepted, thanks to benefits like rationalizing IT expenditure. By driving change, in an ever-changing disruptive reality we live in now, they've been pressed to drive change faster. The practice depends on descriptions of how organizations function, or could function. However, organizations in many cases are similar to other organizations. And, barring innovative changes, the transformations that the practice steers have a source, either research, consultancy, or other organizations. As such, using patterns would help the practice.

Patterns in this context are reusable solutions to repeatable problems. Which could be leveraged when describing structures and behaviors of organizations that have already been thought of. As well as sharing how organizations could change when there is a common objective.

One such objective, is one of the biggest threats to humanity, and it looms on the horizon. Climate Change is calling for change at a pace that hasn't been seen before. Change which the younger generations are starting to call for, not taking no for answers, across the globe. Now is the moment we need to plan for change faster, and with wider scope than ever.

Results

The result of this study is a methodology for the specification of Enterprise Architecture using patterns for sustainability. This methodology is developed using the Architecture Development Model at its' core.

As a requirement for developing a methodology there are two middle results as well. First, the compilation of a set of patterns from literature. Second, a compilation of characteristics of sustainability from literature.

Application

The methodology will help architects steer the change that is needed, by providing a methodology based on patterns to hasten the process.

Validation

The methodology was validated using by a panel of experts, who then filled out a questionnaire based on the Unified Theory of the Acceptance and Use of Technology (UTAUT). As part of its' development it was also applied to a case study where the specification of a sustainable organization was the goal.

Conclusions

The use of patterns in Enterprise Architecture would help in providing a common vocabulary for architects. By re-using solutions other organizations, or academics, have created. This calls for the accumulation of patterns from practice, their classification with the ultimate goal of usage by architects in their own practice. Such a common knowledge base would enable other uses, like re-usable projects for the actual implementation of the change, simpler ways of integrating between organizations, or simulating the results of an organization.

Contents

List of acronyms

ADM	Architecture Development Method
BMC	Business Model Canvas
BMI	Business Model Innovation
BPM	Business Process Management
EA	Enterprise Architecture
EAM	Enterprise Architecture Management
EAP	Enterprise Architecture Pattern
IaaS	Infrastructure as a Service
ITSM	Information Technology Service Management
SaaS	Software as a Service
SBM	Sustainable Business Model
SLR	Systematic Literature Review
SQ	Sub-question
PaaS	Platform as a Service
RQ	Research Question
TOGAF	The Open Group Architecture Framework

Chapter 1

Introduction

1.1 MOTIVATION

Enterprise Architecture (EA) is a relatively new field of research that aims to steer the change in an organization (M. Lankhorst, 2017). For example, by aligning the goals of different layers of an organization. As a field, it has developed multiple tools to help practitioners in their activities, and as a result there are many frameworks and methods. Such methods include the Zachman framework and The Open Group Architecture Framework (TOGAF), among others (The Open Group, 2018; Zachman, 1987). Most methods and frameworks depend on descriptions of the organization, both of how it is working at the moment and how it should be working in the future (M. M. Lankhorst, Proper, & Jonkers, 2009). The methods and frameworks define the tools to design the desired future version of the organization, as a result EA has been applied to drive change in organizations.

The organizations EA is applied in, as well as all other organizations, have similarities in their structure and behavior with other organizations, similarities that could be also called patterns. In the words of Alexander, Ishikawa, and Silverstein (1977), the authors of the book A Pattern Language, “Each pattern describes a problem which occurs over and over again in our environment, and then describes the core of the solution to that problem, in such a way that you can use this solution a million times over, without ever doing it the same way twice” (Alexander et al., 1977). From this definition we can extract four key attributes, first, patterns are a solution to a recurring problem. Second, the pattern is the core of the solution, meaning the solution has a scope, and does not aim to describe anything that is not needed to solve the problem. Third, the pattern should be usable as many times as needed. And fourth, each specific use of the pattern might look different than the last. Thus, patterns provide reusable solutions to problems that occur repeatedly.

Patterns have been used in other fields, most famously in Computer Science, where patterns describe solutions to common problems when developing software

(Gamma & al, 1995). These patterns helped to hasten the development of software, as they offered ready to use solutions to some common problems. Thus, similar effects are expected in EA by applying the concept of patterns, helping drive change faster.

In the global context Sustainability has become the goal to many, ranging from individuals to the United Nations as a response to climate change and other obstacles (United Nations, 2015). The effects of climate change are clear: climate change, impacts to human health, mass extinction of species, among others (Braungart, McDonough, & Bollinger, 2007; Ceballos, Ehrlich, & Dirzo, 2017; Stahel, 2016).

Climate change calls for a transformation, one that is widespread and towards sustainability, which is being demanded by millions around the globe (Taylor, Watts, & Bartlett, 2019). The rate at which needs to increase, as the looming deadline of 2030 for reducing carbon emissions by 45% worldwide, to avoid a warming higher than 1.5 degrees Celsius, nears (Allen et al., 2019). Although, the kind of changes required are similar for all organizations. For example, all organizations can reduce their CO2 footprint by avoiding using paper in their internal processes, something that can be solved in a reusable manner with technology.

1.2 CONCEPTUAL FRAMEWORK

Following the motivation, the conceptual framework defines the pillars upon which the entire study is supported. The main concepts have already been mentioned, namely patterns, EA and sustainability.

EA provides the tools with which an organization can express and describe its inner structure and behavior. These tools can be split into three: first a framework defines what theEAis, then a methodology describes the process by which theEAis developed, finally a language must be used to actually develop the EA. For this study the framework used will be TOGAF (The Open Group, 2018), which is one of the widely accepted standards in the field. It defines the division of focus into Business architecture, Application architecture, Data architecture and technology architecture. This framework also describes a methodology, the Architecture Development Method (ADM), which is based on phases where practitioners work on different aspects of the EA, e.g. the different foci mentioned above. The language used for this study is Archimate, which is the standard language used in conjunction with TOGAF and ADM (The Open Group, 2019)

Patterns as reusable solutions have been used in the fields of Architecture (Alexander et al., 1977) and Computer Science (Gamma & al, 1995). Its use in EA makes an Enterprise Architecture Pattern (EAP), where the problem to be solved considers the point of view of the organization, and provides an internal solution.

1.3 RESEARCH QUESTION

The research question that is answered in this study is:

How would a practitioner build an EA specification for sustainable organizations using EAPs?

In order to answer it the following knowledge questions are required:

1. What EAPs are there in literature?
2. What characteristics of sustainability are relevant for EA?
3. What EAPs build a sustainable organization?

1.4 CONTRIBUTION

The contribution of this study to the academic community is twofold. First a set of EAPs present in literature is compiled through an exhaustive Systematic Literature Review (SLR). Second a set of defining characteristics of sustainable organizations in literature is compiled, again with the use of a SLR.

At the same time, the contribution to the practitioner community is twofold. First, a methodology on how using the compiled set of EAPs is developed, and a case study is prepared. Second, an analysis on what is needed to express sustainability in the specification of an EA is provided, as well as an example applied to EAPs.

1.5 REPORT ORGANIZATION

The remainder of this report is organized as follows. In Chapter 2, a SLR is performed in order to identify the EA patterns in literature and what defines them. Second, in Chapter 3, a second SLR is performed to find the characteristics that define a sustainable organization, as defined in the literature. Thirdly, in Chapter 4, a cross analysis is performed to classify which of the previously foundEAPs could support characteristics of sustainability. Then, in Chapter 5, a methodology for the use ofEAPs is proposed, specifically for developing a specification ofEAfor a sustainable organization. Furthermore, in Chapter 7, the validation of the methodology is performed with an expert panel of enterprise architects. Finally, in Chapter 8, conclusions and recommendations are given.

Chapter 2

Enterprise Architecture Patterns

As mentioned in the previous Chapter, patterns in the case of Alexander et al. (1977) refer to patterns in architecture, but the concept has been applied to other fields as well. One of the fields using patterns is Computer Science, where they are used as a standardized solution that can be reused in multiple cases, an approach that has become a best practice to solving problems in the field (Gamma & al, 1995). An example is the Facade pattern that defines a central interface of access acting as a front to a complex structure, simplifying the access (Gamma & al, 1995).

Applying patterns toEA would entail that practitioners document both recurring problems and the solutions they use to solve them within their organizations. This documentation would help future organizations explore alternative configurations to their current way of operation, as well as inspire what direction to move to in their future. This approach is mentioned as best practice in the TOGAF, so it is not a new idea, however the execution of the practice is left to the readers (The Open Group, 2018).

By having similarities in their functioning, organizations could reuse solutions to the challenges they face often. However, today using publicly available patterns forEA is not a widespread practice. Stemming first from a lack of said public patterns. Thus a first step towards popularizing pattern use is to identify them and their sources.

2.1 METHODOLOGY

In order to achieve the study's goal the SLR methodology of Rouhani, Mahrin, Nikpay, Ahmad, and Nikfard (2015) is used, as it is a very thorough work in theEA field. The method they used is first introduced by Kitchenham and Charters (2007) a guideline for Software Engineering, but was modified for its' use in EA. This method outlines three stages to a SLR: a planning phase, an execution phase and a re-

sult analysis phase. In order to enhance this method, some techniques described by Wolfswinkel, Furtmueller, and Wilderom (2013) will be included, specifically, the backwards and forwards citation steps of their selection phase to detect any work that builds upon patterns that was not present as results of the query, to include additional articles that might be relevant but were not present in the results of the query. In order to execute this last step, Google Scholar was used, which shows both, backward and forward citations, easily. The process is shown in Figure 2.1.

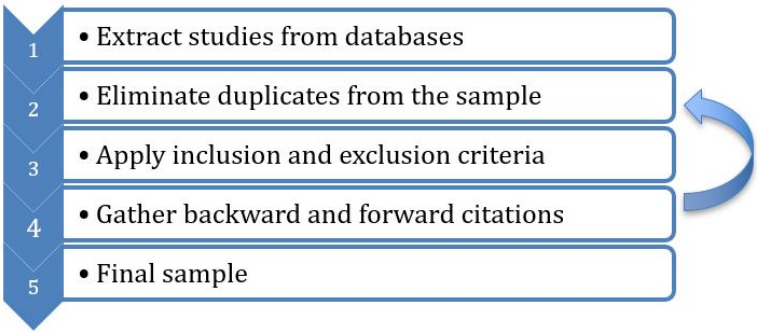

Figure 2.1: Overall process

2.1.1 Design Phase

In this phase the design process followed to perform the SLR according to the chosen methodology is presented.

Research Question

Identifying patterns in order to then apply them to subsequent work is a generalized human practice, this research aims to identify what patterns there have been researched in theEA field. The expectation was to find a list of patterns that could be used to answer some of the challenges today's organizations face. As such, the main Research Question (RQ) to answer was the following:

RQ: What is the state of the literature ofEA Patterns?

Which derives some Sub-question (SQ) as well: **SQ1: What patterns are present in the sample?**

SQ2: What other fields of research are present in the sample?

SQ3: What ways of representing patterns are used?

SQ4: What methodologies are used for pattern extraction?

By identifying other fields that are related toEA in their text the list of patterns will be expanded beyond the ones found strictly in theEA field. This would serve to classify the patterns found based on which field it comes from. The expectation is to

find fields that are related to EA , in a way that the patterns found can be used byEA practitioners in the future.

In order to compare the patterns found information regarding how these patterns are represented is gathered. The expectation is to find studies using standard modeling languages like Archimate, UML, BPMN; as well as strictly written descriptions, among others.

In order to compare the studies themselves the methods used to extract the patterns will be gathered. In other words, how did the authors produce the pattern. The expectation is to find that studies used a mix of methods, e.g. SLR.

Search Process

In this section the process followed in the SLR is described. These are the steps previous to the actual execution of the review. First, the keywords to be used in the queries were selected : *(“enterprise architecture” AND “Pattern”)*

The aim of this query is to produce a sample of the literature, in order to then answer the RQs. This query was executed with the scope of the full body of articles instead of the more popular Title-Abstract-Keywords, in order to widen the variety of articles in the resulting sample. With these keywords at hand the databases to apply them to were selected:

- Scopus.
- ACM Digital Library.
- IEEE Xplore.
- Science Direct - Elsevier.
- Springer Link.
- Taylor and Francis.
- Web of science.

Using the Google Scholar database in the design was decided against, due to it containing results that are already present in all the databases above (Rouhani et al., 2015). However, due to the simplicity by which one is able to find specific articles, information about the references of articles and the articles that cite them, Google Scholar was used for the forward and backward citation gathering. It must be mentioned that during the backward and forward citation gathering the exclusion criteria was relaxed, accepting studies without a DOI registry, as well as books.

In accordance with the methodology selected (Rouhani et al., 2015), inclusion criteria is designed to produce a sample of studies that would best serve the goal of this study. In order to ensure recent scientific research as well as relevant patterns to today's challenges, articles published in the past 10 years were selected. To ensure scientific rigor studies published in journals and conference proceedings were selected, furthermore indexed books were also included because after an exploratory phase it was found that there were several books published containing repositories of patterns. For an international scope the search was limited to studies written in English. Finally, only articles referring to patterns were selected, in order to be able to answer the RQs. Inclusion Criteria:

- Peer-reviewed papers published in journals, conference proceedings, book chapters and books
- Published in the last decade
- Written in English
- Studies that focus on Patterns

In terms of the exclusion criteria to ensure scientific rigor short works, and non-studies (e.g. introductory texts) were excluded. In order to automate the gathering of bibliographic information articles without a DOI registry were excluded. Finally, to simplify the answering of the RQ, studies focusing on anti-patterns and patterns referring to Software were excluded. The first due to the goal of compiling reusable solutions to common problems organizations face instead of things they should not do; the latter due to their narrow scope of how to program better software. Exclusion criteria:

- Short works, e.g. posters
- Duplicated work, unifying under the database with more results
- non-studies, e.g. Introduction texts to conference proceedings
- Articles without a DOI registry
- Articles referring to anti-patterns
- Articles referring to Software Architecture, or Software Patterns

Once the results were extracted from all the databases, the steps below were followed:

1. Eliminate all duplicates.

2. Based on the title whether exclusion criteria apply.
3. Based on the title and abstract select those articles where both inclusion criteria apply, and exclusion criteria don't apply.
4. Repeat step 3 but reading through the full text.
5. For each remaining article review the reference section and repeat steps 1 to 4.
6. For each remaining article use Google Scholar to review the forward citations and repeat steps 1 to 4.

2.1.2 Execution Phase

In this phase the process and results of the execution phase of this SLR is explained. As defined during the design phase, the steps were followed and criteria defined was applied. First, a description of our experience executing the defined steps is given. Second, the form used to extract the useful information of the studies is shown.

Query - Enterprise Architecture Patterns

Table 2.1: Results of query

Database	**# of results**
Scopus	2071
The ACM Guide to Computing Literature	81
IEEE Xplore	1174
Science Direct	609
Springer Link	2746
Taylor and Francis	125
Web of Science	42
TOTAL	7669

As shown in Table 2.1, the initial results of the query included 7669 non-unique items. After removing duplicates and those without DOI registry the sample size was reduced to 3236 articles. Those studies were then filtered by reading their titles and based on the exclusion criteria, resulting in 556 studies. Then the abstracts were read and those studies that referred to patterns were selected, this reduced the sample size to 33 articles. These were further refined to 16 studies based on their full text. From these 16 studies both forward and backward citations were gathered,

upon which the same starting steps were executed. The result was the final sample of 24 studies, as seen in Appendix A.

Data Extraction

In this section the data extraction form, that facilitates the gathering of the information present in the selected studies, is introduced. This information serves as the basis upon which answers to the RQs are drawn. Separately, for each pattern presented in the studies the information shown in Table 2.3 was gathered.

Table 2.2: Data extraction form - article

No.	Extracted Data	Description
1	Bibliographic Information of the study	Information on the Authors, year of publication, medium of publication and any publication ID (DOI, ISSBN, etc)
2	Times cited	As mentioned above, Google Scholar was used to gather how many times each study was cited
3	Type of document	Journal, Conference proceedings, published book, Lecture Notes, dissertation
4	Research Method	No method, case study, survey, interviews, experiment, literature review
5	Scope of patterns presented	The patterns can be of a segment of the architecture, e.g. Business layer, Strategy layer, etc. It could also be cross-layer but in the scope of a function, e.g. HR.
6	Field of origin for the pattern presented	Where the pattern comes from, i.e. the field of research that prompted the pattern
7	Language of representation	A formal modelling language (e.g. Archimate), representation formalisms (i.e. a Framework), a non-standard modelling language (boxes and lines), written description
8	Number of Patterns presented	How many patterns are presented in the article
9	Validation of the patterns	No validation, conceptual validation, expert panel, etc.

Table 2.3: Data extraction form - pattern

No.	Extracted Data	Description
1	Id	An identifier
2	Name	Name of the pattern as written in the article
3	Description	Description, or summary of the pattern as written in the article
4	Source	Which article it appeared on, could be possible that multiple articles refer to the same pattern by name
5	Publication year	What year was the pattern published on
6	Field of origin	From which field does the pattern come from
7	Scope	The patterns can be of a segment of the architecture, e.g. Business layer, Strategy layer, etc. It could also be cross-layer but in the scope of a function, e.g. HR.

Synthesis

The final sample of studies contained 24 items, of which 11 are journal articles, 8 are conference papers and 2 are books, as shown in Table 2.4. While in Table 2.5 each study, their year of publication, what type study they were, as well as their number of citations is shown. The highest cited works were the 2011 book Architecture and Patterns for IT Service Management, Resource Planning, and Governance: Making Shoes for the Cobbler's Children with 82, and 2009's conference paper Using enterprise architecture management patterns to complement TOGAF with 76. A special note must be made regarding the 2019 journal article A Review and Typology of Circular Economy Business Model Patterns that within a short period of time has gathered 48 citations. Although the number of citations has many contingencies it can be used to draw some comparisons. E.g. when comparing two articles of the same type the one with higher citations has informed a wider opinion than the article with a lower citation count.

Seven articles in the sample have been cited less than 10 times, five of them conference proceedings and two journal articles, and three of them published in the last year. On the other hand, the other 17 studies in the sample have been cited between 10 and 86 times. In the sample the years 2009, 2011 and 2015 are the publication years for the biggest concentration of studies.

Table 2.4: Studies by type

Study type	**Number of study**
book	2
Book Section	1
Conference Paper	8
Journal Article	11
Report	1
Website	1
Total general	**24**

Table 2.5: Studies by year of publication and citations

ID	**Study Type**	**Publication Year**	**Number of citations**	**ID**	**Study Type**	**Publication Year**	**Number of citations**
P1	Journal Article	2018	3	**P13**	Journal Article	2009	17
P2	Journal Article	2019	48	**P14**	Book	2014	29
P3	Conference Paper	2010	11	**P15**	Conference Paper	2015	5
P4	Book Section	2019	0	**P16**	Conference Paper	2015	2
P5	Book	2011	82	**P17**	Conference Paper	2010	0
P6	Journal Article	2015	51	**P18**	Conference Paper	2011	1
P7	Journal Article	2019	0	**P19**	Journal Article	2009	42
P8	Conference Paper	2016	13	**P20**	Journal Article	2017	59
P9	Journal Article	2009	14	**P21**	Journal Article	2018	28
P10	Report	2015	0	**P22**	Conference Paper	2013	30
P11	Journal Article	2011	43	**P23**	Conference Paper	2009	76
P12	Journal Article	2011	52	**P24**	Website	2011	47

2.2 RESULTS

After the selection of the final sample and the subsequent extraction of the data the contents of the studies are explored. This section presents the findings and discussion of this review, as well as a narration of the challenges faced, and exploration done throughout the process.

In order to better present the results they will be aggregated based on the fields found in the sample. The fields found in the sample were: EA , Business Model Innovation (BMI), Business Process Management (BPM) and Information Technology Service Management (ITSM). Each field will be explored deeper in the following subsections.

2.2.1 Enterprise Architecture

In theEA field the focus on patterns has been split between patterns of enterprises, and patterns of theEA practice itself. The latter has been spearheaded by a group of researchers in the TUM who have been working on such patterns and concluded their work with the version 2 of their pattern catalog in 2015, codified as P10 in this work. This team of researchers are also responsible for P9, P15, P19 and P23, which represents 20% of our sample.

In Table 2.6 each study of theEA field found in the sample is shown. As mentioned before, P9, P10, P15, P19 and P23 focus on the management ofEA as a practice. These Enterprise Architecture Management (EAM) patterns total 34 out of the 111 patterns. All other works focus on the Enterprise as a whole. The publication year was also shown, where it can be seen that most of the works in the sample are from 2009 (44%), barely inside the scope of the SLR. Among these studies the one with most citations is P12 where 32 patterns are defined, dealing with every degree of application support on Business Processes. E.g. a business process is entirely supported by an application, or a business process having no application supporting it.

These studies base most of their patterns on their own experiences as experts in the field, which is classified as No Method. Except for P13 which performed a literature review in order to gather the patterns they presented.

Finally, in terms of means of representation all the works focusing on EAM have followed the same format. Which is understandable, as they're outcomes of the same research group. Other studies use Archimate and a written description (P4, P12). Where the written description contains a summary of the solution, an example of it, with P4 also explaining the problem the pattern solves. P13 uses only a written description and P14 uses multiple diagramming languages (UML, BPMN,

Table 2.6: EA Studies and patterns

Study	Research Method	Publication Year	Patterns	Citation Count
P4	No Method	2019	4	0
P9	No Method	2009	3	14
P10	No Method	2015	23	0
P12	No Method	2011	32	52
P13	Literature review	2009	28	17
P14	No Method	2014	13	29
P15	No Method	2015	2	5
P19	No Method	2009	6	42
P23	No Method	2009	0	76
Total			111	235

Archimate) as well as written description of the context, problem and solution.

2.2.2 Business Model Innovation

The patterns found coming from the BMI field focus on describing the Business Model, where frameworks like the Business Model Canvas (BMC) and its' constructs are popular in our sample (Osterwalder & Pigneur, 2010). These constructs include revenue stream and customers. Another interesting finding is the research on Business Models from the Sustainable Business Development field, which focus on evaluating what types Business Models are sustainable (P2, P7, P11). For example, P2 focuses in the sub-field of Circular Economy Business Development.

As can be seen in Table 2.7 the primary pattern publication is P20 in 2017, that gathered multiple repositories in the field from previous work and consolidated it. P20 has more than 176 Business Model Patterns, which prompted others to follow and expand on, further extending the number of patterns. It has also served the sustainable business development field as a basis for their own work, both for them to expand the repository (P2) as well as evaluate the patterns through sustainability research (P21).

In Table 2.7 it can be seen that all publications happened in the past four years. With the ones focusing on sustainability being even more recent.

For research methods, these studies leveraged the existing literature, in the form of reviews, as a source for the patterns presented (57%). Those that deviated from the literature went instead to the market and analyzed how real-world organizations operate.

Finally, the means of representation they used was heterogeneous. P1 uses the

Table 2.7: Business Model Studies and patterns

Study	Research Method	Publication Year	Patterns	Citation count
P1	SLR	2018	30	3
P2	Literature review	2019	6	48
P6	Market research	2015	27	51
P7	Case studies	2019	7	0
P8	Market research	2016	27	13
P20	Literature review	2017	176	59
P21	Literature review	2018	45	28
Total			318	202

Business Model Canvas as presented by Osterwalder and Pigneur (2010). P2 develops a morphology based on the Business Model Canvas. P6 uses a framework developed by Köster (2013) which mainly presents the constructs defined by the Business Model Canvas in four categories: Supply model, Customer model, Value creation model, and financial model. P7 uses only written descriptions of the solutions. P8 uses the template defined by Weill, Malone, D'urso, Herman, and Woerner (2005) where each pattern has a name, a short description and a real-world organization that uses it. P20 compiles a table with pattern name, description, alternative names, example of the real-world and its' source study. P21 used a template based on the one presented by Alexander et al. (1977) with written descriptions of the problem and the repeatable solution. Except for P7 that uses only written descriptions and P21 that uses a proper pattern representation, all articles from this field can be split by similarity into two groups: the ones that use the constructs from the BMC or similar (P1, P2, P6), the ones that compiled a table with minimal information (P8, P20).

2.2.3 Business Process Management

The BPM field had their own primary publication in 2011 with P24 where the authors have been working through multiple articles and publishing their work in web format. Their work is publicly accessible through their website which makes it easy for other researchers to use it for future work, something that shows in their citation count. They aim to be exhaustive in their work, and it shows, as their repository now contains 127 patterns for Business Process Modeling. However, no recent articles were found other than the publication of a book gathering their findings in 2016 (Russell, van der Aalst, & ter Hofstede, 2016). They use a colored petri net to represent their patterns in diagrams, along with a written description of the solution. As a source for their patterns they leverage their own expertise.

Table 2.8: ITSM Studies and patterns

Study	Research Method	Publication Year	Patterns	Citation count
P3	No Method	2010	6	11
P5	No Method	2011	19	82
P17	No Method	2010	1	0
P22	No Method	2013	3	30
Total			29	123

The other work from this field in our sample was P11 in 2011, using an abstract representation of an enterprise based on the most essential processes. They use written descriptions and diagrams written in ANSI/IEEE 1471-2000. They have based their patterns on their own experience and have seen them applied to many organizations in Chile.

2.2.4 IT Service Management

The articles from the ITSM field that were in the final sample were clearly split on either conference papers or a book, where the book (P5) has the highest citation count out of the entire sample. The conference papers (P3, P17) only documented 10 patterns among them, however they hinted at a technical report by the same authors that was not possible to acquire. It must be mentioned that the authors were unable to access P5 in its' current 2nd edition, instead only the 1st edition from 2007 was analysed.

As for means of representation, As can be seen in Table 2.8 all of the studies in this field base their patterns on experience. With the special mention of P22 which translates the ITIL standard into Archimate concepts. P17 and P3 use a template that is based on Alexander et al. (1977) and describes a context, a problem, the forces that foster the use of a pattern, the solution itself, its' consequences and some facts to help the understanding and usage of the solution, for example depending on the number of systems managed in a remote location the use of a single distributor may not be enough. The patterns are accompanied by diagrams made using a non-standard modelling language and UML. Both works refer to a research group that has published a technical report with a more complete collection of patterns, but the report was inaccessible to the authors of this paper. Finally, P5 uses written descriptions without following a specific template like other studies in the sample, as well as with UML and non-standard diagrams.

2.3 DISCUSSION

In this section, the results of the SLR and overall findings are shown. This section also contains the discussion on the RQs. Finally, limitations and possible future work are discussed.

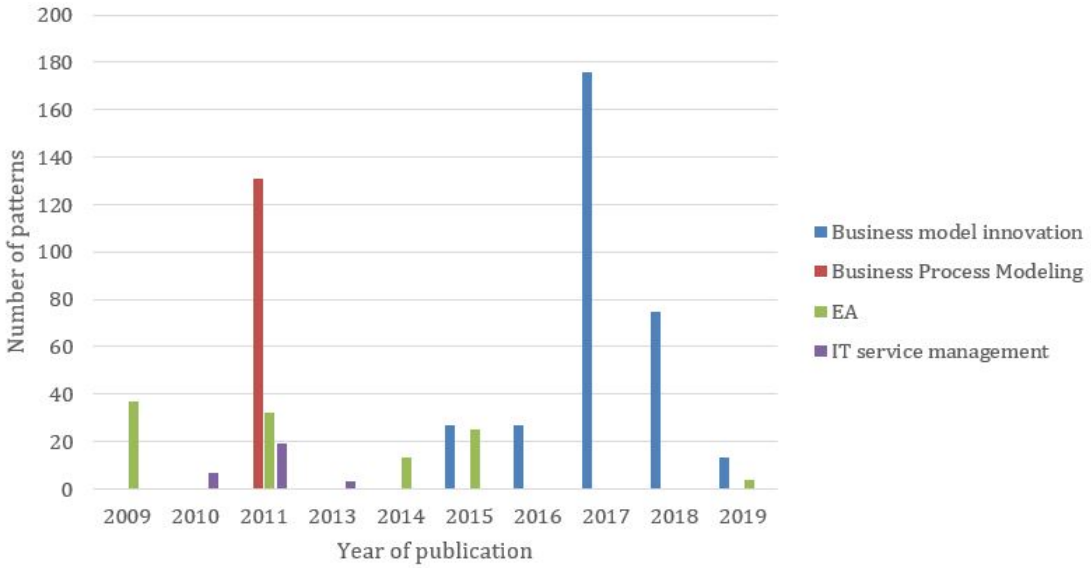

Figure 2.2: Patterns per year and field

2.3.1 General Discussion

During the overall execution of the SLR it was noticed that the concept of patterns has been used by all fields in the sample with different time spans. In Figure 2.2 it can be seen how each of the fields has peaks in different years. The latest one being the studies on BMI, particularly in the Sustainable Business Development field. The recent surge of the BMI field's effort on documenting the patterns has been welcomed with open arms by the academic community, as seen by the citation count mentioned in earlier sections. Such interest extends to the sub-field of Sustainable Business Model (SBM)s, that expands the Business Model Patterns. P2 which expands upon the Repository and adds more Business Model Patterns. Contrary to all other studies in this sample, all the studies related to BMI, SBM and Circular Economy are based around the framework proposed by Osterwalder and Pigneur (2010). Although the representation of the patterns may differ, their basic constructs are the same, which would make it possible to translate these patterns into anEA representation of them, based on the work of Iacob et al. (2012). This method would pave the way to take these Business Model Patterns repositories intoEAPs.

Being able to relate the patterns extracted from SBMs and translating them toEA is aligned with the overall interest of society to a more sustainable world. With the call for sustainability, as seen by the Sustainable Development Goals of the UN (United Nations, 2015), it means that organizations will need to develop new functions or transform their current ones. This change could be supported by EA , and, being a generalized need, would benefit from having a repository of patterns to draw from.

2.3.2 State of the Literature on Enterprise Architecture Patterns

Each of the 24 studies reviewed in this SLR have described patterns, however not all of them seem to be written in a way that can be used by future works. For example in the conference proceedings and journal articles, where the authors report mostly on how they arrived at the patterns (P3, P17), or describes how one could extract and write patterns (P16, P22), but do very little in actually documenting them. As such, when extracting the information, which was described in Section 2.1 as name and description, there are some patterns without a description as well as some where it was difficult even to gather the names of. This lack of information may be related to the space limitations when submitting studies for publication in conferences or journals. Which is aligned with our findings that the most detailed and complete patterns are found in books, technical reports and online databases.

With space being such a valuable resource in journal articles and conference papers it raises the question what is the best way to gather patterns in a way that is usable for future research as well as practitioners. Within this SLR, books and technical reports focused more on the patterns themselves, while journal articles and conference proceedings focused more on methods or presented sample patterns. Although P24 fused the two, by publishing each new kind of pattern in journal articles while at the same time keeping the online repository updated they were able to present a high amount of information on their work while avoiding the space limitations scientific publishing implies.

Based on the initial definition, patterns solve a repeating problem. In the case ofEAPs then, the problem is a deficit in the organization as perceived by the stakeholders. Thus,EA practitioners would be in the best position to detect both the problems that repeat themselves, as well as the solutions that could be reused to meet them. This line of thinking means that researchers must be in contact with practitioners far and wide in order to expand patterns, or that researchers must be practitioners as well. This poses a limitation, or it could be taken as an opportunity to include practitioners in future works on patterns.

2.3.3 Fields Researching Patterns

On Figure 2.3 we have classified the four main types of patterns found through the SLR in terms of the four main layers of the Archimate Language (M. Lankhorst, 2017). Based on Iacob et al. (2012) and the Archimate constructs they use to describe a Business Model (Osterwalder & Pigneur, 2010) it can be concluded that Business Model Patterns are confined to the Strategy and Business layers. While the Business Process Patterns was mapped to the Business Layer due to its' scope, Business Processes, which is enclosed in this layer.

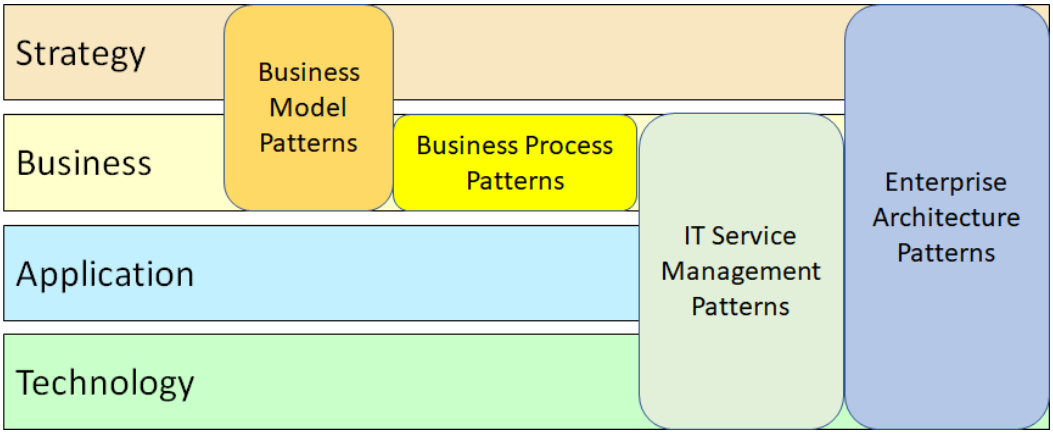

Figure 2.3: Classification of Fields

EAM Patterns are omitted from this graph. This is due to their focus on the practice ofEA itself, the methods enterprise architects use to gather information, as well as how they present it to stakeholders. As such these patterns are more akin to anEA framework and methodology. Thus, although the focus of the EAM patterns is theEA practice itself, this is different to theEAPs, which is the enterprise.

2.3.4 Means of Representation

The overall heterogeneous way to represent patterns could be attributed to the multitude of fields and languages comes into play. However just as Perroud and Inversini presented in their work (P14), these patterns may need to express concepts that any one modelling language is unable to combine. They (P14) used multiple languages, each showing a specific point of view to the pattern, and tied it all with natural language description, due to the complexity of communicating these patterns. In detail, the structure proposed by Alexander et al. (1977) work, should have the following components:

- A title
- a diagram

- an Introduction describing the context and how it builds larger patterns;
- A detailed description of the problem, its' validity, and ways the pattern manifests to solve it
- A detailed description of the solution, written as instructions for people to follow;
- A diagram of the solution;
- How it links to other patterns, both smaller and larger in scope.

This structure is used in a similar fashion by some of the works in the sample, (P14, P3, P17), while all of the works described at least some of the concepts. It is the authors' belief that the structure detailed by Alexander, is the best basis to representEAPs. Such a statement is echoed by a study by Kotzé, Tsogang, and van der Merwe (2012) in theEA field that has laid out guidelines to the elaboration and documentation of patterns, as well as defined a pattern template, which follows:

- Pattern Name: A unique name to identify a pattern.
- Problem: The design problem which is addressed the creation of a pattern.
- Context: In which circumstances and domain is this pattern applicable?
- Forces: The various forces that impact the creation or existence of a pattern.
- Solution: Describe what needs to be done as a solution that resolves forces from strongest in this context in relation to addressing the recurring problem.
- Related Patterns: What enterprise architecture patterns are closely related to this one?
- Rationale: Is a description of why the solution is an appropriate one and not another.
- Example: An artefact (e.g. a graphical model, an algorithm, a formula, a structured rule (text), etc.), which illustrates how the pattern operates.

The above template comes from a study on how to write patterns, but does not elaborate any examples. Thus Kotzé et al. (2012) did not run into some of the issues that authors in our sample did. As evidenced by the template used by P14, shown in Figure 2.4, the solution section of the template requires a longer and deeper understanding. This is due to the multiple viewpoints and layers a pattern may cross, like Pattern170, that describes business, application and technology layers.

Table 2.10 Structure of a pattern

Section	Subsections
X.11.1 Introduction	
	Name and overview
	Definition
X.11.2 Example	
X.11.3 Context	
X.11.4 Problem	
X.11.5 Solution	
	Vision
	Principles
	Holistic view
	Business view
	Data and application view
	Technology view
X.11.6 Resulting context	
	Interaction
	Consequences
X.11.7 References	

Figure 2.4: Table 2.10, taken from P14

Both P14's and Kotzé et al. (2012) representation ofEAPs overlap by many of the concepts they propose with some exceptions. In Figure 2.4 there are some concepts that are missing according to Kotzé et al. (2012) representation but can be found in the details: Forces and Related patterns. This means that P14 has every concept proposed by Kotzé et al. (2012) except for the rationale behind the proposed solution. Also, when one compares this way of representation with the one proposed by Alexander et al. (1977) it's missing a description of the validity of the problem. Due to this, we propose that the template presented by P14 can be enhanced upon with a more exhaustive structure where all the pieces can be perceived at first glance, and the rationale behind both the problem and the solution is explicit.

As previously mentioned above, by combining the template used by Alexander et al. (1977), Kotzé et al. (2012), and Perroud and Inversini (P14) a more complete representation of EAPs can be achieved. The basis for the representation will be the one proposed by Perroud and Inversini (P14). A simple reorganization of its contents will be done, e.g. making the related patterns a subsection of its own. This reorganization aims to make its general structure show explicitly components present in Kotzé et al. (2012). Beyond the reorganization two additions will be made: to the problem definition a subsection describing the validity of the problem; and to the solution description a subsection with the rationale behind it. These are components

proposed by Kotzé et al. (2012) and Alexander et al. (1977) respectively, that are described as needed in the representation of patterns.

The final means of representation is as follows

1. Introduction
    (a) Name and overview
    (b) Definition
    (c) Supporting forces
2. Example
3. Context
4. Problem
    (a) Validity of the problem
5. Solution
    (a) Vision
    (b) Rationale
    (c) Principles
    (d) Holistic view
    (e) Business view
    (f) Data and application view
    (g) Technology view
6. Resulting context
    (a) Interaction with other patterns
    (b) Consequences

2.3.5 Methodologies for pattern extraction

A Challenge faced by all the fields in this SLR was the gathering of the patterns. While the Business Model Patterns can be extracted from an organization through literature reviews and researching real world organizations. On the other hand the patterns presented by theEA field are based on authors' experience. For example P14 mentioning that the source of these patterns is the day to day experience of the practitioner and detecting a repeating problem. This mention of repeating problem

is also present in other works on patterns (Alexander et al., 1977). Another avenue seen is presenting a framework that is built with discreet choices of concepts and then building patterns exhausting all possible combinations. This method is used by P2, P11, P12, and in a more limited way P24 which strives for a exhaustive work but do not explicitly show all possible combinations. Finally, P22 took current standards and made them into patterns.

As seen in Section 2.2, the 50% of studies in the sample based the patterns from the author's experience. When reviewing the definitions by Alexander et al. (1977) the source of patterns is an experienced professional experiencing the same problem again and again, so this would explain this method's commonality. What is missing, however, is the argumentation on the existence of the problem, one that fosters the need for a pattern in the first place. With most of the studies in the sample were missing a framing of the problem they're set to solve.

The second most common method of extracting patterns is the literature review (25%), which extracts patterns from current literature. Determining what method is used in the sources of these literature reviews is outside the scope of this SLR. These sources apply their own methods.

The studies that deviate from literature review and author's experience are P5 and P17 which base their patterns on standard practices. In case of P5 it's the ITIL library, which dictates practices on how to operate the IT function of an enterprise. With P17 it's a framework of their own which extends upon ITIL, Cobit, CMMI and other standards, that models the entire IT function as an enterprise by its' own worth. This approach could be expanded upon to include other standards that detail how organizations should act.

In order to give the patterns validity, their definition must come accompanied by some kind of argument supporting that using the pattern indeed solves the problem (Alexander et al., 1977). In the sample this came from identifying organizations that worked under patterns in question (P20, P1, P9, P11, P14, P16, P21), from personally applying the patterns (P18), from having practitioners apply the pattern (P8), from building business cases (P5), or from having other researchers validate the patterns found (P1, P24). However, the majority of the works in the sample describe no manner of validation (P2, P3, P4, P6, P7, P8, P10, P12, P13, P15, P17, P19, P22, P23), a majority of the sample.

Chapter 3

Sustainable Development

In this chapter the sub-question: ”What characteristics of sustainability are relevant for EA?” is answered. Using a SLR following the same methodology based on Rouhani et al. (2015) that was used in Chapter 2.

In Chapter 2, there were works found in the sample focusing on sustainable development. These did so from both the sustainable business development (P7,P21) and circular economy points of view (P2). It is upon these three studies that this SLR is built. Particularly P7, that focuses on solving sustainability issues along the phases of the life cycle of the smartphone industry. A sustainability characteristic that is found in P7 is *establishing long-term customer relations*, implemented by the pattern *Sufficiency-advocating network provider* (Pattern046). Such characteristics are the expected result of this SLR.

Sustainable Development can be defined in three ways, according to the research by Geissdoerfer, Vladimirova, and Evans (2018): first, as a situation in which human activity is conducted in a way that conserves the functions of the earth's ecosystems; second, as a transformation of human lifestyle that optimises the likelihood that living conditions will continuously support security, well-being, and health, particularly by maintaining the supply of non-replaceable goods and services; third, as an indefinite perpetuation of all life forms (Geissdoerfer, Savaget, Bocken, & Hultink, 2017). In contract to these definitions, today the world is using approximately 1.5 times the resources the earth can supply in a sustainable manner WWF, 2012. This over-consumption puts the survival of our way of life at risk, and in order to avoid the worst consequences changes must be made Meadows, Randers, and Meadows, 2004. These could be the implementation of patterns that support sustainability.

3.1 METHODOLOGY

The methodology used in this chapter is the same used in chapter 2, which is the methodology applied by Rouhani et al. (2015). Compared to Chapter 2, there are some differences: the main one being the scope of the review, previously the full text of articles was used in the query in this SLR only the Title, Abstract and Keywords were used. Another important change was the omission of the backward-forward citation analysis steps.

3.1.1 Design Phase

The RQ to be answered is *"What characteristics of sustainability are relevant for EA?*. In order to answer this RQ a sub-question arises *"What characteristics of sustainability applicable to organizations are there?"*.

The keywords to be used in the query are: "characteristics of sustainability" or "characteristics of circular economy" or "characteristics of sustainable business" or "sustainability characteristics" or "circular economy characteristics" or "sustainable business characteristics". The keywords are composed of characteristics, which are the main focus of this SLR, and both sustainable business and circular economy which reflect the focus of EA, organizations.

As described by the methodology followed (Rouhani et al., 2015), the sample will be filtered using inclusion and exclusion criteria. The inclusion criteria selected are:

- Peer-reviewed papers published in journals, conference proceedings, book chapters and books
- Written in English
- studies that present characteristics of sustainability in organizations

The exclusion criteria to be used are:

- Short works, e.g. posters
- Duplicated work, unifying under the database with most results
- non-studies, e.g. Introductory texts to conference proceedings
- Studies without a DOI registry
- Studies focusing on chemistry, building techniques, healthcare techniques, agricultural techniques, pedagogy techniques, Biomedical engineering, Urban design, consumer perceptions, governance

3.1.2 Execution Phase

In this phase the process and results of the execution phase of this SLR is explained. As defined during the design phase, the steps were followed and criteria defined were applied. First, a description of the results of the query is shown. Second, the form used to extract the useful information of the studies is described.

Query

As shown in table 3.1 the results of the query produce a total of 1012 non-unique items. After removing duplicates the sample is reduced to 837 studies. These were then filtered by reading their titles and applying the exclusion criteria, resulting in 142 studies. These were filtered further based on their abstracts, resulting in a final sample of 9 studies.

Table 3.1: Results of query

Database	**# of results**
Scopus	168
The ACM Guide to Computing Literature	6
IEEE Xplore	10
Science Direct	192
Springer Link	357
Taylor and Francis	159
Web of Science	120
TOTAL	1012

In order to extract the information necessary to answer the RQ the information shown in table 3.2 was extracted from each study. Afterwards from each study the characteristics were extracted using the form shown in table 3.3.

3.2 RESULTS

After selecting the final sample of studies the characteristics of sustainability were extracted using the forms. This resulted in 209 Characteristics across the nine studies found, the complete list of characteristics and their description can be found in Appendix D. The final sample these were extracted from are shown in table 3.4. As can be seen in the table, the studies found are recent, the oldest was published in 2011, but all others were published after 2015. The studies in the sample are (77%) journal articles and conference proceedings, the first being the majority (77%).

Table 3.2: Data extraction form - Sustainability study

No.	Extracted Data	Description
1	ID	An identification
2	Bibliographic information	Information on the Authors, year of publication, medium of publication and any publication ID (DOI, ISSBN, etc)
3	Type of document	Journal, Conference proceedings, published book, Lecture Notes, dissertation
4	Research method used	No method, case study, survey, interviews, experiment, literature review

Table 3.3: Data extraction form - Sustainability Characteristic

No	Extracted information	Description
1	ID	An identification
2	Source	The source's identification
3	Name	Name of the characteristic
4	Description	Short description based on the text

Table 3.4: Final Samples of Sustainability Studies

ID	Item Type	Publication Year	Characteristics	Research Method
S1	book Section	2020	22	Literature Review
S2	journal Article	2016	28	Literature Review
S3	journal Article	2018	26	Literature Review
S4	journal Article	2017	48	Case study
S5	journal Article	2015	18	Loose grounded theory-based inspection of corporate sustainability reports
S6	book Section	2016	15	Literature Review
S7	journal Article	2018	29	Literature Review
S8	journal Article	2011	12	Action research
S9	journal Article	2019	11	Case study

Also in table 3.4 the number of Characteristics per source is shown. The source with the most Characteristics is S4 from 2018, and least is S9 with 11. In this table

the research method employed is also shown, where 55% of the studies used a Literature Review to form the basis of the Characteristics. The remaining 45% were a mix of case studies, action research and inspection of corporate sustainability reports.

3.3 DISCUSSION

In this section the RQ, *"What characteristics of sustainability are relevant for EA?*, is answered. First a classification of the characteristics found is offered. The resulting classes are then compared to concepts of the Archimate language, in order to identify how feasible it is for an architect to express the characteristics of sustainability. From this comparison the final set of classes as well as their descriptions and constraints is produced, which will serve as input for Chapter 4.

3.3.1 Classification of Characteristics

In order to better analyze, and apply, the set of characteristics shown above, they are classified. To do so, the classification used by S2 is taken as a basis, which uses an extended version of the BMC. The changes introduced in S2 are two new components: Take-back systems and Adoption factors. Where the former describes the mechanisms needed for some sustainable organizations that need to recall products, e.g. for maintenance or replacement. The latter describes factors that can not be attributed to any of the other components, mostly related to capabilities of the organization. These, and all other classes, are explained in further detail below.

The new building block, *take-back systems*, is in it is core a combination of Customer Channels and Customer Relations but in a reverse direction. It describes, for example, how an organization manages the end of life of their products. In order to maintain the BMC succinct, the take-back building block will be fused together with Customer Channel and Customer Relations.

In Figure 3.1 the Canvas as shown in S2 is presented. Here the authors show all the classes, as well as how they fit together.

Customer Segments

This class defines the groups of people (and organizations) the business in question aims to serve. The grouping varies between cases, practitioners may use geographical barriers, demographics, among other attributes to describe what constitutes a group of customers (Osterwalder & Pigneur, 2010).

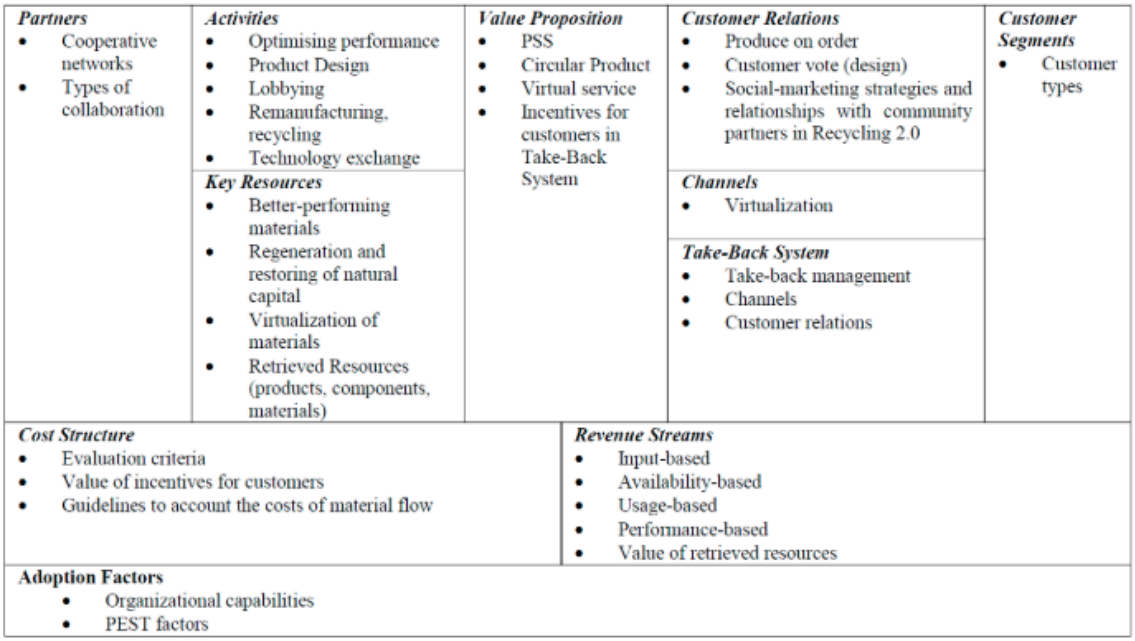

Figure 3.1: Extended Canvas - Figure 3 in S2

In this SLR there are few characteristics found that are attributed to this class, one is environmentally aware customers for example. It could be argued that environmentally aware customers is a segment made of innovators and early adopter, the first two segments to adopt new services (Rogers, 2003).

Customer Relations

This class describes how the organization relates with their customers. This could range from personal to automated (Osterwalder & Pigneur, 2010).

In this SLR the characteristics found to belong to this class all focus on the relationship between the organization and their customer. Among them there are some focusing on the co-creation of the value proposition, this could be including customers in the product design phases for example (C31, C32, C77). Some others focus on broadening the concept to include relationships with the community (C8, C110, C111, C112), which reflects one of the pillars of sustainability, the society the organization embeds itself in (P21) (Geissdoerfer et al., 2018).

Also found in this building block are those characteristics that used to belong to the take-back systems building block, and characteristics describing how an organization might relate to a customer regarding the return of goods to the organization (C27, C49).

Channels

This class defines how the organization communicates with the customer to deliver on its value proposition. Focusing on communication, distribution, sales, and any other point of touch with the customer, as such its closely related to the value proposition, the customer relation and the customer segments (Osterwalder & Pigneur, 2010).

In this SLR, the characteristics found to belong to this class focus mainly on digital communications (C3, C28, C29, C30). And, as mentioned before the building block focusing on how the organization manages the reverse channels (C47, C48).

Value Proposition

This class describes the product or service the organization is offering its customers. By solving a need or problem of the customer (Osterwalder & Pigneur, 2010).

Among the characteristics found to belong to this class there are some that focus on defining the product or service, e.g. C25 describes virtualized services (C23, C24, C25, C79). Others focus on how the product is designed, referencing that the choices made during this process include sustainability metrics (C145, C159, C160, C161, C162, C163, C164, C165). Then there are those that describe attributes the products should have for sustainability, for example *easy to recycle or reuse* (C101, C102, C115, C79, C80, C92, C93, C94, C132)

Key Activities

This class describes the most important actions an organization must perform to actually function. These are required to produce the value proposition, maintain the customer relations, operate the channels (and in this case, take-back system) and so on (Osterwalder & Pigneur, 2010).

The characteristics found to belong to this class vary in many ways. An example of characteristics are those focusing on the implementation of agile practices, process re-engineering (C194, C41, C65, C124, C147, among others). Another example is the automation of tasks using Information Systems (C117, C104, C105, C42). Many others describe activities related directly to sustainability, e.g. harvesting rain water, conserving natural resources, and avoiding using slave labor (C126, C128, C131, C204, C152, C151)

Key Resources

This class describes the most important assets the organization needs in order to function. These are needed to create the value proposition, maintain the relation-

ships, access channels and so on (Osterwalder & Pigneur, 2010).

In the same way as the Key Activities, the Key Resources vary in many ways, but refer roughly to the following ideas. Some refer to the IT systems for communication, Business Process Management, multimedia, among other uses (C120, C121, C122, C199...). Others refer to the sustainability of the inputs of the organization, using biomaterials and waste (C200, C15). In a similar vein, some characteristics refer to the use of better insulated spaces, using natural light, using water efficient appliances, using solar panels, among others ;all to diminish energy consumption (C55, C127, C206, C207, C205, C208, C209)

Key Partnerships

This class describes the networks of suppliers, providers, and other partners the organization needs to work (Osterwalder & Pigneur, 2010).

The characteristics found to belong to this class do not focus on the partners so much as focus on the relationship the organization maintains with them. For example some characteristics focus on coordination along the supply chain and adopting Supply Chain Management practices (C72, C114, C116, C119, C130, C192, C138, C85, C16). Others focus on the selection of these partners, describing that organizations must choose suppliers and partners that are efficient, that would reduce waste in the entire chain, that ensure dignified working conditions for their employees (C133, C134, C54, C58, C66, C72).

It could be argued that these are not Key Partnerships, but Key Activities. Some of these characteristics were assigned to this class either by the original authors of their respective sources. The others were assigned by the author of this work, due to the specific focus of the characteristic on external actors. It could also be mentioned that the relationship with the community and local governments could be associated with this class, however this is not the case for this study.

Revenue Streams

This class describes the revenue the organization generates from each customer segment after providing them with the value proposition (Osterwalder & Pigneur, 2010).

The characteristics found to belong to this class are mainly those that define new ways of generating revenue stream, or that affect the stream in some way. For the former, examples include the revenue generated from providing a product as if it were a service, engaging in the circular economy, and achieving funding from other actors (C33, C34, C35, C67). The latter includes characteristics describing reducing time to market, avoiding waste, optimizing supply chain, etc (C18, C20, C17, C19).

It could be argued that the latter is better suited as Costs, since they are not describing new revenue but diminishing costs.

Cost Structure

This class describes all the costs incurred by the organization (Osterwalder & Pigneur, 2010).

The characteristics found to belong to this class are divided in two. The first are those that focus on the costs of production and sourcing green materials (C21, C22, C46, C86, C87, C88). The second are those that focus on the wastes of the organization, e.g. the emissions it generates and physical wastes, like paper or (C95, C155, C156, C53, C68, C69). The latter also includes characteristics describing the use of triple bottom line practices, where the accounting of the organization also includes environmental and social costs (C196, C175, C178).

Adoption Factors

This class is proposed by S2, based on their research were the adoption and implementation of sustainable business models hinges on certain capabilities of the organization. These capabilities are difficult to include in the classes above, e.g. the capacity of the human capital of the organization to adopt any of the other characteristics. An example are the characteristics focusing on learning at an organizational level, as well as educating the community its embedded in (C52, C74, C75, C107, C136, C189). Another example are the characteristics describing the awareness of the organization, the knowledge the organization already has on sustainability (C144, C76, C71, C50). Lastly there are characteristics describing the organization's management and how they conduct business, e.g. the flexibility of the organization to change how they operate and implement any of the characteristics; and explicitly including sustainability in business models (C193, C188, C189, C190, C146, C149, C153, C154, C123, C125, C84, C106, C70, C62, C63, C64)

3.3.2 Description

In Figure 3.2 each class and the total amount of characteristics found to belong to it are shown. Also shown is whether the classification comes from the source or from the author. It must be mentioned that the ratio of characteristics classified under the classes mentioned above by the source, when compared to the ones classified by the author, are 58:151. Where the classification of adoption factors and cost structures have 33% of all characteristics, most assigned by the author. This is due to many of the other studies referring to some of the following ideas: management

participating in activities, or having capabilities, that would catalyze the adoption of sustainable practices; management including the needs of stakeholders beyond the customer; business flexibility, or the ability to change. On the cost class, many sources describe the organizations waste water, physical waste, emissions, and end of life of products of organizations.

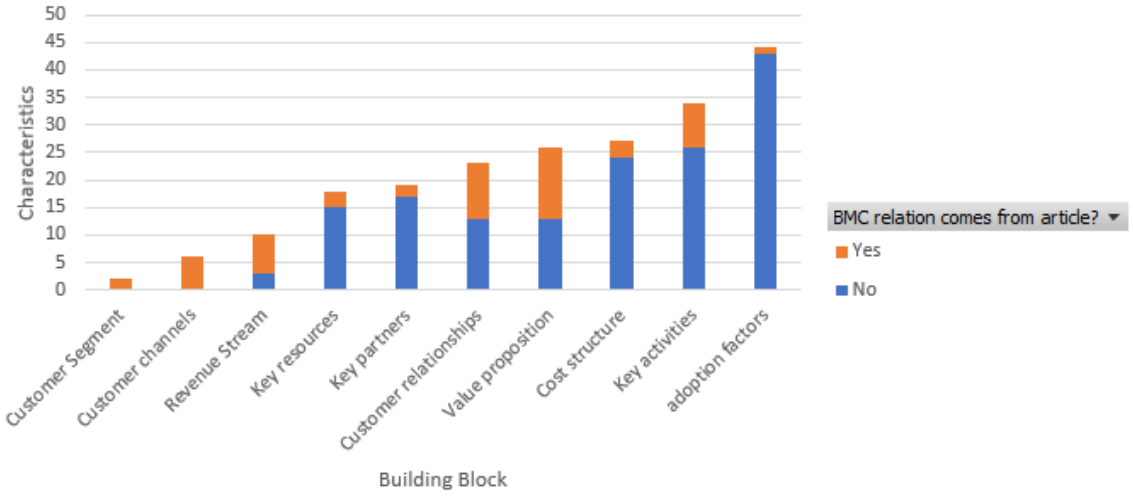

Figure 3.2: Characteristics classified

3.3.3 Applicable characteristics

The following section relates the characteristics with Archimate concepts, mainly through he use of their assigned classes. Previous research is identified and expanded.

Previous research has analyzed the BMC meta-model and mapped it into Archimate concepts (Iacob et al., 2012). They found that, as the BMC represents an entire organization in the most abstract terms, that the Archimate concepts each building block relates to are concentrated in the Strategy and Business layers. Although, thanks to the flexibility of the language, one can specify the Strategy layer's resource into lower layer's concepts, e.g. an application component. In table 3.5 the BMC building blocks, including the two extensions mentioned above, are shown. With an X the relationship studied by Iacob et al. (2012) is shown, and with a C the relationship proposed after reviewing the Sustainability Characteristics. The reasoning behind each assignment is explored below.

The adoption factors building block, as it's a new concept being introduced in S2, is not present in the previous studies (Iacob et al., 2012). As such these characteristics have not been related to Archimate concepts before, and had to be analyzed to find which layer's concepts relate. As most of these relate to intangible things, e.g.

Table 3.5: Relation between extended BMC and Archimate. X means relationship is defined by Iacob et al. (2012), C means it is proposed by this study

Class/Layer	Motivation	Strategy	Business	Application
Adoption factors	C			
Cost structure	X			
Customer channels		X	X	C
Customer relations	C	X	X	
Customer segment			X	
Key activities	C	X	C	
Key partners	C		X	C
Key resources	C	X	X	X
Revenue stream		X		
Value proposition	C	X	X	C

leadership creating strategies for reducing waste (C62, C63, C64), that describe how the organization should act then it is closely related with the Motivation layer concepts. In this layer the architect can represent the drivers of multiple stakeholders, as well as define constraints, goals, and value. With these concepts the characteristics found in this class can be built. However, it calls for a wide implementation of the motivation concepts to the more traditional layers (Business, Application and Technology).

The cost structure is found to be problematic within the concepts of Archimate, as there is no concept that ties directly. The language specification mentions that object attributes could be used for costs (The Open Group, 2019). Iacob et al. (2012) also faced difficulties when defining cost, they decided on using *negative* value. These obstacles are maintained in this study, as the concept is expanded to include environmental and social costs as part of the triple bottom line approach described by some characteristics (C175, C177, C178). A solution

As the Key Partnerships building block refers to the actors, organizations, and other parties the business has to partner with; then it had to be extended beyond the Iacob et al. Iacob et al. (2012) study. For this study, in order to avoid overloading the other building blocks, the characteristics assigned to Key partnerships goes beyond external parties. This extension is reflected with the addition of the motivation and application layers.

Along the verticals, it can be seen that two layers are added to multiple building blocks: Motivation and Application. The former reflects the characteristics that call for activities, or resources, to be included with a sustainability goal or constraint in mind, e.g. avoid using slave labor in the business processes (C152). The latter

reflects the characteristics that call for virtualization (C28, C42, C37, C25), digitalization or the implementation of IT in some way (C29, C3, C30, C6, C7, C117, C104, C105, C120, C121, C122, C199, C90).

The need to include motivation concepts is interesting in its own right, as it shows the limitation of the Archimate language to show the impacts or consequences of the objects. Which may be simple to assume under normal circumstances, the basic goals and constraints of what an organization does is to generate revenue and will generate a cost. While in sustainability the costs go beyond monetary and have to include every impact the organization produces on the environment and society. This change may call for an extension of the language, or for EAPs to be written in a way that they include sustainability characteristics explicitly.

Chapter 4

Enterprise Architecture Patterns supporting Sustainability characteristics

In this chapter the resulting EAPs found in Chapter 2 are related to the characteristics found in Chapter 3. Each relationship is proposed based on the classification done in the previous chapters, as well as the description of both Pattern and Characteristic. With the goal of helping organizations propose target architectures that implement some characteristics of Sustainability. As such, the need for knowing which EAPs are able to support these characteristics arises. By identifying the relationships between Patterns and sustainability characteristics one could then classify the patterns that are of value to an organization that wants to transform into a more sustainable business. This classification also helps when deciding which EAPs to use during the specification of an architecture.

In order to make this analysis simpler to perform, and due to the extent of the EAPs found in Chapter 2 it was decided to apply a filter in order to simplify this process. The patterns excluded are those found to add no value to the analysis whatsoever. As such the following lists encompasses the exclusions, which would produce a set of 432 EAP:

- Patterns found in source P24, from the BPM field, due to their smaller scope. This sources include, for example, Patterns like Pattern242 that describes the sequential execution of tasks in a process. This could certainly be found in Patterns found in the Sustainable Business Patterns found in P2, and by extension, are also Sustainable.

- Patterns found in sources P9, P10, P15 and P19. These sources focus on EAM, and as described in Chapter 2 describe how to implement an EA area in an organization. Due to not finding any Characteristic in Chapter 3 that focuses

on EA then these would not correlate with any.

- Patterns found in P4. This source described EAPs related to line members solving problems, these patterns are needed in most other EAPs

4.1 METHODOLOGY

The methodology followed in order to what characteristics are supported by each EAP is simple. By evaluating the name, description and field of origin of the EAP the author classifies which characteristics apply. However, the sheer magnitude of the task would take too long for the scope of this study, as it meant 428 EAPs and 209 characteristics, which an exhaustive process would mean a matrix of 59064 items. Instead the classes used in chapter 3 will be used. These are shown in Figure 3.1, and are: Adotion factors, Cost structure, Customer channels, Customer relations, Customer segment, Key activities, Key partners, Key resources, Revenue stream, and Value proposition.

4.2 RESULTS

The result is a set of 191 EAPs that support 1 to 6 different classes of characteristics. In figure 4.1 The distribution of the amount of themes a specific EAP supports, and how many do so. This figure shows that the majority of EAPs support only 1 Characteristic, while 4 support 5 of them, and two of them support 6 classes. This means that supporting multiple classes of characteristics from just one solution is less common. The complete list of the classified EAPs, and which classes it supports can be found in Appendix E.

On figure 4.2 the detailed field of origin of the EAPs and their quantity is shown, along with how many characteristics are supported by them. Here it can be seen, following the same findings as shown in Chapter 2 the majority of EAPs come from Business Model Innovation, even after the specific patterns regarding sustainable business development or circular economy were divided.

On figure 4.3 each of the classes of characteristics and how many EAPs support them are shown. The main class, with 84 patterns, is Key resources. With all other classes having less than 55 patterns. It must be mentioned that each EAP can support more than one theme, as seen in 4.1.

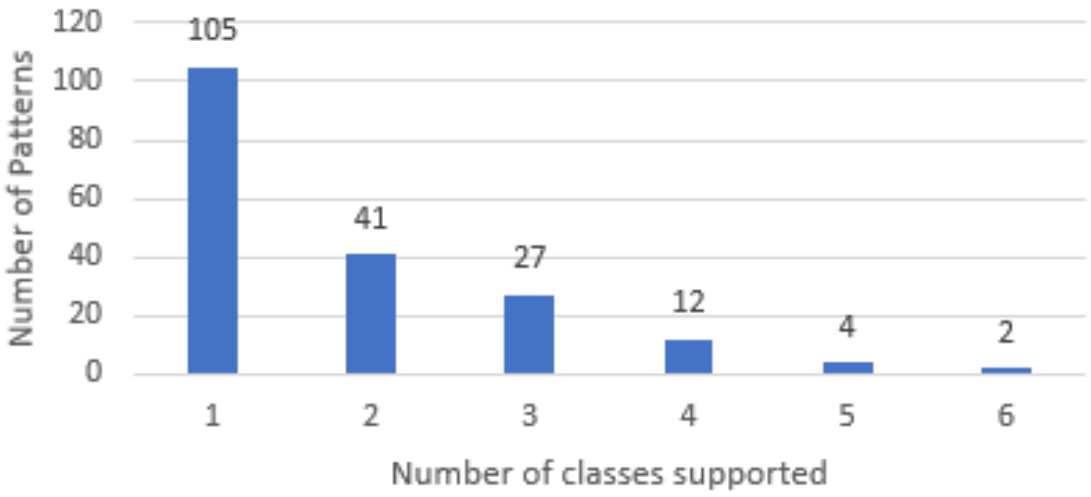

Figure 4.1: Distribution of EAPs supporting characteristics

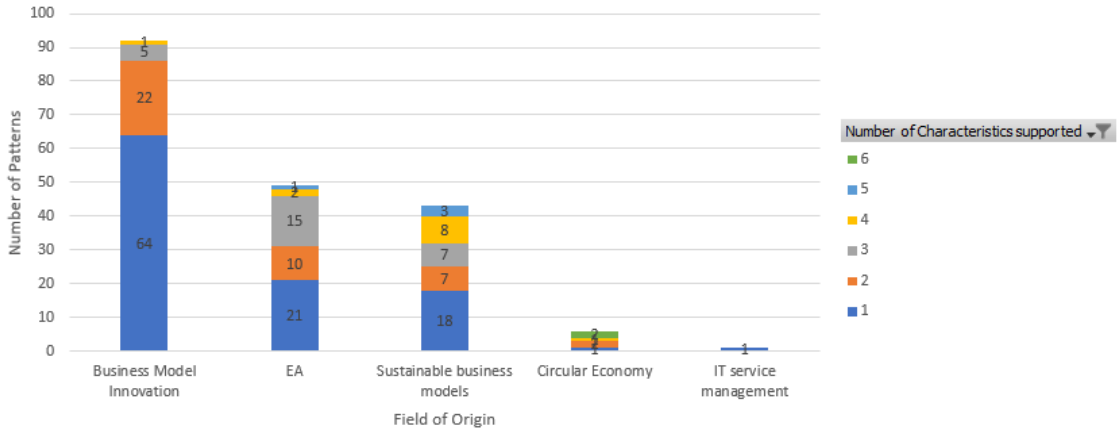

Figure 4.2: Fields of origin and number of EAPs

4.3 DISCUSSION

The result of this chapter is a matrix of EAPs supporting themes among SD characteristics. However it must be said that this classification has been performed to the best of the author's abilities. As such, it is limited both by its scope, and by the previous chapters.

In alignment with the findings of Chapter 2, the patterns for Business Models are the majority of the patterns supporting sustainability characteristics, as shown in Figure 4.2. This was to be expected due to two aspects. First, thanks to the sheer number of patterns present in the sample, as shown in Appendix B, it was highly probable that the patterns found in this chapter would be skewed towards the Business Model ones. Second, some of the sources in the sample used in Chapter 2 were already focusing on sustainable businesses. As it's unlikely that an

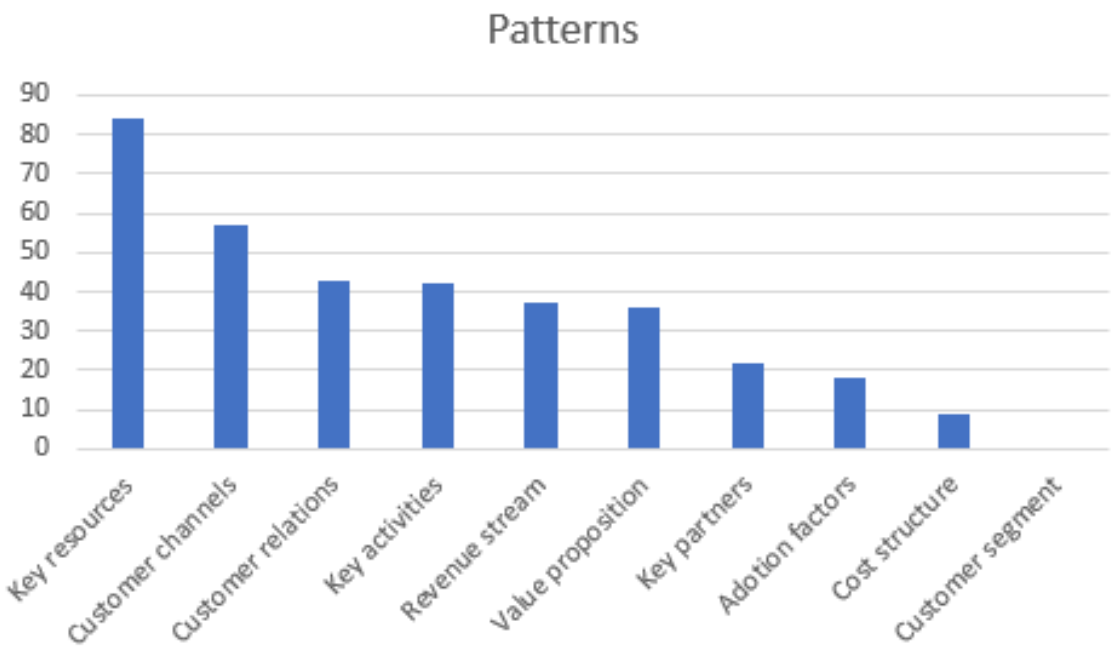

Figure 4.3: Themes and number of EAPs

organization implements many Business Models, then the set of patterns that can be implemented in any organization is 93. However, this number excludes all EAPs that could be of great use to a sustainable organization but do not support sustainability by itself.

Some of the other EAPs found in the Chapter 2 were of special interest, a subset of can serve as building blocks inside the EAPs supporting sustainability. Some clear examples are the patterns presented in P24, where their level of abstraction make them easily applicable as components of other patterns. patterns may build on top of other patterns as they become more abstract or complex, this is explored in Chapter 2, and specifically in studies like P14. An example is Pattern012, which describes an IT infrastructure pattern of a fail-over cluster to increase the availability of applications. Such an example could be used to build others, like Pattern059 describing an Business Model of a digital service provider.

Dependencies between patterns could prove useful for the future, as it facilitates understanding and navigation. Being able to easily go top-down perusing patterns as they become more concrete and focused would make them easier to use. It would also offer an approach to extending the knowledge base of EAPs as it offers building blocks with which architects can build new patterns. It could also give way to a simpler way of using them. It is also upon this idea that the next Chapter of this work builds.

The 210 characteristics found in Chapter 3 were classified along the building blocks of an extended BMC, and these classes were in turn compared to the Archi-

mate layers needed to express them. Among this comparison it was found that the Adoption factors and Cost structure would need objects from the Motivation layer only. The patterns that were classified as supporting of these classes were done so because they were Sustainable Business Model patterns, which share most of the constructs used in Chapter 3. However, these classes were found to be unsupported by any of the other EAPs, signalling the need for an expansion of patterns with the sustainability goals, drivers, constraints, and other constructs.

4.3.1 Limitations

The biggest limitation to this chapter is that due to the scope of the study there is no opportunity for repeating the process with more researchers. Another limitation is the inputs of this study, mainly the EAPs and the characteristics of sustainability. However, this is true for most research in the world, where their quality depends heavily on the cited research.

Chapter 5

A methodology for the specification of EA in sustainable organizations

In this Chapter a methodology is proposed, which enables sustainable organizations to prepare the specification of their EA using patterns. The methodology is then showcased within a case study. In order to do so, the previous chapters have provided a definition and initial list of EAPs; the characteristics of sustainable businesses; and the list of EAPs that support those characteristics.

5.1 PREPARATION

Based on the results of the previous Chapters there are some activities needed. First is the translation of some EAPs to the Archimate language. Many of the patterns found in Chapter 2 are not present in this representation, and those that are, need to be transcribed from the source to the modelling tool used in this study. Second, some new EAPs are proposed, with the goal to expand the set of patterns found previously. Third, new sustainable patterns are proposed, with the aim to expand the set of patterns in this aspect.

5.1.1 Translating the subset of Patterns to Archimate

As mentioned before, some EAPs are translated, the rationale behind the selection of each pattern is explained in section Chapter 6. First, Pattern108 and Pattern116 are already presented in Archimate, but none of the others were. Some others were already described using other modelling languages, these were translated by the author concentrating on being as close as the source as possible. All other patterns had to be drawn based on their description, this was done by the author at the best of his abilities.

The resulting diagrams can be accessed in Appendix F. There, both the source file and extracted images are present. In Figure 5.1 an example of one of the translated EAPs is shown.

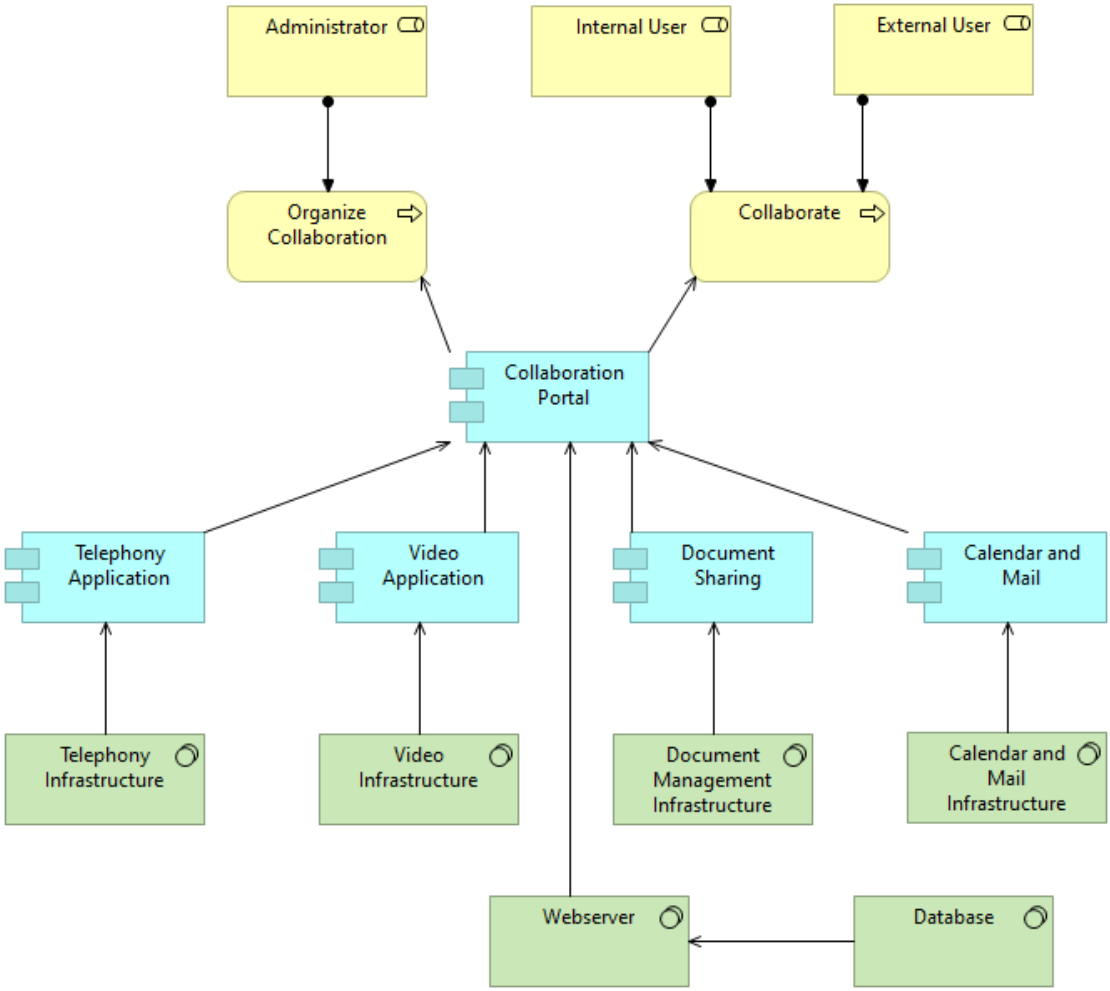

Figure 5.1: Pattern168 - Holistic View in Archimate

5.1.2 Proposing New Patterns

After performing the translation, some gaps were identified and in some of the EAPs the applications are deployed to nodes in the internal facilities of the organization. However, as is shown in the Characteristics found in Chapter 3, sharing and virtualization is a characteristic of sustainable businesses, and the currently best representation of this are Cloud Services.

With this gap in mind, three new EAPs are proposed: NewPattern001, NewPattern002, and NewPattern003. Representing the use of a Software as a Service (SaaS), Platform as a Service (PaaS), and Infrastructure as a Service (IaaS) service

respectively. These were built using the guidance established by Nardi et al. (2016). In Figure 5.2 the NewPattern001 is shown, the other two follow the same structure. Under Appendix G the diagrams and source files of these EAPs can be found.

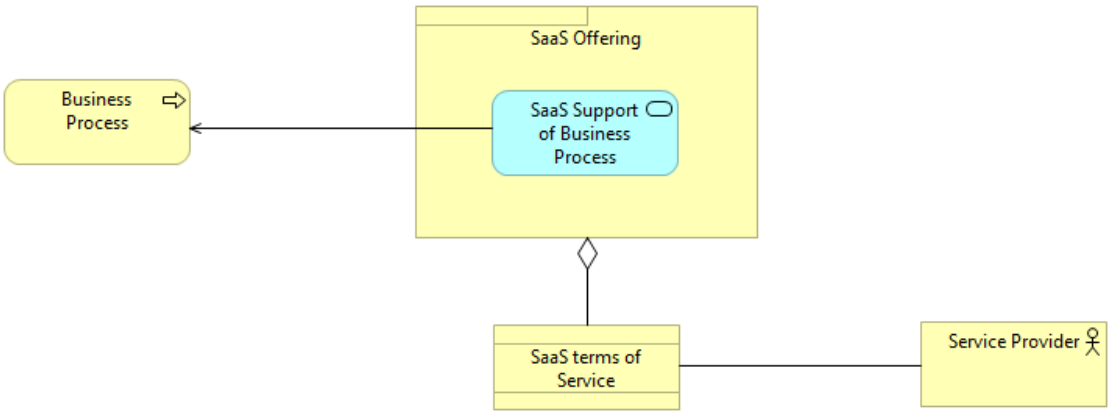

Figure 5.2: NewPattern001

As described in Chapter 3 and Chapter 4, most of the sustainability characteristics found refer to the motivation layer concepts of Archimate, and the only EAPs including them are of the SBM field. Because it's uncommon for organizations to implement multiple Business Models at the same time, the need arises for more EAPs that better implement the characteristics. To remedy this, in Figure 5.3 NewPatter004: sustainable supply chain is shown. Developed under Pattern174: FromSupplierToCustomer, as an extension. It shows the Motivation layer concepts to describe some of the characteristics found in Chapter 3. The characteristics implemented are shown in Table 5.1.

5.1.3 Proposing sustainable patterns

Following the findings of Chapter 4 and section 5.1.2 the need arises for another set of patterns. Patterns that describe the characteristics of sustainability that an organization wants to implement.

In order to be applicable in a large range of settings, an approach similar to P12 is taken. Here the different characteristics resulting from 3 as they were compared to Archimate concepts in table 3.5 are used as a basis. In terms of Archimate, the scope of these patterns is limited to the Business and Application layers of the organization for this exercise. In terms of sustainability, the scope is defined by the characteristics that can apply to the layers mentioned: Customer channels, Customer relations, Key activities, Key resources, Key partners and value proposition. From these building blocks, and within the scope, some sustainable patterns are proposed. These were catalogued in the Appendix G.

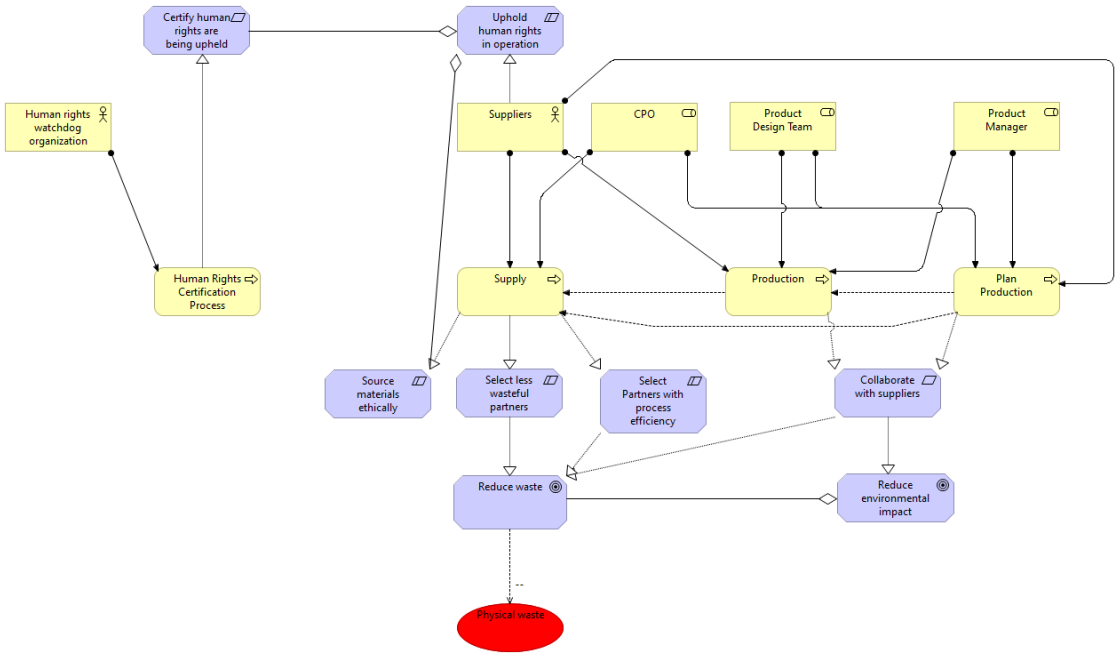

Figure 5.3: NewPattern004

The resulting patterns use Archimate concepts from the layers described in Chapter 3. With the exception of Key partners which does not include application layer concepts. Instead, the characteristics describe business concepts with certain requirements, however it's arguably impossible to fulfill the requirements and constraints of the characteristics without application support.

After developing the patterns it was clear that within the scope of some of the building blocks there were separate groups of object. The building blocks where this is seen are Customer channels, Key activities and Key resources. All other blocks were able to be described as one coherent pattern. These groupings are explained as follows.

The patterns describing customer channels may be divided into two: one focusing on customer as the buyer of the value proposition; and another focusing on the relationship with other stakeholders like government.

The patterns describing Key activities may be split in six groups. First, a group detailing the requirements the waste management process must follow. Second, the requirements related to the implementation of new capabilities. Third, activities and requirements related to product design and the production activities. Fourth, a group that applies to any activity. Fifth, the goal of being a sustainable organization and the principles that go with it. Sixth, requirements related to IT systems.

The patterns describing Key resources can be split into three. First, a group describing service centers. Second, a group describing IT resources. Third, a group describing production processes and buildings.

Table 5.1: Characteristics implemented by NewPattern004

Char.	Source	Description
C16	S1	Collaboration with material suppliers, logistic providers and other stakeholders to reduce environmental impacts.
C45	S2	choosing and cooperating with partners, along the value chain and supply chain, which support the circular economy
C54	S3	ethical sourcing of materials
C66	S3	selecting suppliers with standards in process efficiency
C72	S3	partnering with suppliers to reduce waste, emissions and ethical use of materials
C114	S4	Better coordination along supply chain
C118	S4	Involvement of suppliers in product development
C119	S4	Strategic network in SCM to exercise zero inventory system
C133	S5	responsible sourcing
C134	S5	working conditions of suppliers

Beyond divisions within each building block there were commonalities observed across the different building blocks. There were mainly two found, the product, its design and production; and IT aspects of the organization.

One of these sustainable patterns can be seen in Figure 5.4, where the characteristics for key activities focusing on products are implemented. These patterns can be reduced, i.e. some of the requirements and goals can be removed, when needed by architects. They serve organizations as they need to explicitly present their sustainability requirements for the future.

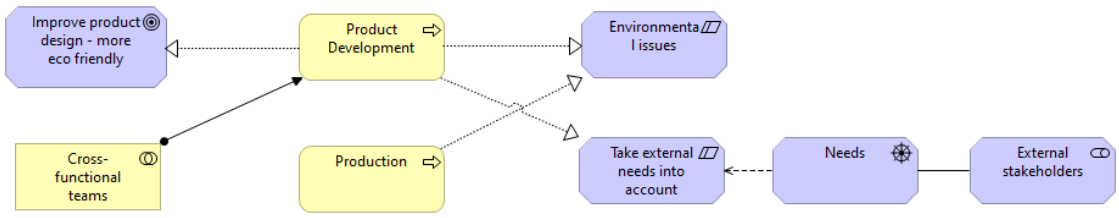

Figure 5.4: Key activities - product

5.2 METHODOLOGY

To avoid falling into the Yet Another Model trap, the proposed methodology is based on the ADM. A diagram showing the ADM's steps can be seen in Figure 5.5 (The Open Group, 2018). Focusing on the first phases: Preliminary phase, Phase A Architecture Vision, Phase B Business Architecture, Phase C Application Architecture and Phase B Technology Architecture. During an EA specification project each of these phases will be executed in sequence by a team of architects, where phases B,C and D focus on the description of the organization's future (or old) state. It is during these phases that the use of the Archimate language is concentrated.

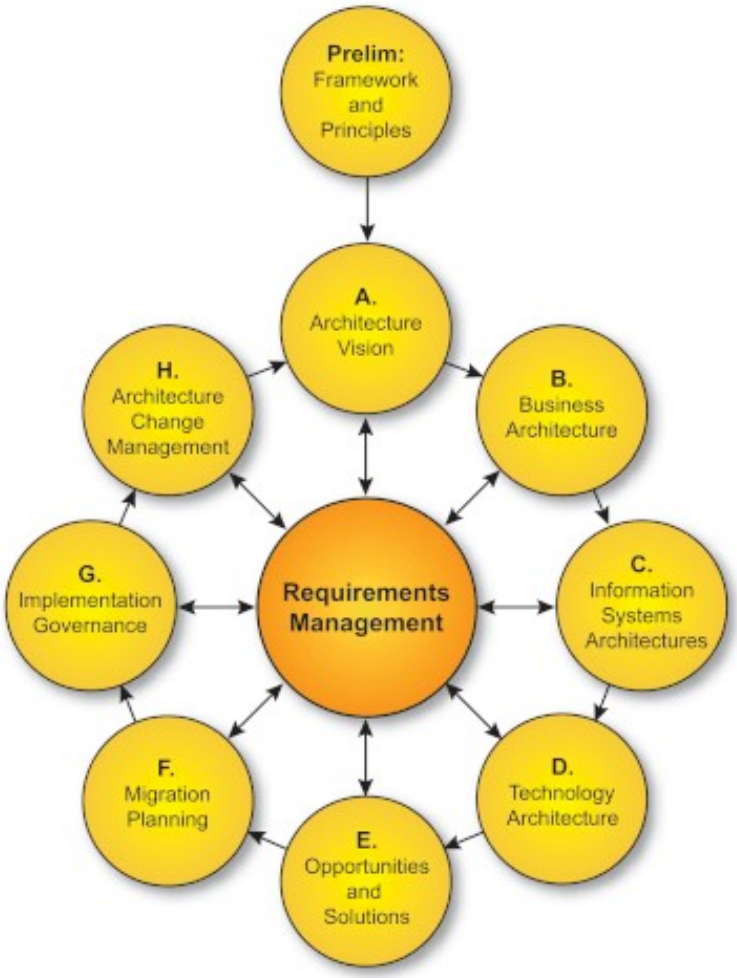

Figure 5.5: Architecture Development Method

5.2.1 Preparatory Phases

The proposed methodology assumes that the architect wishes to describe a future state of the organization that is sustainable. As such, the method starts with the preliminary Phase and Architecture Vision phases as shown in Figure 5.6. During these phases the focus will be on defining the main constraints of the EA. With the most important one being that the resulting organization must be sustainable. This constraint will frame all other tasks in the methodology.

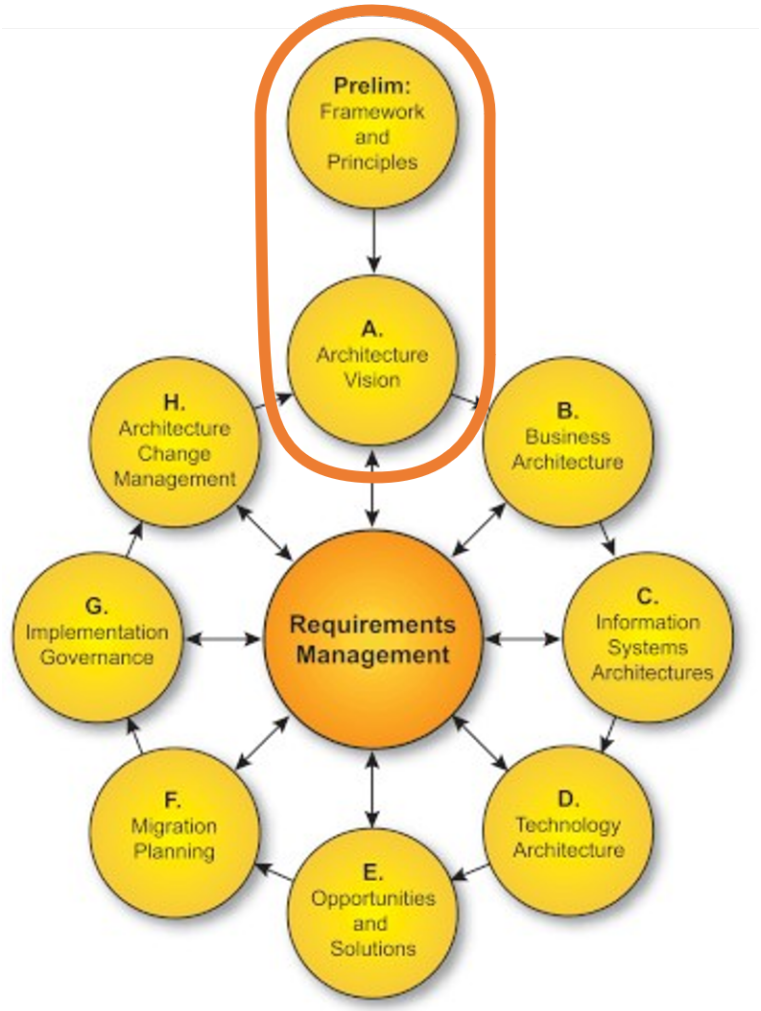

Figure 5.6: Architecture Development Method

In the same preliminary phase, a second constraint will be added, a guiding Pattern. In this method, the guiding pattern will serve as a general abstraction of the target's organization. Within the findings of this thesis, the authors find that an acceptable guiding pattern is a Business Model pattern in combination with an operational model pattern (as defined by P11).

Next is Phase A Architecture Vision, in which a subset of EAPs is selected. The constraints resulting from the previous phase introduce problems and questions as

is natural from their level of abstraction. E.g. a Business Model Pattern that calls for interactions with customers will introduce questions like: How will the customers be contacted? Who will do it? And so on. These questions and problems will feed a search for EAPs that may solve them. At this phase, the search is performed only to form a subset of EAPs with all possible solutions to problems, the constraint and guiding pattern pose. This is similar to the Palette artists have at hand while they're developing their works. In order for this selection to be within the context of sustainability, the classification performed in Chapter 4 is used, in conjunction with the patterns shown in section 5.1.

The detailed process of finding the problems and questions is similar to that of requirement elicitation. The precise nature of how these should be is outside the scope of this study, and is left to the experience of each architect when following the proposed method. However, it is an iterative process in two aspects. First, as the selection of EAPs introduce problems and questions of their own solutions for these in turn have to be included. Second, by nature of the layered approach of ADM, the architect must add patterns that solve the problems in the lower layers of each solution, i.e. in a manner of supporting pillars, Business Layer patterns will need Application Layer patterns to stand upon. The author's approach to this process is provided in Chapter 6.

5.2.2 Specification Phases

Following on comes the specification of the EA, through phases B, C, and D; as shown in Figure 5.7. These phases each focus on a different layer, on the Business Layer, the Application Layer and finally the Technology Layer. These layers will be built using the patterns in the selected subset, by selecting and combining them, thus producing the EA specification. The selection of each pattern will be based on its' compliance to the constraints defined in the previous Phase and each other, e.g. when presented with different EAPs in the subset that can solve a specific requirement, the one that can arguably support a more sustainable organization will be chosen. Multiple patterns can be selected to solve the same problem, in the same way that organizations may have their own retail stores and sell their goods in other stores at the same time.

During these phases EAPs have to be combined, this can happen in five ways. The exact way they can be combined depends on the architect, but there are some possibilities presented in section 5.3.

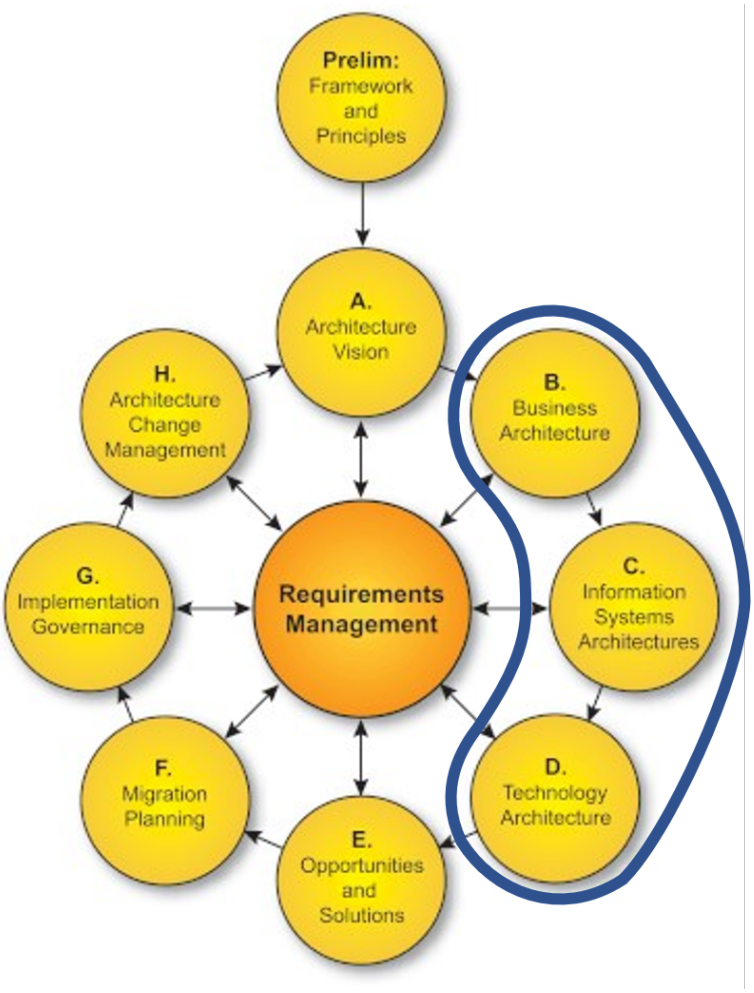

Figure 5.7: Architecture Development Method

5.3 TOOLS

In this section two tools that are valuable for the execution of the methodology are described.

5.3.1 Requirements

As part of the preliminary phases the requirements of the guiding pattern and the patterns added to the subset have to be found. This can be achieved using Archimate diagrams, as shown in Figure 5.8. By describing the patterns that are derived from pattern X and the patterns Y that fulfill it.

It is possible to document all the requirements that each pattern introduces, which would make the creation of the subset a matter of choosing the guiding pattern. The guiding pattern would have its' requirements previously defined, as well as those of all other patterns. Thus, creating the subset based on the relationships

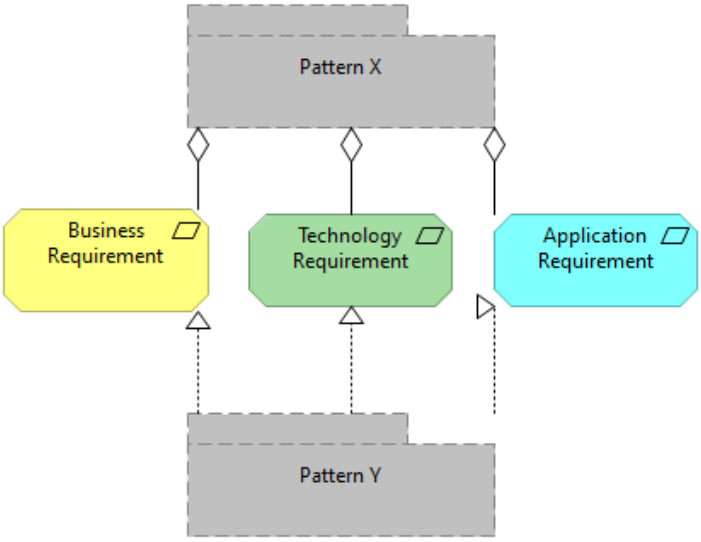

Figure 5.8: Requirements and Patterns

between patterns documented previously would be automated.

5.3.2 Combining Patterns

As previously stated in the specification phases, patterns have to be combined to form a final EA specification. During this study five ways of combining patterns were found. The first is a parallel combination, in which there is no relationship between the patterns.

The second way of combining patterns is shown between pattern X and Y in Figure 5.9. Here, a description of two patterns that are related with an association is shown. This is the most complex form of combination as it revolves around the contents in common between the patterns. These commonalities may be present in one or many objects, where the higher the overlap the more complex it is to combine them. An example would be combining patterns of supply chain and production, as they are closely related concepts.

The third way of combining patterns is shown in Figure 5.9 between pattern I and J. This combination happens mainly when pattern J is focused in a lower layer than pattern I. For example, a pattern showing how a business process is supported by applications. In this form of combination P12 defines exhaustively the ways concepts of the Business and Application layers can be combined with each other. However, such patterns do not exist between the application and technology layers. Between the business and the motivation and strategy layers there is also a lack of patterns, except for the sustainability patterns shown in section 5.1.3.

The fourth way of combining patterns is through the aggregation relationship.

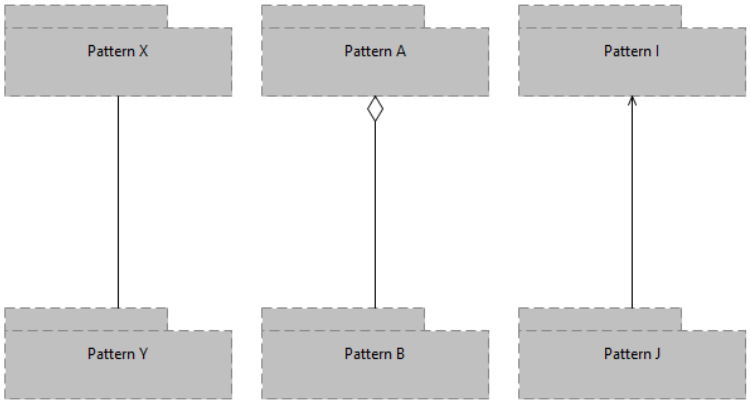

Figure 5.9: Patterns combined

This case is shown in Figure 5.9, between pattern A and pattern B. Here pattern B provides a narrower focus and higher level of detail to the ideas presented in pattern A. An example would be adding individual Business Functions to a more abstract pattern like a Business Model Pattern.

A final aspect of the combination of patterns is their decomposition. As shown in Figure 5.10. In some cases, EAPs describe multiple layers of EA, Business, Application and even Technology. Which is one of the findings of Chapter 2. However, due to the ways patterns can be combined with each other, and specially the way this happens between layers, an architect may decompose a pattern in its' layers. This would then give the architect freedom of building the lower layers as they please. This is shown in Figure 5.10, where Pattern Q is decomposed in its layers, and its sub-patterns for application and technology layers are exchanged for Pattern R. An example to this is Pattern173, which describes concepts from the Business, Application and Technology layers. In this pattern, an architect may take only the concepts of the business layer and the application needs, and replace the two lower layers.

Following the ways of representing patterns, and their relationships, one may model the specification in terms of the patterns and their relationships. This would offer a high abstraction view of the organization as defined by the solutions being re-used.

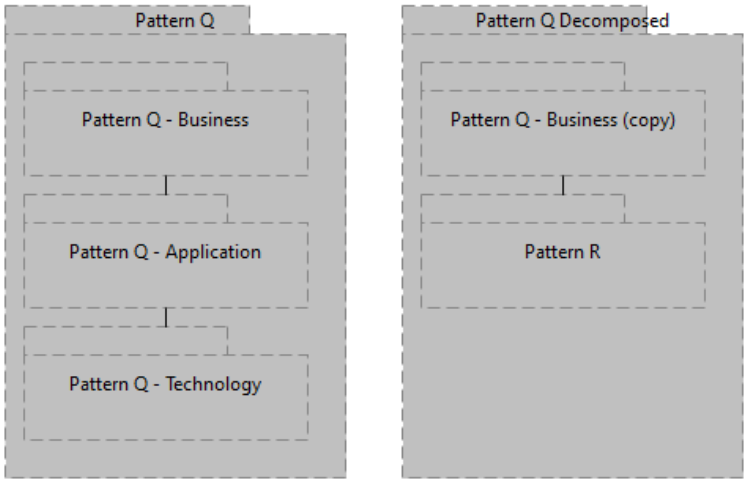

Figure 5.10: Patterns decomposed

Chapter 6

Case Study

6.1 CASE DESCRIPTION

In this section a case study is presented. Involving the sustainable transformation of a fictitious company. This case will serve as the backdrop for the application of the methodology described in Chapter 5.

6.1.1 The case

This case study involves the company *Sierra Nevada*, a manufacturer of kitchen utensils and appliances. With their Headquarters based in Amsterdam, they serve customers primarily in Europe, but have started investing to market their goods in the Middle East region. *Sierra Nevada* has a strong brand, as they have been part of households in Europe for decades, since their foundation in 1975. Throughout the years they have transformed themselves alongside their customer's needs.

Sierra Neavada has been able to strengthen their position with high quality products, which follows a move proposed by current CEO Marie Stigter. Her ability at delivering results has gained her the full support of the board. Which she has leveraged to gain approval for some modernization of their IT resources, and expansion into new regions.

Lately, Stigter has seen that the awareness of sustainability issues in their customers has been rising. Anecdotally, she sees more people close to her becoming vegetarians, preferring eco-friendly products, avoiding fast fashion goods and so on. She wants to make *Sierra Nevada* into a frontrunner for the industry in the sustainability aspects.

Introduction

The case focuses on the new strategy Stigter is presenting the board. She wants to improve upon the already aggressive social responsibility strategy the organization has. By going beyond incremental improvements, she wants to start from innovating the business model. This improved strategy is based on recent studies that show that investment into sustainable practices bring important returns when evaluated in a long-term view (Haefele, 2018; University of Cambridge Institute for Sustainability Leadership (CISL), 2016).

The board, emboldened by the surge in sales generated by the Corona Pandemic, where their number of users expanded thanks to the stay-at-home measures, and judging by Stigter's ability to deliver on promises, have accepted the strategy. Stigter was asked to take their smallest product line, home ovens and stoves, and implement the strategy there first as a large proof of concept.

The *Sierra Nevada* ovens are known for their quality. They've competed mainly with Philips in this market, and have been able to capture the cooking enthusiasts niche. However, the unit has been suffering decreasing sales due to the introduction of cheaper imported products, which has forced Philips to compete in the same niche with *Sierra Nevada*.

The products in this line are all designed by a small team of employees based in *Sierra Nevada*'s HQ in Amsterdam. The products are then manufactured in the main plant in rural Netherlands. As is expected, the production of current models need different suppliers for their parts: the electronic parts are supplied locally, metallic parts are supplied from Germany, Plastic parts are supplied from China. As for the packaging, logistics and sales channels *Sierra Nevada* uses local suppliers. Those are the suppliers the product line is currently using, but they can be changed due to business needs. The parts' specifications are derived from the product design, which then is used to negotiate on. Due to this, the current business model requires months of preparation, as the designs needs to be finished, then negotiations with suppliers must be done with the designs and need projections, suppliers must then execute their own processes to produce the parts and ship them.

Stigter has decided that the situation is prime for a bold proof of concept, but to do so inside an established organization is difficult. So she's decided to form a team of intrapreneurs to propose how such a thing would look like.

The Problem

Stigter's vision for this reborn product line is simple. Propose a way of doing business that is sustainable in every way possible. The new line would be offered initially only within the Netherlands.

Within this situation you're tasked to devise an Enterprise Architecture that describes Stigter's vision. Propose an architecture that has sustainability in its core, and along every facet of the organization.

6.1.2 The Approach

With the case at hand, a useful way to tackle the challenge is the methodology shown in Chapter 5. The execution of the method is shown below in section 6.2.

6.2 SOLUTION OF CASE STUDY

This section delves into the application of the methodology proposed in Chapter 5 to the solution of the case study described in section 6.1. This section is divided in the phases described by the method.

The scope of the specification will be focused on using the methodology and the patterns that have been gathered throughout this study, this means that there will be gaps as not all aspects of an organization can be described with the current set of EAPs. Another limitation is that for simplicity's sake, there will be no data structures described, only active structure and behavior concepts will be used.

6.2.1 Preliminary Phase

According to the ADM, besides the activities described in the proposed methodology, in the preliminary phase the Architecture capability needs to be established. Capabilities like the tools, languages, frameworks to be used, as well as the project members. For this case study the framework used will be TOGAF, implementing the ADM (The Open Group, 2018). The artifacts produced will be written in the Archimate modeling language (The Open Group, 2019), using the Archi modelling tool (Archi, 2012). Finally, the project team is composed by the author of this thesis, as lead architect of the team formed by Stigter.

As mentioned in the methodology, a *guiding pattern* needs to be selected, one describing a Business Model. The architect chose the Pattern001: *Repair and Maintenance* from P2 as the guiding pattern for *Sierra Nevada*'s reborn oven product line. There are two main arguments behind this choice. First, this Business Model Pattern describes how an organization makes the extension of the life-cycle of its products a priority, and describes how an organization might provide a Product-service system instead of ownership to the product. Second, but still related, Pattern001 is the pattern that supports the most characteristics of sustainable business, five.

In figure 6.1 the summary of the pattern is shown, as it is present in P2. The representation uses four main categories, each with two sub-categories: Value proposition, which divides into products and services; value delivery, which divides into target customers and value delivery process; value creation, which divides into partners and stakeholders and value creation process; and value capture, which divides into revenues and costs. Along these categories the EAP is defined as such:

- Services: Maintenance, repair and control
- Target Customer: cost-conscious customer; and B2B customer
- Value Delivery Process: providing product-based services and results
- Partners and Stakeholders: Manufacturers; and Service Providers
- Value Creation Process: Maintaining or repairing products, components
- Revenues: Payments for functions or results
- Costs: Labor; and repair, maintenance and control

BM Dimensions		CEBM design options								
Value proposition	Products	Repaired, refurbished, remanufactured, or recycled products	Reusable or recyclable products	Products based on recycled waste	Long-lasting products	Used products, components, materials, or waste as production inputs	Reusable or recyclable production inputs			
	Services	Facilitating collaboration	Take-back management	Customer education	Waste handling, processing	Product-/service-based functions	Maintenance, repair, control	Product-/service-based results	Upgrading	Auxiliary services
Value delivery	Target customers	Quality-conscious customers	Cost-conscious customers	Green customers	B2B customers	B2C suppliers	B2B suppliers	C2C suppliers		
	Value delivery processes	Connecting suppliers and customers	Providing access to a product's functionality	Providing (product-based) services and results	Providing used products, components, materials, or waste	Taking back used products, components, materials, or waste	Sharing products, components, materials, or waste			
Value creation	Partners and stakeholders	Suppliers	Manufacturers	Retailers	Service providers	Public institutions	Collectors of products, components, materials, waste	Others (e.g., researchers)		
	Value creation processes	Maintaining or repairing products, components	Refurbishing or remanufacturing products, components	Recycling of products, components, materials, waste	Upgrading or upcycling of products, components, materials, waste	Reselling products, components, materials, waste	Taking back or recapturing products, components, materials, waste	Winning back base materials	Using used products, components, materials, waste as input	Matching over- and under-capacities	Designing products, components, materials
Value capture	Revenues	Additional product revenues	Payments per unit of service	Payments for functions or results	Price premiums					
	Costs	Labor	Repair, maintenance, control	Waste handling, processing	Manufacturing	Resource inputs	Transportation, logistics	Supply risks		

Figure 6.1: Pattern001 - Figure 4 in P2

Besides the Business Model, an operating model has to be selected. Due to Stigter's directive of making this line the most sustainable possible, depending on the parent company for shared services is not an option. As such, in the scope of the case study a simple operating model is selected, which is represented in Pattern104: Basic Process Architecture Pattern. This pattern describes a simple operating model built of Business Processes, where the above is the description of

the Business Process 1 (i.e. the central value chain). Business Process 2 describes the collection of processes an organization must perform for the development of new capabilities, e.g. new products. Business Process 3 presents the business planning and general strategy needed for guiding the organization. Business Process 4 is a collection of supporting processes focused on managing specific resources, financial, human, infrastructure and materials.

6.2.2 Phase A: Architecture Vision

As mentioned in the methodology, Following the constraints and guiding patterns defined in 6.2.1, the Architecture Vision is developed. In order to do so the EAPs resulting from Chapter 2, and ranked on Chapter 4, will be used. From these a subset of patterns are to be chosen. This subset will serve as the palette from which the architecture team will build the specific Business, Application and Technology Architectures.

In order to identify the EAPs to include in the subset the focus will be on identifying requirements. Through these requirements the EAPs that **may** fulfill them are selected. First, by leveraging the constraints and guiding pattern defined in section 6.2.1, some requirements of the Business Architecture are found, thanks to which the EAPs that may fulfill them are then added to the subset. This discovery of requirements-EAP is performed again based on the contents of the subset, as these patterns selected introduce requirements of their own. This is then repeated for the Application Architecture and Technology Architecture.

In order to better organize this process, the next few subsections delve into the requirements on a layer by layer basis.

Business Architecture Vision

Within the Architecture Vision, this section focuses on defining the specific EAPs that may pertain to the Business Architecture. In order to do so, the guiding patterns, Pattern001 and Pattern104, define some Business requirements that have to be fulfilled in this. In figure 6.1 the pattern is shown, based on it some requirements can be derived, e.g. the business model requires human labor. It also *implies* other requirements, which are defined as follows:

- BR1: The organization must be able to manufacture a good
- BR2: The organization must be able to repair and maintain the goods it produces
- BR3: The organization must be able to monitor its goods

- BR4: The organization must be able to interface with customers to provide their goods
- BR5: The organization must be able to interface with other organizations to provide their goods
- BR6: The organization must be able to provide its customers with a repair or maintenance service
- BR7: The organization must be able to provide its customer with a service based on the goods it manufactures
- BR8: The organization must be able to gather payments on services provided
- BR9: The organization must be able to employ human labor for its activities
- BR10: The organization must be able to contract suppliers for the elements of their goods that they won't be manufacturing directly
- BR11: The organization must be able to contract services from outside firms if needed

These requirements are a rough description of the organization's value chain (Porter, 1998). And can be extended by applying the operating model concept, which Pattern104 introduces as a guiding pattern. The Business Processes it describes, are used to enhance the previous list of requirements:

- IBR1: The organization must be able to manage its financial resources
- IBR2: The organization must be able to manage its Human Resources
- IBR3: The organization must be able to manage its infrastructure, technological, office space, manufacturing space, among others
- IBR4: The organization must be able to manage its material resources
- IBR5: The organization must be able to market its service to its customers
- IBR6: The organization must be able to sell its service to its customers
- IBR7: The organization must be able to communicate with its customers
- IBR8: The organization must be able to generate a strategy
- IBR9: The organization must be able to design new products
- IBR10: The organization must be able to manage the execution of business processes

- IBR11: The organization must allow its members to work from home

From these requirements some relationships to the characteristics found in Chapter 3 can be drawn. Through the classification performed in Chapter 4, Pattern001 was found to support Adoption factors, Key partnerships, Revenue streams, take-back system and value proposition. This support can be seen already in the requirements elicited above:

- BR2: C101- value proposition
- BR3: C180- adoption factor
- BR6: C47, C48, C49- take-back systems
- BR7: C34- revenue stream
- BR10: C130- Key partnership

These supported characteristics can be enhanced further with the sustainable patterns proposed in section 5.1.3. And, following Stigter's goal of an organization as sustainable as possible, all the sustainable patterns are added to the subset.

In order to fulfill the requirements presented, the following patterns are chosen:

- Fulfilling IBR1 and BR8: Pattern171
- Fulfilling IBR2 and BR9: Pattern173
- Fulfilling IBR7 and BR5: Pattern153
- Fulfilling IBR6: Pattern169, Pattern141
- Fulfilling incompletely BR2: Pattern156
- Fulfilling IBR5: Pattern170, Pattern141
- Fulfilling incompletely IBR8: Pattern166
- Fulfilling BR4 and BR7: Pattern162
- Fulfilling BR10: Pattern174
- Fulfilling IBR10: Pattern159
- Fulfilling IBR11: Pattern168
- Patterns applicable to the relationship between Business layer and Application layer: Pattern108 and Pattern116

This selection means that IBR3, IBR4, IBR9, BR1, BR3, BR6 and BR11 have no Patterns fulfilling them.

In Figure 6.2 the requirements elicited so far have been presented in an easy-to-see diagram. Here the requirements that are derived from Pattern001 and Pattern104 can be differentiated in a single view. Furthermore, in Figures 6.3 and 6.4 these requirements are expanded, showing which Patterns may fulfill the requirements, where possible.

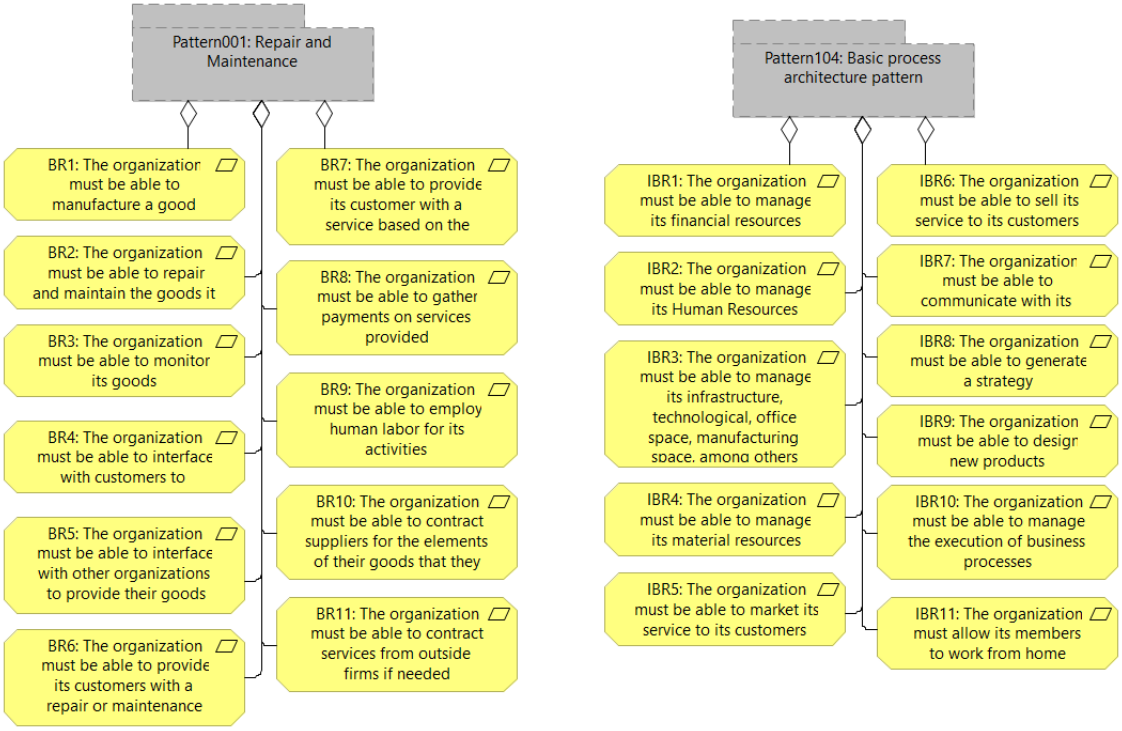

Figure 6.2: Business Architecture Vision Requirements

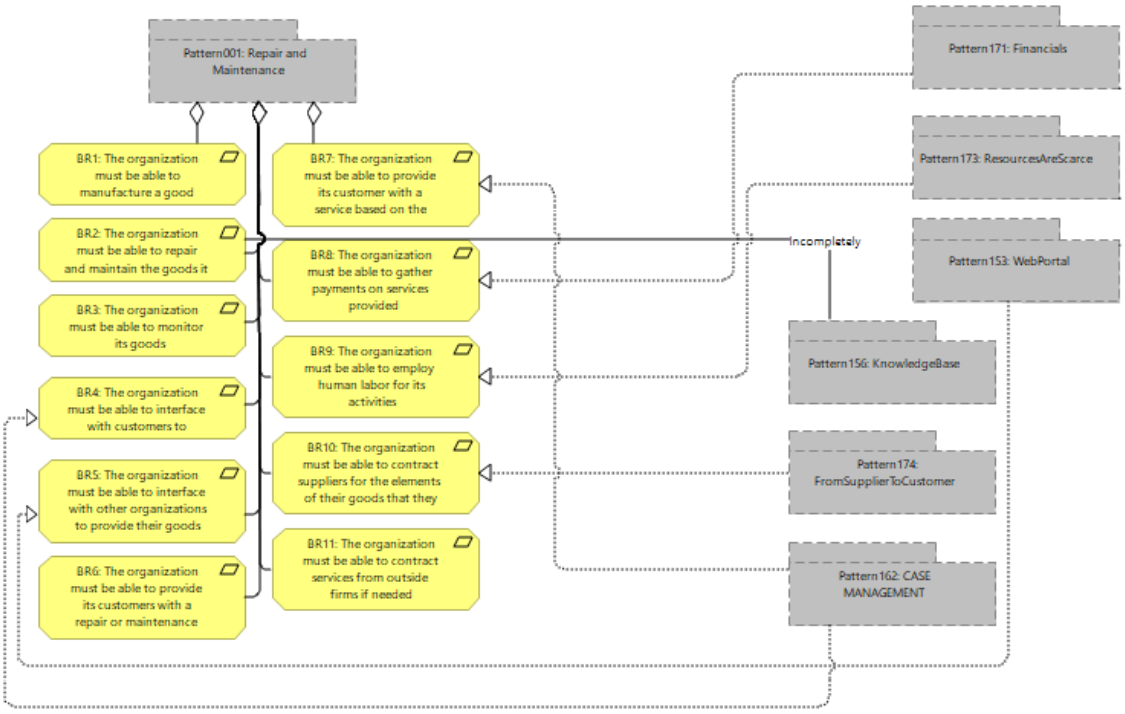

Figure 6.3: Business Architecture Vision - Pattern001 requirements

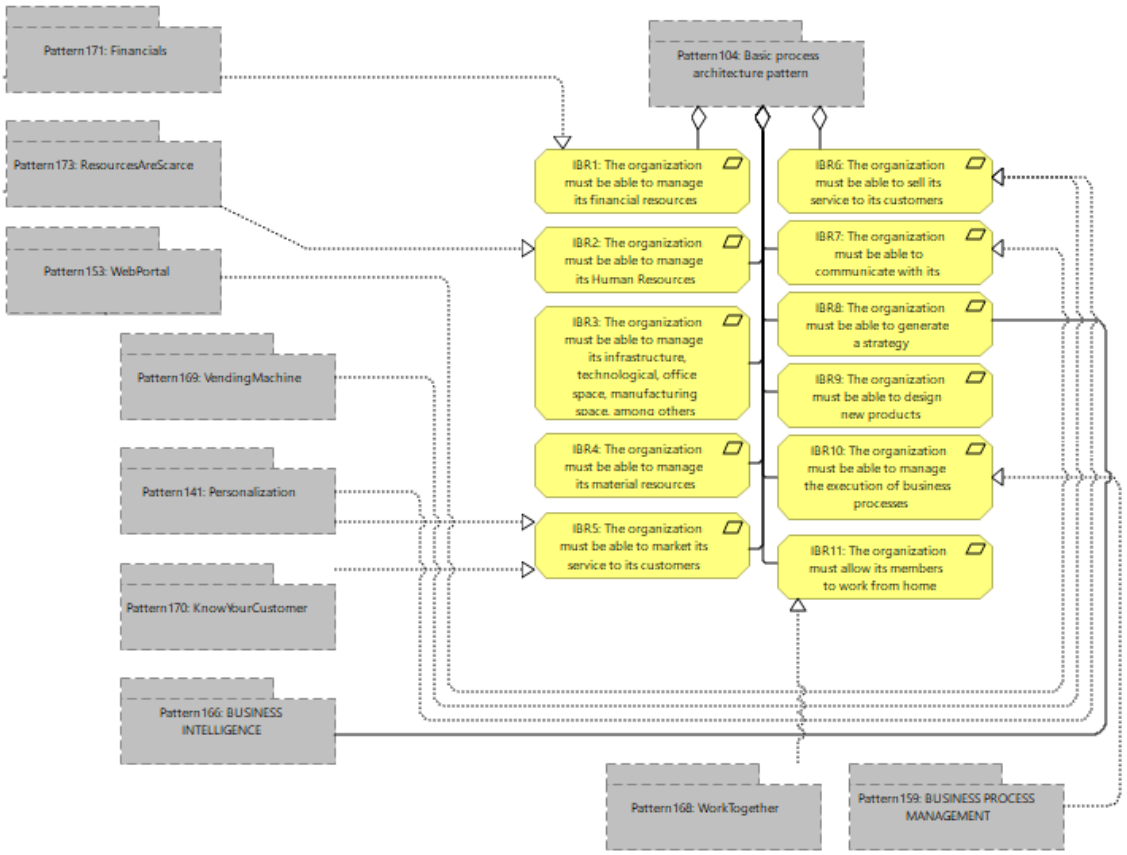

Figure 6.4: Business Architecture Vision - Pattern104 requirements

Information Systems Architecture Vision

Following the same approach as with the Business Architecture Vision, this section focuses on the Information Systems Architecture Vision, which is split into Data Architecture and Application Architecture, but as mentioned above this study avoids the data aspect. Similar to section 6.2.2, there are two kinds of requirements in this section. In this case its those that are derived from the Business Architecture results, and those that are derived from the characteristics of Sustainable Development. The following are those requirements derived from the Business Architecture:

- AR1: The organization must provide a web portal accessible to customers
- AR2: The organization must provide e-commerce capabilities through their web portal
- AR3: The organization must provide a way to monitor its goods' status
- AR4: The organization must provide its members with digital collaboration tools
- AR5: The organization must provide its members with an application to manage its financial resources
- AR6: The organization must provide its members with an application to manage its human resources
- AR7: The organization must provide its members with an application to manage its repair and maintenance cases
- AR8: The organization must must provide its members with an application to manage customer data and interactions
- AR9: The organization must provide its members with an application to manage its knowledge base needed for repairs and product development
- AR10: The organization must provide its members with an application to manage the execution of business processes
- AR11: The organization must provide its members with an application to manage its physical resources
- AR12: The organization must provide its members with an application to manage its materials
- AR13: The organization must provide its members with an application to manage the product design process

- AR14: The organization must provide its members with an application to manage its strategy initiatives
- AR15: The organization must provide its members with an application to manage the manufacture of goods
- AR16: The organization must provide with an application to manage the service delivery

The following are the requirements derived from the Sustainability Characteristics. With the exception of SAR3, that is derived from the current COVID-19 crisis. However SAR3 does support sustainability in the form of reduced emissions from commuting.

- SAR1: The organization must allow for digital communications with customers
- SAR2: The organization must provide its members with an application able to integrate with its providers
- SAR3: The organization must provide its members with an application to work from home

In order to choose the patterns for this phase there will be two sources: the patterns from the previous phase and the patterns that can fulfill the requirements above. For the former, the patterns selected in phase B that have Application Architecture components are the following: Pattern108, Pattern116, Pattern159, Pattern168, Pattern169, Pattern170, Pattern171, Pattern173. There are other EAPs that may have components of this phase, but in their representation in the sources they don't have that level of detail, this is the case for Pattern141, Pattern153, Pattern162 and Pattern166. As for the latter source, the EAPs fulfilling the requirements could be either new ones or ones already listed, they are as follows:

- Fulfilling AR1: Pattern153
- Fulfilling AR2: Pattern169
- Fulfilling AR3: Pattern116
- Fulfilling AR4: Pattern108 and Pattern168
- Fulfilling AR5: Pattern108, Pattern116 and Pattern171
- Fulfilling AR6: Pattern108, Pattern116 and Pattern173
- Fulfilling AR7: Pattern108, Pattern116 and Pattern162

- Fulfilling AR8: Pattern108, Pattern116, Pattern163 and Pattern170
- Fulfilling AR9: Pattern108 and Pattern156
- Fulfilling AR10: Pattern108, Pattern116 and Pattern157 and Pattern159
- Fulfilling incompletely AR11: Pattern108, Pattern116
- Fulfilling incompletely AR12: Pattern108, Pattern116
- Fulfilling incompletely AR13: Pattern108, Pattern116 and Pattern156
- Fulfilling incompletely AR14: Pattern108, Pattern116 and Pattern166
- Fulfilling incompletely AR15: Pattern108 and Pattern116
- Fulfilling incompletely AR16: Pattern108 and Pattern116
- Fulfilling SAR1: Pattern108, Pattern116, Pattern153 and Pattern179
- Fulfilling SAR2: Pattern108, Pattern116 and Pattern174
- Fulfilling SAR3: Pattern168

The NewPattern001, NewPattern002 and NewPattern003 are also added to the subset, as these can be used to fulfill any of the requirements that Pattern108 fulfills. As they describe the use of cloud services in the Infrastructure, Platform and Software level.

In Figure 6.5 and Figure 6.6 the figures showing the relationship between the Business layer requirements, the application layer requirements and the patterns fulfilling them is shown.

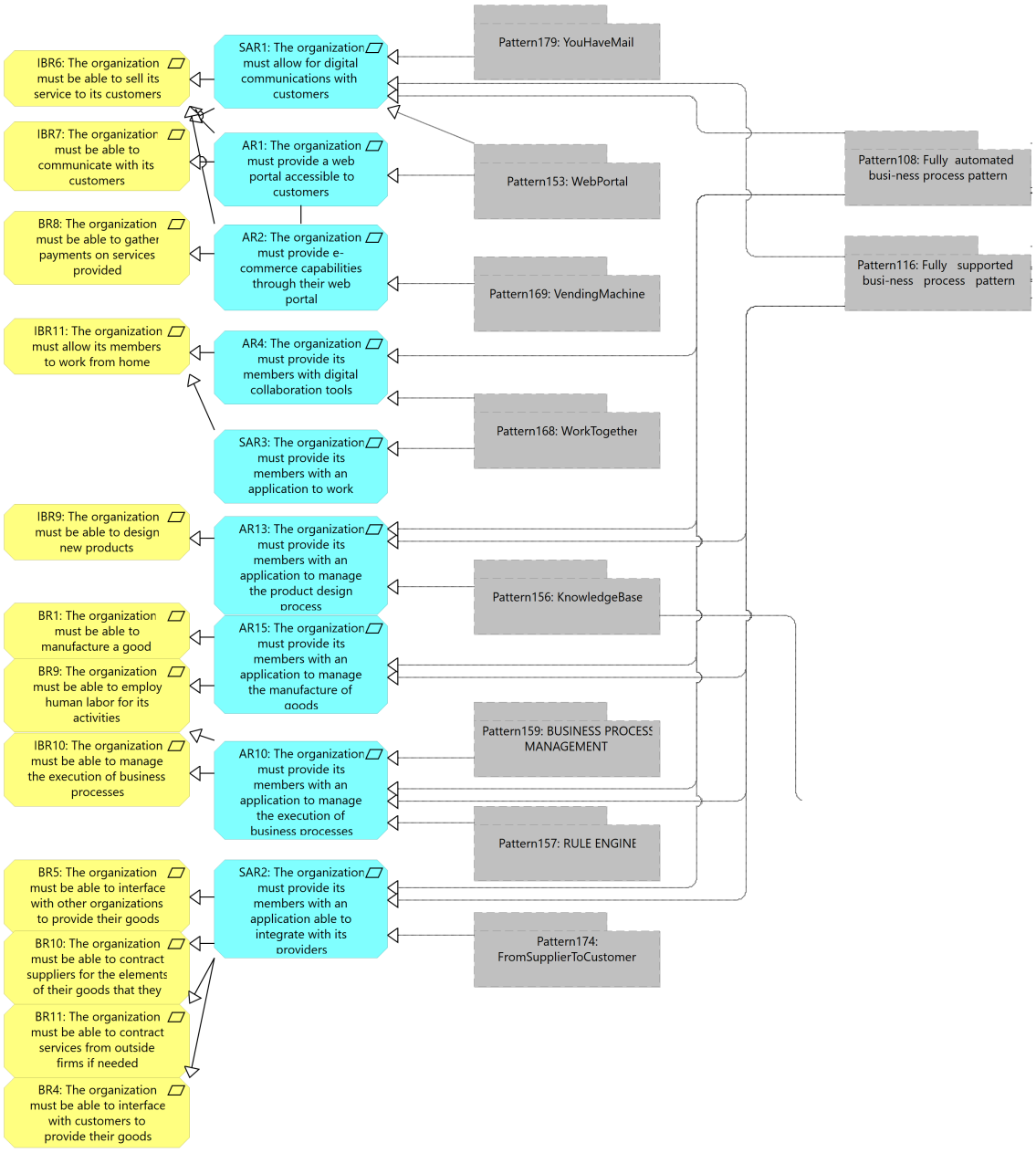

Figure 6.5: Application Architecture Vision requirements part A

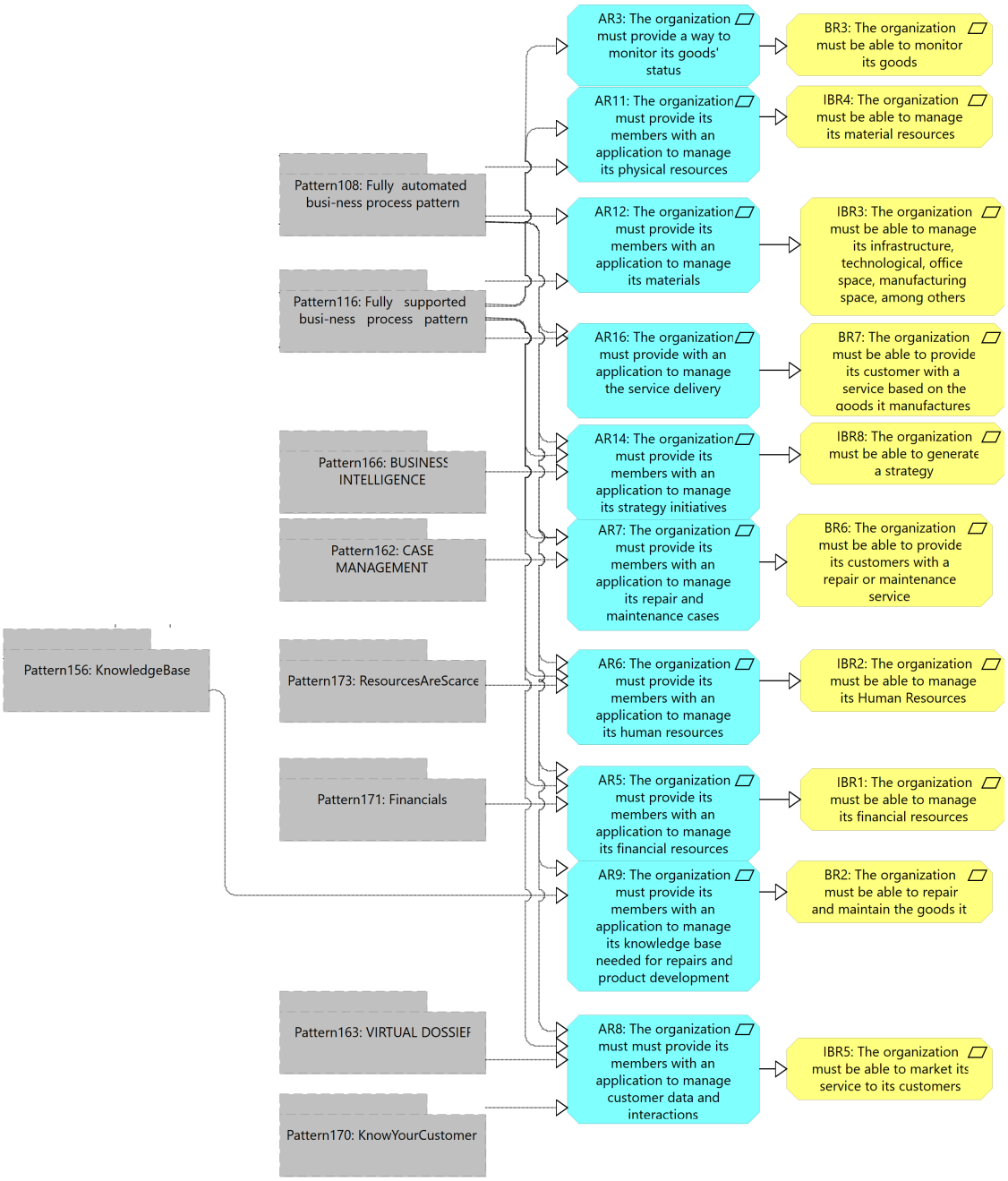

Figure 6.6: Application Architecture Vision requirements part B

Technology Architecture Vision

Continuing with the same exercise, the focus now is on Technological Architecture and the EAPs that can be leveraged. Drawing from previous sections, the main requirements derived are related to the deployment of applications and its networking. However, the filtered list of EAPs that support sustainability characteristics does not contain any such patterns, so this constraint must be relaxed for these to be included. The main EAPs supporting these aspects are: Pattern007, Pattern008, Pattern011 and Pattern012.

A special case is SAR3, that would need remote access to internal systems. This requirements is not fulfilled by the EAPs selected.

Subset of Patterns selected

On table 6.1 the selected EAPs are shown, as well as their respective information and description. A clear distinction can be made among the patterns, 11 of them have a simple way to translate into the Archimate Language for their use forward. These patterns can be found described in a detailed manner in their respective sources, including diagrams and written descriptions. The EAPs that do not have a simple way to translate were modeled in Archimate by the author, according to the descriptions given.

Table 6.1: Patterns Selected - The patterns implemented in the solution shown in bold

Id	**Pattern presented**	**Source**	**Field of origin**	**Phase**	**Translate able**
Pattern001	Repair and Maintenance	P2	BMI(CE)	A	No
Pattern007	Border Router Security Lockdown	P3	ITSM	D	Yes
Pattern008	Tiered Distribution	P3	ITSM	D	No
Pattern011	Load balanced cluster	P3	ITSM	D	No
Pattern012	Failover Cluster	P3	ITSM	D	No
Pattern104	Basic process architecture pattern	P11	BPM	A	Yes
Pattern108	Fully automated business process pattern	P12	EA	B-C	Yes
Pattern116	Fully supported business process pattern Identification:	P12	EA	B-C	Yes
Pattern141	PERSONALIZATION	P13	EA	B	No

Pattern153	WEB PORTAL	P13	EA	B-C	No
Pattern156	KNOWLEDGE BASE	P13	EA	B-C	No
Pattern157	RULE ENGINE	P13	EA	C	No
Pattern159	BUSINESS PROCESS MANAGEMENT	P13	EA	B-C	No
Pattern162	CASEMANAGEMENT	P13	EA	B-C	No
Pattern163	VIRTUAL DOSSIER	P13	EA	C	No
Pattern166	BUSINESS INTELLIGENCE	P13	EA	B-C	No
Pattern168	WorkTogether	P14	EA	B-C	Yes
Pattern169	VendingMachine	P14	EA	B-C	Yes
Pattern170	KnowYourCustomer	P14	EA	B-C	Yes
Pattern171	Financials	P14	EA	B-C	Yes
Pattern173	ResourcesAreScarce	P14	EA	B-C	Yes
Pattern174	FromSupplierToCustomer	P14	EA	B-C	Yes
Pattern179	YouHaveMail	P14	EA	C	Yes
NewPattern001	Using SaaS	This study	EA	B	N/A
NewPattern002	Using PaaS	This study	EA	B	N/A
NewPattern003	Using IaaS	This study	EA	B	N/A
Customer Channels	Sustainable Characteristics in **Customer Channels**	This study	EA	A	N/A
Customer Relations	Sustainable Characteristics in **Customer Relations**	This study	EA	A	N/A
Key Activities	Sustainable Characteristics in Key Activities	This study	EA	A	N/A
Key Partners	Sustainable Characteristics in Key Partners	This study	EA	A	N/A
Key Resources	Sustainable Characteristics in Key Resources	This study	EA	A	N/A
Value Proposition	Sustainable Characteristics in Value Proposition	This study	EA	A	N/A

6.2.3 Phase B: Business Architecture

With the constraints, guiding patterns and subset of patterns at hand, the architect moves to Phase B. The goal of this Phase is the specification of the Business Layer. To do so, the diagrams that describe the *Sierra Nevada*'s reborn oven product line will be drawn using the EAPs selected in the subset. The choices that were made between patterns, as well as the description of how were they combined are detailed here. Following the requirements of section 6.2.2, in many cases there are no EAPs to choose from except for one.

First, the guiding patterns are the two main EAPs that will serve to structure this layer. Pattern001, detailing the Business Model of a Sustainable Business, and Pattern104 that describes the Macro Processes an organization should perform. Here the Business Processes of Pattern001 are placed in Business Process 1 in an aggregating relationship.

Afterwards, starting with the Pattern169 VendingMachine is added to describe e-commerce capabilities. Aggregating also in the Business Process 1 of Pattern104. Then, due to the need to relate with customers as part of the service of selling, maintaining and repairing goods the Pattern170 KnowYourCustomer is added to describe the relationship with the customer. Finally the organization needs to interact with suppliers and providers, thus the Pattern174 FromSupplierToCustomer is added, both patterns aggregating Business Process 1. These three patterns are decomposed at this phase, including only their respective Business Layers concepts.

As was mentioned in the scope of this exercise, the architect will only be using EAPs to develop the specification. As such, Business Process 2 is left empty, as from the subset of EAPs there are no patterns that might be used to perform the the New Capabilities Development.

The only Pattern that was found to fit in Business Process 3, Business Planning was Pattern166 BUSINESS INTELLIGENCE. Through it the processes needed for the elaboration of dashboards is described. It could be also placed in Business Process 4 as a support process, but due to the need of analytics in the elaboration of strategy it was decided to place it here instead.

As for the Business Process 4, the supporting processes found in the subset are: Pattern171 Financials; Pattern173 ResourcesAreScarce; and Pattern168 WorkTogether. The first describes the financial planning of an organization. The second describes the Human Resource Management function of an organization. The third describes how members of the organization can collaborate through online resources. These three are also included as aggregating Business Process 4, and are decomposed to take only their Business Layer concepts.

At this layer the sustainability characteristics also have to be made explicit. Here the sustainability pattern Key Partners is combined into the Pattern 174 FromSuppli-

erToCustomer, which the architect must combine with more care than the previous cases as they overlap in many points. Mainly around the Supplier actor and the plan supply process. As these patterns come from different sources, the naming conventions differ, as such the architect must reconcile the differences for a coherent combination.

Another sustainability pattern included is the customer relations. which is combined with Pattern170 KnowYourCustomer. Here an overlap of concepts also happens, mainly around the customer actor. Again the Architect must exercise their experience and *Sierra Nevada*'s vision.

The third place the sustainability patterns are added to is to Pattern001, here both Key Activities regarding the products and Value Proposition are added. Naturally as the three focus on the product, and its' design. Here the combination is simpler as Pattern001 does not include details at the same level of abstraction that the sustainability patterns are built in.

The fourth place for sustainability patterns is Business Process 2 and 4. The sustainability pattern focusing on key activities relating to projects is combined with Business Process 2, altough it does not detail its' internal structure or behavior further, it does provide requirements that must be met. Similarly, in Business Process 4 an empty process called waste management is added that serves to convey the requirements the oven product line must follow in terms of waste.

Figure 6.7 shows a view with patterns combined. Each of the functions in it are described in more detail in other diagrams. In the Figure a Business Function called Human Resources is shown, which is detailed further in Figure 6.8. These figures refer to the included Pattern173: ResourcesAreScarce. As mentioned above, only the Business Layer objects are included in this view, as it's the scope of this Phase. Delving another level of abstraction deeper, Figure 6.9 describes the HR Management Process.

As the Patterns are included into the architecture, some duplicates happen. Common objects like *Customer* occur in multiple Patterns, so after including all patterns there will be duplicated objects in the specification. To address this a small Python script was written that removes duplicates.

Once the EAPs from the subset are included there are some gaps that can be identified. The lack of patterns applicable to the Business Process 2 is mentioned above, but adding to it there is the lack of details for the Business Model components. Because Business Models describe an organization in very abstract terms, it naturally lacks details. As part of this case study the details are not developed further, as the goal is to leverage the patterns.

The relationships between the patterns can be seen in Figure 6.10. Where the descriptions given in phase B and C are shown in a single view, using the relation-

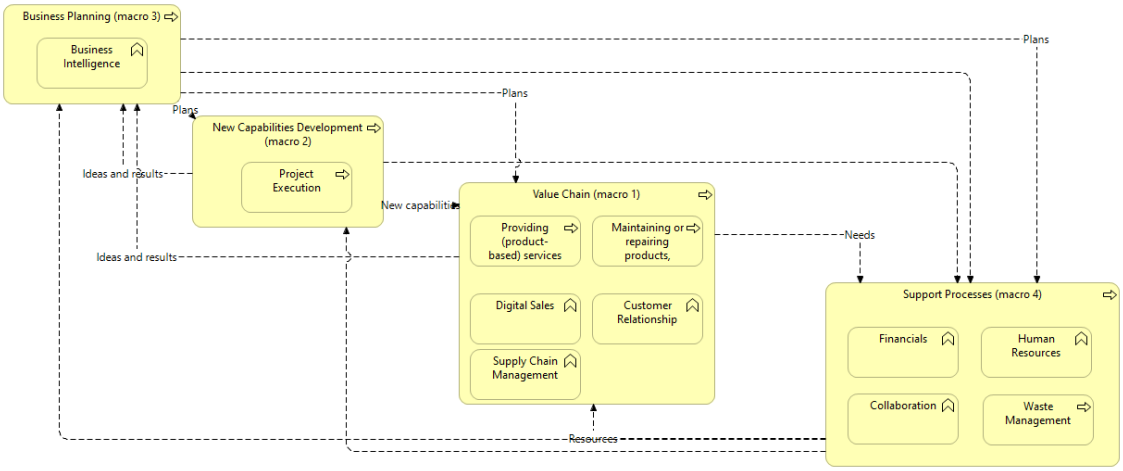

Figure 6.7: Business Process View

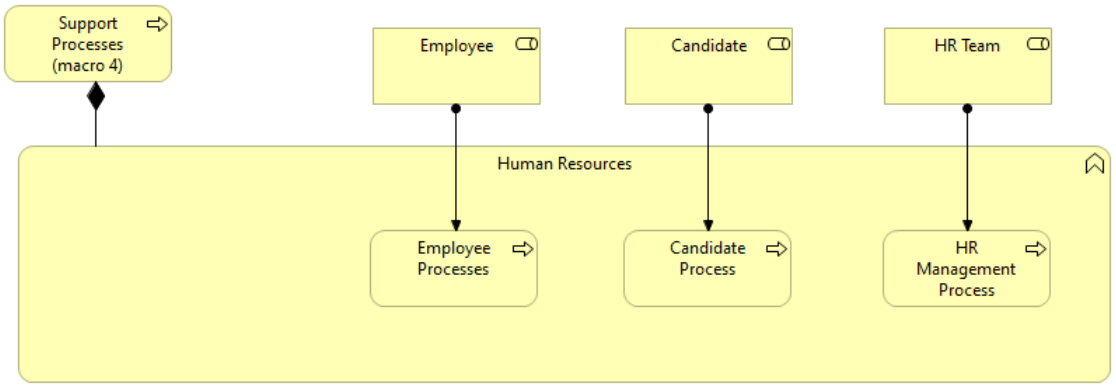

Figure 6.8: Human Resources View

ships described in Chapter 5.

As for the combination of sustainability patterns into business layer patterns, in Figure 6.12 an example is shown. Here the Pattern174 FromSupplierToCustomer is shown after it has been combined with the Key Partner sustainability pattern. In order to see how it compares with the same pattern as it's described in its source, Figure 6.11 shows Pattern174 without the sustainability changes. Similar changes happen to the other patterns where sustainability has been combined.

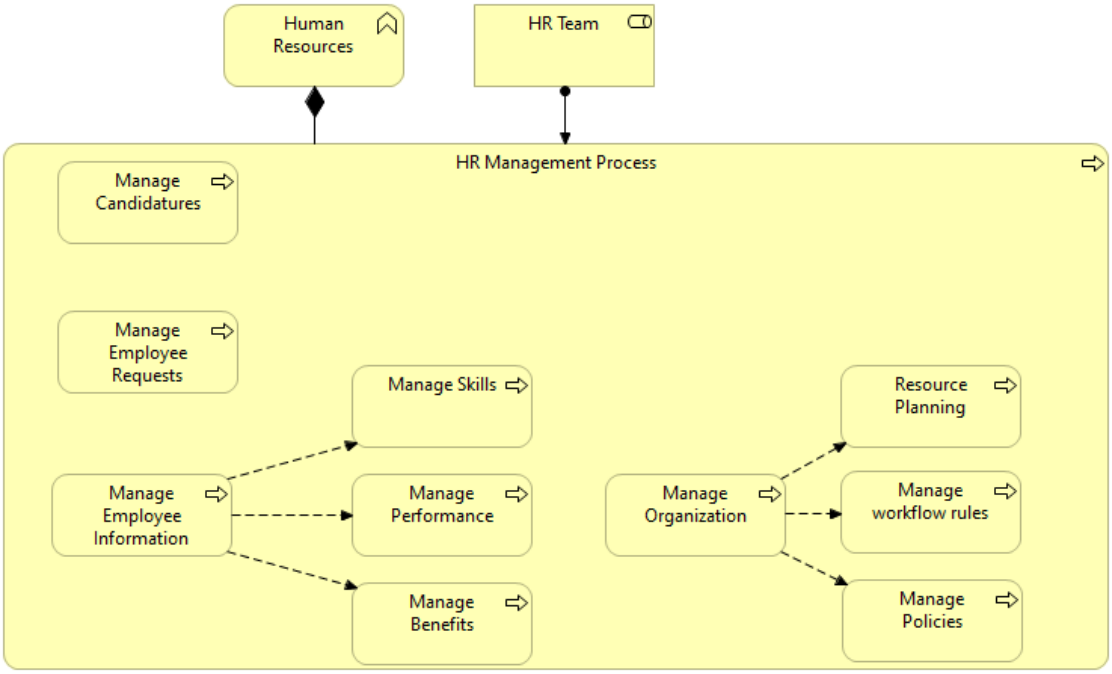

Figure 6.9: HR Management View

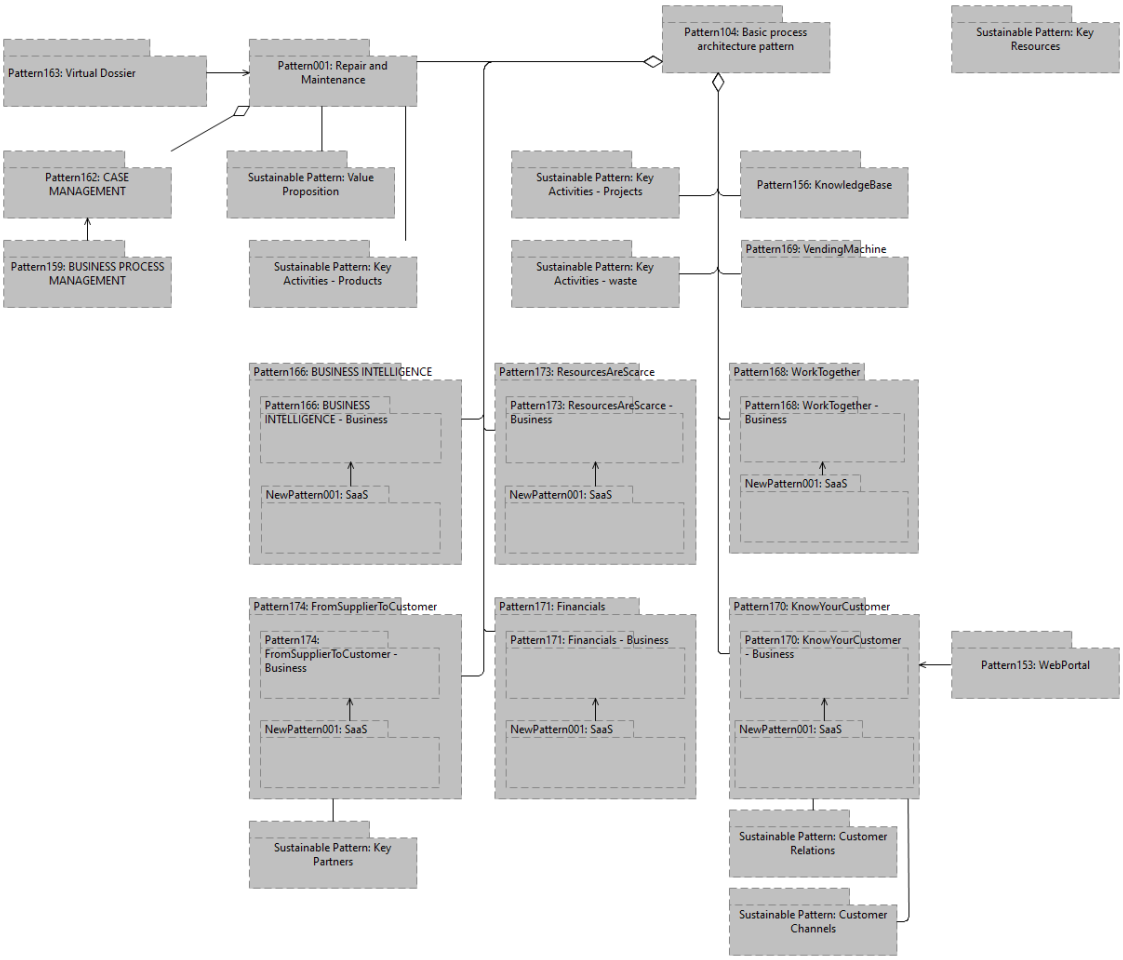

Figure 6.10: Relationship between patterns

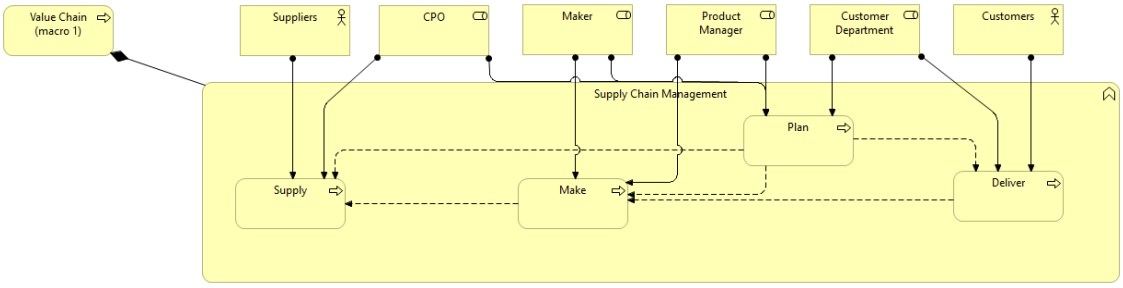

Figure 6.11: Pattern174: FromSupplierToCustomer - as translated from source

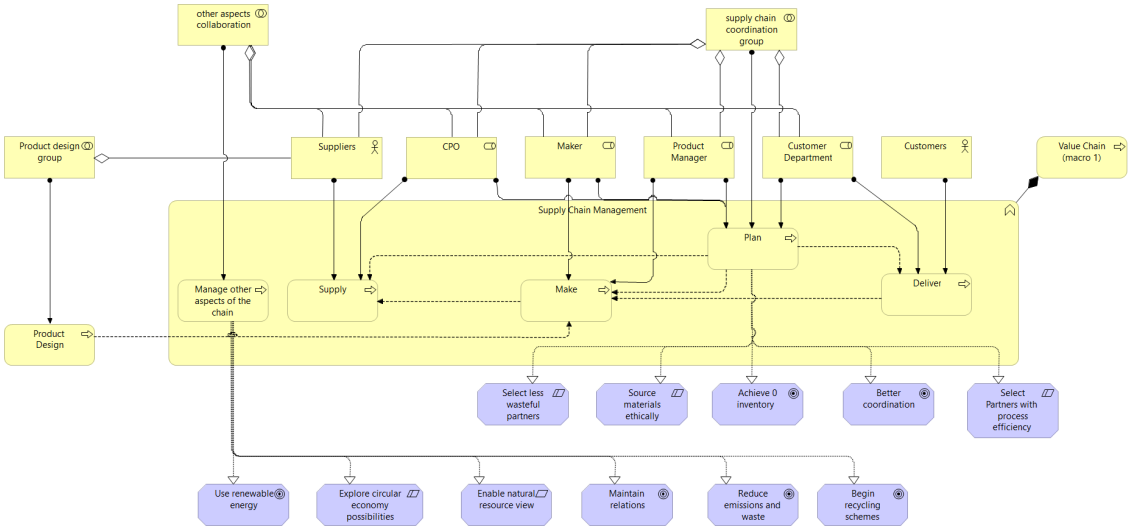

Figure 6.12: Pattern174: FromSupplierToCustomer - Combined with Key Partner sustainability pattern

6.2.4 Phase C: Application Architecture

The goal of this Phase is the specification of the Application Layer. In order to do so there are two inputs: The subset of selected EAPs generated during the Architecture Vision, and the Application Layer objects present in the EAPs applied during Phase B.

In this Phase a choice emerges for the architect, that is to keep the selected EAPs as presented in the source or to change them. This choice surges from the decomposition of EAPs performed in Phase B. For this case study the latter was selected. Specifically, EAPs like the one shown in Figure 6.8 describe a way in which Applications provide the services needed to support the Pattern. Her,e an alternative can be presented using SaaS offerings specialized in the Business Function of the Pattern. This is the path the architect chooses for *Sierra Nevada*, this provides a quick way to implement the reborn product line as cloud services are generally faster to acquire and enable when compared with the alternatives, also it's aligned with some of the Characteristics found in Chapter 3 describing the use of sharing and virtualization (C25 and C42).

Following this argument, the Application View of Pattern173: ResourcesAreScarce is described in the Pattern NewPattern001: SaaS, and is shown in Figure 6.13. This same approach is chosen for Pattern171: Financials; Pattern168: WorkTogether; Pattern170: KnowYourCustomer; Pattern174: FromSupplierToCustomer; and Pattern166: BUSINESS INTELLIGENCE.

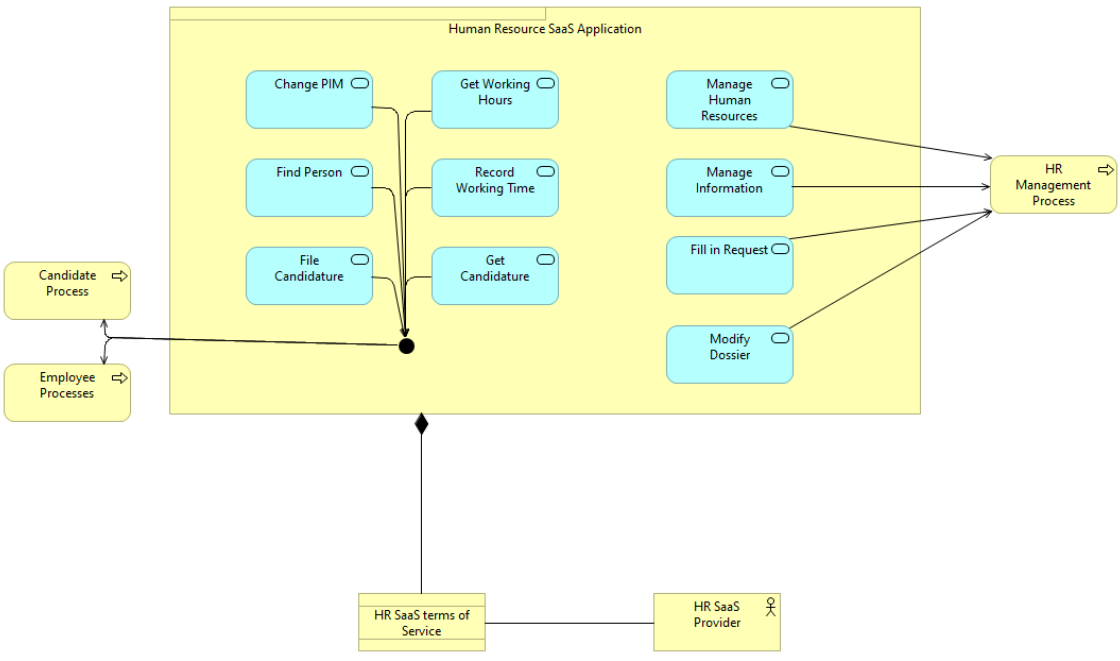

Figure 6.13: HR Application View

There are four EAPs that are added in this Layer. Pattern153: Web Portal describes the functioning of a web portal, this overlaps in some ways with some components of Pattern169: Vending Machine and Pattern170: KnowYourCustomer. These overlaps are taken as points where the patterns can be integrated into a more cohesive specification. The other EAPs added are: Pattern 156: Knowledge Base; Pattern159: Business Process Management; and Pattern163: Virtual Dossier.

In the intersection between the Application and Business Layer the Pattern116: Fully supported business process was chosen. This Pattern describes that the Business Process is supported entirely by a unique application, and there is no need for other resources.

In terms of sustainability patterns, the key activities and key resources that focus on IT aspects are added. These apply to all applications.

6.2.5 Phase D: Technology Architecture

The goal of this Phase is to specify the Technology Layer architecture. In order to do so the layers developed in Phases B and C are taken as input, as well as some of the EAPs found in the subset developed in the preliminary and Phase A.

Due to the choice of modifying the Application layer of some of the EAPs in section 6.2.4, the complexity of this phase is diminished. As the Technology components of a SaaS offering are beyond the scope of the organization contracting the services. What is left are some application components, and under the same rationale as in Phase C, a PaaS approach was chosen. In Figure 6.14 the main diagram for this Phase is shown, following NewPattern002: PaaS.

6.3 DISCUSSION

The resulting Enterprise Architecture Specification for *Sierra Nevada* is shown in Appendix H, in this section the findings of following the process are described.

As mentioned during Phase C and D some changes were performed on the EAPs. The modifications of the patterns are contained to the *lower* layers in the patterns, e.g. for Pattern171: Financials the pattern includes elements in the Business, Application and Technology layers and the changed occurred only to the application and technology layers. These changes do not change the underlying problem nor the solution, arguably, using a SaaS based application to manage Financial information does not contradict the problem that is solvable by Pattern171. This EAP could be implemented in an organization by any number of technology and application-based means, acquiring enterprise software licences, building the software in-house, using a monolithic application, using a microservices architecture,

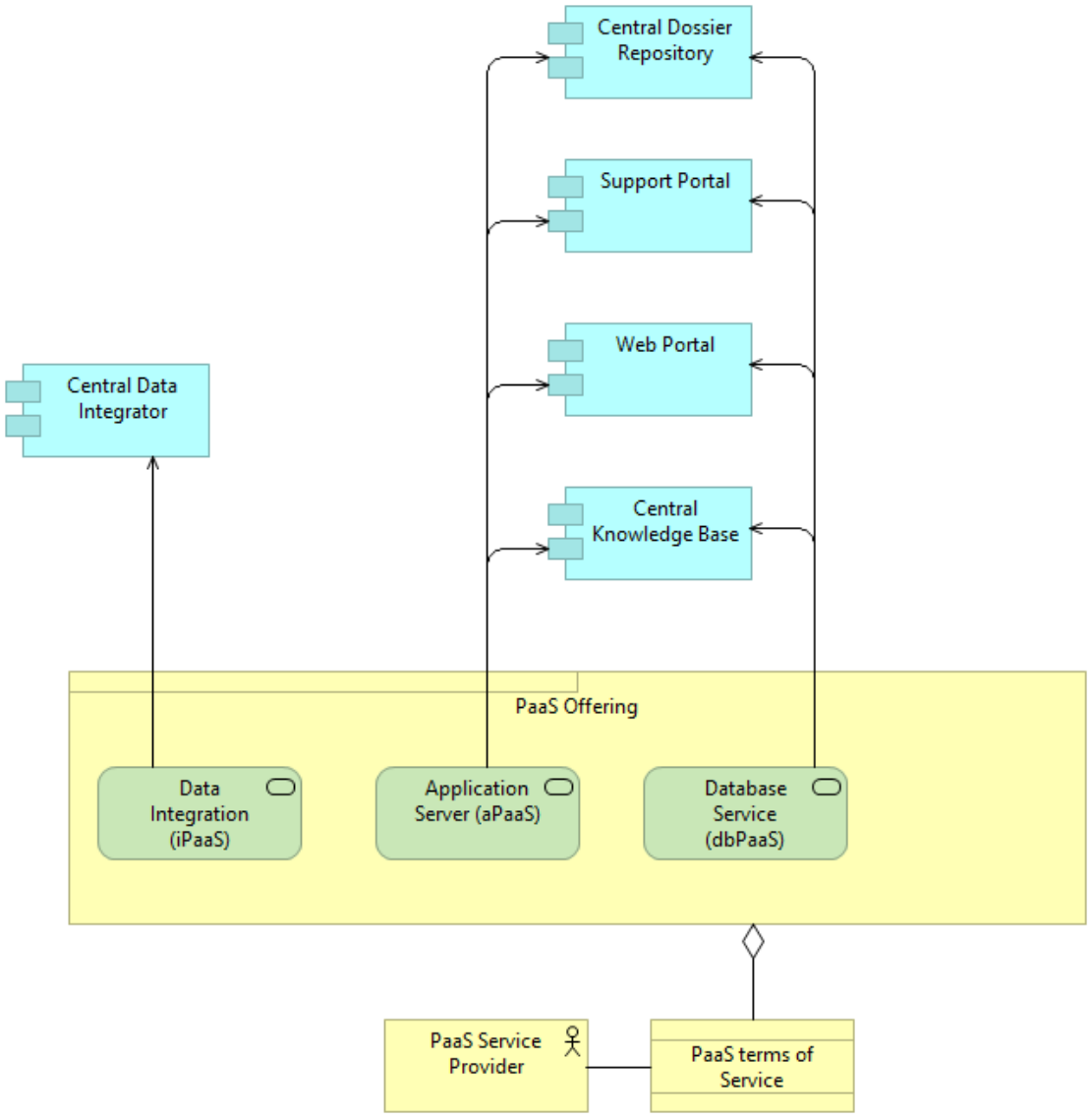

Figure 6.14: Technology Layer

etc. Any of those choices would open options for the interaction with the Technology Layer as well, e.g. using a single computing node, using a virtual machine, etc. By leveraging decomposition of EAPs, and then making changes e.g. by combining other patterns, an architect is able to fit

Although the EAPs present in the subset come from different sources, they're relatively simple to combine and transform after translating them to Archimate. As is expected, the complexity of combining them increases the more overlapping they are, as the number of touch points between the two would increase.

However, the resulting specification does have some gaps. These gaps stem from two reasons, either the Pattern that addresses it is not found in the EAPs that support sustainability, or they were not found in chapter 2. Some of these were

addressed by the NewPatterns shown in Chapter 5, e.g. the usage of cloud services. Some of the gaps detected by the author are the following:

- How to describe the process to establish a business strategy
- How to describe the process of executing a project of change
- How do the main processes of the Business Model work
- How are the customers supported
- How do the different applications work together
- How does the IT department manage the application landscape

Chapter 7

Validation

In this chapter a validation is performed of the methodology proposed in Chapter 5. Following the Design Science methodology, after developing a solution it must then be validated, prior to its implementation (Wieringa, 2014). In order to do so, a panel of experts is assembled and shown the method. These same experts are then asked to partake in a questionnaire based on the Unified Theory of acceptance and use of technology (UTAUT) (Venkatesh, Morris, Davis, & Davis, 2003). This questionnaire is present in Appendix I.

7.1 EXPERT PANEL

The five experts that agreed to take part in the validation process are five:

1. A professor for EA in a dutch technical university, with more than 10 years experience (expert A)
2. An architect from an important bank in the UK, with 8 years experience as architect (expert B)
3. An architect from an major cloud provider, with 2 years experience as architect (expert C)
4. An architect working with a large consulting firm, mainly dealing with financial sector customers, with 8 years of experience as architect (expert D)
5. An architect working with a large consulting firm, mainly dealing with financial sector customers, with 6 years of experience as architect (expert E)

For each expert, the methodology was explained using a set of powerpoint slides. The overall developing process was explained as well as the methodology itself. Afterwards an unstructured discussion session took place. Finally, they were asked

to complete the questionnaire. It is important to note that expert D and E were interviewed together, and consequently their commentaries are presented as one.

Expert A

Expert A mentioned that they have re-used solutions and parts of them in their experience. For example, a tiered approach to handling customer interactions, or how to handle logistics in an organization. They have also used solutions from other researchers, specially in research projects where sharing solutions happened. They mention that they have also transformed solutions to fit their needs at the moment.

Their main positive comment is that the methodology is ”natural”, as in it is aligned with the TOGAF and its ADM in a way that feels like an extension. Their main negative comment is that it has not been used in a real case. By testing it, areas that would need some compensation or work would be revealed. A neutral comment is that they would like to see concretely how the Business Model patterns were translated to Archimate concretely. A second neutral comment is that they are curious about the guidelines for selecting patterns.

Expert B

Expert B mentioned that they have re-used their own solutions, but also those that are deemed as ”good practice”, as well as emulating other organizations. They focus on the importance of how the solution is implemented, as this will differ between organizations based on their previous experience and capabilities.

Their main negative comment is their concern regarding innovation. Whether re-using similar solutions across many organizations would stifle innovation, as it would make it harder for organizations to steer away from the *proven* way of doing things. The argument of ”this is how things have always been done” is expanded by ”this is how things have always been done, by us and everyone”, which they argue would present a higher obstacle. They also ask if it is achievable, as any change is met with resistance.

Their main positive comment is that the method, and the question that arises, is interesting, as it describes and provides a structure to a common practice.

A neutral comment is that beyond the patterns shown in the methodology, it is the way the pattern is implemented that matters. The realization of the pattern means that among organizations using the same patterns, the way they implement it may all be different.

Expert C

Expert C mentioned that they re-use solutions but are careful when doing so, as sometimes solutions assume that an organization is working in a certain way and it may not always be so. This was particularly emphasized, as their experience is that the organization dictates what solutions are applicable through their capabilities.

Their main negative comment is the pattern (de)composition that was described in the methodology. In this process architects may be caught in a fractal-like deadlock, continuously combining patterns upon patterns.

Their main positive comment was that this pattern approach could help architects in sales positions. Because these do not need to go into the full detail of an organization as an in-house architect does. Elaborating a to-be sustainable architecture for a big corporation, using their annual reports and other resources, by using patterns to hasten the process would be of great value.

A neutral comment provided was that the relationship the methodology has with the ADM seemed *complicated*. Another neutral comment is that patterns should have other requirements, mainly they should be succinct and easy to understand. As EA is based on communication, these patterns should be exemplar in this aspect. The final neutral comment provided was based on possible future work, once enough data has been gathered researchers could analyse an extensive body of patterns and reduce them to a set of axiomatic objects. Thus providing the minimum building blocks for any organization.

Experts D and E

Experts D and E mention that their customers try to take solutions found in one department and re-use them in other departments of the organization. And, in their own firms they try to re-use effective concepts throughout the Request for Proposals (RFP) they participate in.

Their main negative comment lies with the method's way of introducing sustainability concepts into EA. The organizations they work with are implementing sustainability, but not into their overall operation but instead as separate aspects to be included in the Corporate Social Responsibility report. This means that, today, organizations do not include these aspects in their EA practice. This is enhanced by the fact that they have not seen the motivation layer concepts being used in a great majority of their customers.

Their second negative comment echoes expert C, that the relationship between the proposed methodology and the ADM is confusing. It's unclear what the differences are between the the methodologies. This confusing relationship worries them because their customers do not usually use the TOGAF and its' ADM as defined,

they fit it to their own needs and purposes.

One of their neutral comments also echoes expert C, that they use EA artifacts mostly as a communication medium, drawn mainly in Powerpoint. As such, they have little need for the level of detail and speed provided by the methodology and patterns.

Their main positive comment is that, going forward sustainability will take a more central place in discussions. And they have seen it happen already in an selection of a provider, where one of the criteria was how sustainable the candidates were.

7.2 QUESTIONNAIRE

All three experts filled a questionnaire based in the UTAUT theoretical model. The questions used are presented in the Appendix I.

7.2.1 Results

The details of the questions can be seen in Appendix I. Now, the results for each construct can be seen in Table 7.1. Finally, the results for each item can be seen in Table 7.2.

Table 7.1: Questionnaire results - Constructs

Construct	**Average**	**St dev**	**Min**	**Max**
Performance Expectancy (PE)	3.9375	2.205107707	1	7
Effort Expectancy (EE)	5	1.673320053	1	7
Attitude toward using technology (ATUT)	4.125	1.821171784	1	6
Social Influence (SI)	2.875	1.962141687	1	5
Facilitating Conditions (FC)	3.5	2.033060091	1	7
Self Efficacy (SE)	4.4375	1.412739655	2	7
Anxiety (ANX)	1.375	0.6191391874	1	3
Behavioral Intention (BI)	3.75	2.050498831	1	7

Table 7.2: Questionnaire results - Items

	Item	Average	Std deviation	Min	Max
PE	**U6**	4.25	2.22	1	6
	RA1	4.00	2.16	1	6
	RA5	3.75	2.06	1	6
	OE7	3.75	3.20	1	7
EE	**EOU3**	4.00	2.16	1	6
	EOU5	5.25	0.96	4	6
	EOU6	5.25	1.71	3	7
	EU4	5.50	1.91	3	7
ATUT	**A1**	5.00	1.15	4	6
	AF1	4.00	2.45	1	6
	AF2	3.75	1.89	1	5
	Affect1	3.75	2.06	1	6
SI	**SN1**	2.75	2.06	1	5
	SN2	3.00	2.31	1	5
	SF2	2.75	2.06	1	5
	SF4	3.00	2.31	1	5
FC	**PBC2**	4.25	1.89	3	7
	PBC3	4.50	2.65	1	7
	PBC5	2.50	1.29	1	4
	FC3	2.75	2.06	1	5
SE	**SE1**	4.25	1.71	2	6
	SE4	4.00	1.15	3	5
	SE6	4.50	1.29	3	6
	SE7	5.00	1.83	3	7
ANX	**ANX1**	1.75	0.96	1	3
	ANX2	1.50	0.58	1	2
	ANX3	1.25	0.50	1	2
	ANX4	1.00	0.00	1	1
BI	**BI1**	3.50	1.91	1	5
	BI2	3.75	2.22	1	6
	BI3	4.00	2.58	1	7

7.3 DISCUSSION

In this section a discussion of the results of both validation methods is presented. Starting with the commentaries by the panel of experts and then focusing on the results of the questionnaire. Finally, a general discussion of the overall results of both methods is offered.

7.3.1 Experts Commentary

Overall the commentaries of the experts was positive. However, exception were experts D and E that mentioned their worry on the the sustainability concepts were introduced to EA. This is reflected in earlier chapters of this study, where the concepts of sustainability are hard to relate but are finally described using Motivation layer concepts. Experts D and E also mentioned that they have not seen such concepts used in their practice. They also comment their confusion regarding the relationship between ADM and the proposed methodology. This specific question was also asked by expert C, which means that further improvements on the methodology's description are necessary to make this relationship more clear.

A starting commonality across the experts was their re-use of solutions in their day-to-day practice. This was a positive finding as it shows that today the application of patterns happen in an informal way. Aligned with previously mentioned limitations, the patterns and solutions the experts mentioned they have applied are not present in the sample. This means that in the gathering of the solutions present in the field could be a valuable future project.

The patterns themselves generated different reactions among the experts. For expert B, standardizing all solutions to problems could arguably stifle innovation. As all organizations would be simply a combination of publicly known solutions. However, they also mention that what would make them different is how they actually implement them. For expert C, patterns should easily communicate their value and applicability, otherwise any architect would rather use either a different pattern or design their own solution. For expert A, translating patterns from different fields was of interest, mainly the method chosen to do so.

As for the sustainability focus of the methodology, experts C, D and E made mention of it. For experts D and E, this could be due to their own experiences, where they have seen sustainability being used as a criteria in one of their customers. As for experts C this could be their relation to commercial teams made them think of a pattern based approach to present a highly customized sustainable transformation project to an organization. By using publicly available reports of a specific organization as a starting point and then applying the pattern based methodology for a

hastened EA specification of a future sustainable state.

The focus on implementation was something common for experts B and C. Both thought of it as a central differentiating aspect of organizations, as assuming that all organizations use patterns then what makes them different is how they actually implement them. Expert B even went as far as proposing that a next step to this study is the identification of implementation patterns that organizations could use depending on their own capabilities.

7.3.2 Questionnaire

Overall the results of the questionnaire are positive. With the highest score being **EE**, which is aligned with the contribution goal of this study, helping architects drive change faster. There is an exception to be made for Experts D and E, as their evaluation of the method was negative.

As can be seen in the main results, the **EE** and **SE** constructs are the highest ones at and also have a low standard deviation. With this result for **EE**, the experts evaluated that the methodology would be clear or easy to use, and that they perceive that mastery at using the methodology is easy to obtain. Which corresponds with their personal comments on the methodology, that they re-use previous solutions in their day-to-day activities. And, with this result in **SE**, the experts evaluated that they were capable of using the methodology.

In a manner inverse to **EE** and **SE** the **ANX** construct has the lowest score, and the lowest deviation. This means that experts evaluated that using the methodology produces no fear or intimidation. This reflects the high degree of experience all the experts approached have, they have confidence in their capabilities.

The results in the **PE** construct are positive, except for the evaluation of expert D and E. This means that experts evaluated the methodology as being useful and increasing their productivity. There is a slight source of disagreement in the **OE7** item (If I use the method, I will increase my chances of getting a raise), in which the results were (6,1,7). For expert B, working in a bank might be a deterrent to applying solutions found elsewhere or another explanation related to their context.

For the **ATUT** construct a similar results to **PE** exists. A positive result, this means that experts perceive the methodology interesting, fun or a good idea.

The **BI** construct also has a split score, half of the experts evaluated it positively and half as negative. Representing that they are not certain they will actually use the methodology in the future.

The **SI** construct also had similar results to BI. Their answer may be because this method was not shown to any of their superiors, as all items relate to external social influences.

The **FC** construct received a wide scope of evaluations of the items, this can also be seen with the high standard deviation. This could be because this construct has an item that does not align with the others, **PBC5** (The method is not compatible with other systems I use) is a negative item where all others in the construct are positive, i.e. an architect answering positively **PBC2**, **PBC3** and **FC3** would naturally answer **PBC5** negatively. And in the inverse case, experts D and E evaluated this item positively while the others negatively.

7.3.3 General Discussion

As mentioned before, the results were overall positive. However, there was a clear division of opinions between the experts. With experts A and C being more positive towards the methodology, while experts D and E were more negative, and expert B more neutral.

There are two aspects unifying experts A and C, which could influence their views towards the methodology. First, both are involved with teaching EA in their respective universities. Second, both knew the author before the evaluation exercise.

Inversely, experts B, D and E have some commonalities as well. All three are working in the private sector, with expert B focusing only on one organization, while D and E focusing on their customers. This means that the methodology is failing to show its value to practitioners, the intended final users.

Going forward, the methodology should be improved in multiple areas, but most importantly in the following:

- Make the relationship between ADM and the proposed methodology clearer
- Expand the patterns to include best practices and common solutions used today by practitioners
- Finally, test the methodology in a real world organization and identify other strengths and weaknesses.

Chapter 8

Conclusions and recommendations

In this chapter the conclusions of the study are presented, along the limitations detected. Then, the contributions to both the academic and practitioner community are summarized. Finally, future work and the recommendations for practitioners are presented.

8.1 CONCLUSIONS

What follows are the conclusions drawn from this study, first the ones stemming from the RQ are described. Then, the conclusions from each SQ are presented. Finally some overarching conclusions are elaborated.

8.1.1 A Methodology for the specification of EA in sustainable organizations

In Chapter 1 a RQ was defined, **How would a practitioner build an EA specification for sustainable organizations using EAPs?**. A methodology results from answering this question, and is designed in Chapter 5. In preparation for its design there was a need for the characteristics of sustainability to be described explicitly in the Archimate language. This was due to the lack of sustainability concerns in the EAPs found, beyond the sustainability business model patterns. The methodology was designed using the ADM, applying its same phases in an effort to make its adoption simpler to organizations already using the TOGAF. After designed, the methodology was then used in an example in Chapter 6, and validated by using an expert panel as described in 7. The method is evaluated positively. As part of the methodology, a notation is proposed for describing the relationships between patterns implemented in an organization. This specific artifact could also be of use in organizations that are implementing recommendations from multiple standards, e.g.

ISO certification-related aspects.

8.1.2 Enterprise Architecture Patterns

First, the SQ ”What is the state of the literature ofEA Patterns?” was answered, and the result was the set of EAPs found in Chapter 2. The patterns found were heterogeneous in multiple ways, like the field of research they originated from, their scope, the way they’re represented and how they’re extracted. The patterns found were taken from scientific literature, which meant practitioner sources were excluded. For example, industry standards and best practices were not included in the set of patterns. This meant that for some of the studies in the sample the space limitations of journals and conferences was an obstacle. As these are usually limited to a relative short number of pages, it is difficult to present all the information tat may be necessary when describing patterns. This obstacle is missing in the books in the sample, where the authors could elaborate on the details of the patterns, making them more valuable. A good example is P14 - ”Enterprise Architecture Patterns”, which is the source of many of the patterns that were finally used during the case study of Chapter 6.

As previously mentioned, the studies of the sample presented the patterns in many ways. They used multiple modeling languages, combinations of them, and written descriptions of them. This study as well, where some of the patterns were translated to, and some new patterns were drawn in, the Archimate language. This makes the re-use of patterns difficult, as architects would need to translate into the language they’re building their specification.

8.1.3 Sustainability Characteristics

Second, the SQ ”What characteristics of sustainability are relevant for EA?” was answered. Resulting in a set of characteristics of sustainable organizations present in literature, classified based on the BMC building blocks. All of the characteristics were relevant, but by using the Archimate language components a way was found to include them into EA artifacts for each building block.

The literature on sustainability is increasingly wide and complex. For example, there are more than 100 different definitions on Circular Economy alone (Geissdoerfer et al., 2017; Kirchherr, Reike, & Hekkert, 2017). This makes the selection of characteristics difficult, as just the choice of the word ”characteristic” already filters concepts and requirements from this study. A more comprehensive and exhaustive study may result in a more valuable set of characteristics.

Among the characteristics for sustainability found there were commonalities in

the concepts. E.g. a common concept across many characteristics was the use of digital tools. Applying text mining techniques might produce clusters of characteristics, which could then be used to propose more abstract characteristics.

8.1.4 EAPs supporting sustainability

Third, the SQ "What EAPs build a sustainable organization?" was answered. The result was a classification of the EAPs, based in which building blocks' sustainability characteristics they supported. This provided a way to compare between patterns, in a way that selecting the *more* sustainable patterns was possible.

This classification was based on the concepts the patterns describe. In some cases the support of sustainability was clear, e.g. with sustainable business models. In others it was less so, as some characteristics of sustainability describe using digital tools, then in a small degree the patterns describing digital tool supporting business functions also supported sustainability. This classification exercise was manual and subjective, as it depends on the understanding that the author had of the pattern, the characteristics and the building block they were classified into.

8.1.5 Overarching Conclusions

As mentioned earlier, there were difficulties in the description of sustainability concepts. This is also observable when evaluating patterns in terms of their support of sustainability, as none of the patterns found has sustainability aspects in mind for its design. As an effort to making explicit the relationship certain aspects of the organization had with the characteristics found, this study proposes some patterns based on the motivation layer concepts. One of the reasons this difficulty is thought to happen is that sustainability is akin to a non-functional requirement. Similar to security, sustainability permeates the entire organization, making it difficult to place. But, as found in this study, there are key aspects of an organization where these characteristics can be added, some examples are: product design activities, production planning, supplier selection; and in a more generic manner the intersection between business and application layers.

By leveraging only the patterns found in 2 and the methodology designed in 5 a case was successfully prepared. This is presented in chapter 6. In it the value of re-using patterns found in literature is showcased, as it enabled the specification of a standardized organization with sustainability infused in all layers of it's structure and behavior. This methodology could also be of value to architects focusing more on the communicative aspects of EA, as it was found during the validation. For these architects, taking a re-usability approach to the specification of architecture

artifacts would be of value as it forces the re-utilization of artifacts, thus saving time and effort. Such approach would also influence architects to extract patterns from their work to use and share among their organization.

In the field of EA, the use of sustainability concepts is not common, and including them into the practice was not straightforward. This difficulty to express sustainability concepts using EA artifacts may be because of, or causes, the absence of sustainability aspects in EA practice. In this study, the obstacle of expressing these concepts was surmounted by using the motivation layer concepts of Archimate. With them it was possible to describe the requirements sustainability imposes on the operation of an organization, e.g. select suppliers that are not using slave labor. However, a step further would be to design structural and behavioral components in an organization that implicitly implement the requirements used in this study. These newly designed components could then become patterns to be adopted widely.

8.2 CONTRIBUTIONS

8.2.1 Academia

For academia there are multiple contributions. First, a systematic literature review producing an extensive set of EAPs. By applying an exhaustive approach, the resulting review has expanded the existing definitions of EAP beyond just the field of EA, to include fields like BMI and BPM. Furthermore, this systematic literature review on EAPs was published at the 22nd International Conference on Enterprise Information Systems (ICEIS). Second, a systematic literature review producing a set of characteristics of sustainability and circular economy. Extending the knowledge of the aspects organizations need to be sustainable, as today there are many definitions to sustainability, having an aggregated list of such characteristics is needed. Third, extending the EA field, a novel notation based on the Archimate language is proposed to describe the ways architects may combine patterns, as well as a categorization of the ways they may be combined with each other.

8.2.2 Practice

For practice there are multiple contributions. First, the set of sustainability characteristics classified in terms of the building blocks of the BMC. These offer organizations today a classified list, based on scientific literature, of characteristics they can implement to be more sustainable. Second, a methodology for the application of patterns in an organization's EA is proposed, it can be adopted by itself or complementing the TOGAF. The methodology was also used in a theoretical case study, and finally

it was validated through a panel of experts. This methodology serves organizations with simple steps to follow to include patterns in its' EA practice, it is also accompanied by a set of ready-to-use patterns for its implementation. This methodology also enables organizations to include sustainability aspects in its EA practice.

As result of the design effort of the methodology there are some secondary contributions. A notation was proposed to describe the relationships of patterns used in an organization. Which allows for organizations to describe the patterns (best practices, standards, and other re-usable solutions) they are implementing in their current and future states, resulting in a clear abstraction useful . Finally, a case study was prepared in order to apply the methodology. An entirely new case study was needed as, to the best of the author's abilities, there are no business cases in literature which deal with the transformation of an organization towards sustainability.

8.3 LIMITATIONS

The limitations of this study can be clearly divided into the different RQs. The main limitation on Chapter 2 is the language used, where the concept of *pattern* may not be used commonly, especially in other fields of research. An example is the Human Resource (HR) Architectures proposed by Lepak and Snell (2002), which show patterns in HR management.

In terms of Chapter 3 the limitation on language used is still present, as a more in-depth exploration of the terms used in the sustainability field may have gleaned more characteristics. Another limitation is the scope of the field, which make it complex to navigate. Sustainability is approached from a Chemistry, Forestry, Marketing, and many other fields of research, as should be, given that it is a wide problem affecting everyone.

The main limitation of the methodology, which is confirmed by the panel of experts, is the lack of a real-world case study. Until this methodology is applied, in a real organization looking into changing towards a more sustainable future version, then its' true weaknesses will not be perceived.

8.4 Future Work

For the academic community possible future work continuing with this study could be its' application in a real-world organization that is looking for a sustainable transformation. This would reveal the weaknesses of the methodology, if any. Another avenue of research is to define a way in which patterns can be extracted from orga-

nizations, either through literature or with the help of its members. This is in a similar way to the approach taken by P20, which compiled a classification of Business Models, and offered a base by which both academics and practitioners can study and compare organizations. Finally, an avenue of research would be to focus on architects. How they re-use their previous solutions, including those found in literature or those their peers propose. This would offer more understanding of how to better serve these architects with more patterns than those they can already access.

8.5 Recommendations for Practitioners

The main recommendation for practitioners is to take a more open approach to the EA practice. In a similar fashion to the open source movement in Software Development, EA would benefit from becoming open. Serving to communicate patterns, best practices, diffuse knowledge and innovations, etc. Concerns about losing competitive advantage would be ill-placed, as what is truly valuable in an organization is the organization itself, not its' abstraction.

Similarly, architects could work towards compiling a database of patterns based on their work. Such database should follow the recommended representation presented in Chapter 2. And each pattern should be related to others as well, forming a net of patterns. This would help architects find, and use, patterns from the community easier.

The characteristics for sustainability describe some outcomes and behaviors that organizations should be adopting; this is the same expectation when using EAPs that describe structures and behavior. However, for organizations, establishing a future state depends heavily on implementation. The way change is brought to organizations is as important as the change itself, as it depends on the current capabilities and resources it may have. It may be that implementation projects and methods are also re-usable. Thus, expanding the knowledge base of patterns beyond the description of organizations into describing how to transform them.

Bibliography

Alexander, C., Ishikawa, S., & Silverstein, M. (1977). *A pattern language: towns, buildings, construction*. New York, NY, USA: Oxford University Press.

Allen, M., Antwi-Agyei, P., Aragon-Durand, F., Babiker, M., Bertoldi, P., Bind, M., ... Cartwright, A., et al. (2019). Technical Summary: Global warming of 1.5 C. An IPCC Special Report on the impacts of global warming of 1.5 C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the thre.

Archi. (2012). Archi – Open Source ArchiMate Modelling. Retrieved April 9, 2020, from https://www.archimatetool.com/

Braungart, M., McDonough, W., & Bollinger, A. (2007). Cradle-to-cradle design: creating healthy emissions – a strategy for eco-effective product and system design. *Journal of Cleaner Production*, *15*(13-14), 1337–1348. doi:10.1016/j.jclepro.2006.08.003

Ceballos, G., Ehrlich, P. R., & Dirzo, R. (2017). Biological annihilation via the ongoing sixth mass extinction signaled by vertebrate population losses and declines. *Proceedings of the National Academy of Sciences*, *114*(30), E6089–E6096. doi:10.1073/pnas.1704949114

Gamma, E., & al, E. (1995). *Design Patterns - Elements of Object Oriented Software Architecture*.

Geissdoerfer, M., Savaget, P., Bocken, N. M., & Hultink, E. J. (2017). The Circular Economy – A new sustainability paradigm? *Journal of Cleaner Production*, *143*, 757–768. doi:10.1016/j.jclepro.2016.12.048

Geissdoerfer, M., Vladimirova, D., & Evans, S. (2018). Sustainable business model innovation: A review. *Journal of Cleaner Production*, *198*, 401–416. doi:10.1016/j.jclepro.2018.06.240

Haefele, M. (2018). Sustainable investing can propel long-term returns — Financial Times. *Financial Times*. Retrieved from https://www.ft.com/content/292ecaa7-294c-3a4b-bde6-a7a744cb85a9

Iacob, M. E., Meertens, L. O., Jonkers, H., Quartel, D. A. C., Nieuwenhuis, L. J. M., & van Sinderen, M. J. (2012). From enterprise architecture to business mod-

els and back. *Software & Systems Modeling*, *13*(3), 1059–1083. doi:10.1007/s10270-012-0304-6

Kirchherr, J., Reike, D., & Hekkert, M. (2017). Conceptualizing the circular economy: An analysis of 114 definitions. *Resources, Conservation and Recycling*, *127*(September), 221–232. doi:10.1016/j.resconrec.2017.09.005

Kitchenham, B., & Charters, S. (2007). *Guidelines for performing Systematic Literature Reviews in Software Engineering* (tech. rep. No. 3).

Köster, O. (2013). *Systematik zur Entwicklung von Geschäftsmodellen in der Produktentstehung* (Doctoral dissertation, University of Paderborn). Retrieved from http://dnb.ddb.de

Kotzé, P., Tsogang, M., & van der Merwe, A. (2012). A Framework for Creating Pattern Languages for Enterprise Architecture. (pp. 1–20). doi:10.1007/978-3-642-34163-2_1

Lankhorst, M. M., Proper, H. A., & Jonkers, H. (2009). The Architecture of the ArchiMate Language. In *Lecture notes in business information processing* (Vol. 29 LNBIP, pp. 367–380). doi:10.1007/978-3-642-01862-6_30

Lankhorst, M. (2017). *Enterprise Architecture at Work* (3rd). The Enterprise Engineering Series. doi:10.1007/978-3-662-53933-0

Lepak, D. P., & Snell, S. A. (2002). Examining the Human Resource Architecture: The Relationships Among Human Capital, Employment, and Human Resource Configurations. *Journal of Management*, *28*(4), 517–543. doi:10.1177/014920630202800403

Meadows, D., Randers, J., & Meadows, D. (2004). *LIMITS TO GROWTH*. Earthscan.

Nardi, J. C., Almeida, J. P. A., Pereira, M. C., Falbo, R. D. A., Iacob, M.-E., van Sinderen, M., & Pires, L. F. (2016). Service Commitments and Capabilities across the ArchiMate Architectural Layers. In *2016 ieee 20th international enterprise distributed object computing workshop (edocw)* (Vol. 2016-Septe, pp. 1–10). doi:10.1109/EDOCW.2016.7584386

Osterwalder, A., & Pigneur, Y. (2010). *Business model generation: a handbook for visionaries, game changers, and challengers*. John Wiley & Sons, Inc.

Porter, M. E. (1998). *Competitive Advantage: Creating and Sustaining Superior Performance*. doi:10.1016/j.neubiorev.2009.11.015

Rogers, E. M. (2003). *Diffusion of Innovations, 5th Edition*. Free Press. Retrieved from https://books.google.nl/books?id=9U1K5LjUOwEC

Rouhani, B. D., Mahrin, M. N., Nikpay, F., Ahmad, R. B., & Nikfard, P. (2015). A systematic literature review on Enterprise Architecture Implementation Methodologies. *Information and Software Technology*, *62*, 1–20. doi:10.1016/j.infsof.2015.01.012

Russell, N., van der Aalst, W., & ter Hofstede, A. (2016). *Workflow Patterns: The Definitive Guide*. MIT Press.

Stahel, W. R. (2016). Circular economy. *Nature*, 435–438.

Taylor, M., Watts, J., & Bartlett, J. (2019). Climate crisis: 6 million people join latest wave of global protests. London. Retrieved from https://www.theguardian.com/environment/2019/sep/27/climate-crisis-6-million-people-join-latest-wave-of-worldwide-protests

The Open Group. (2018). *The TOGAF® Standard, Version 9.2*. Retrieved from https://www.vanharen.net/the-togaf-standard-version-9-2/

The Open Group. (2019). ArchiMate® 3.1 Specification: Chapter 3 Language Structure. Retrieved November 6, 2019, from https://pubs.opengroup.org/architecture/archimate3-doc/chap03.html

United Nations. (2015). *Transforming Our World: The 2030 Agenda for Sustainable Development*. United Nations Publishing. New York, New York, USA. Retrieved from https://sustainabledevelopment.un.org/?menu=1300

University of Cambridge Institute for Sustainability Leadership (CISL). (2016). *Taking the long view A toolkit for long-term, sustainable investment mandates Publication details*. University of Cambridge Institute. Cambridge. Retrieved from www.cisl.cam.ac.uk/publications

Venkatesh, V., Morris, M. G., Davis, G. B., & Davis, F. D. (2003). User acceptance of information technology: Toward a unified view. *MIS Quarterly: Management Information Systems*. doi:10.2307/30036540

Weill, P., Malone, T. W., D'urso, V. T., Herman, G., & Woerner, S. (2005). *Do Some Business Models Perform Better than Others? A Study of the 1000 Largest US Firms*.

Wieringa, R. J. (2014). *Design science methodology: For information systems and software engineering*. doi:10.1007/978-3-662-43839-8. arXiv: arXiv:1011.1669v3

Wolfswinkel, J. F., Furtmueller, E., & Wilderom, C. P. M. (2013). Using grounded theory as a method for rigorously reviewing literature. *European Journal of Information Systems*, *22*(1), 45–55. doi:10.1057/ejis.2011.51

WWF. (2012). *Living Planet Report 2012*. Retrieved from http://awsassets.panda.org/downloads/1%7B%5C_%7Dlpr%7B%5C_%7D2012%7B%5C_%7Donline%7B%5C_%7Dfull%7B%5C_%7Dsize%7B%5C_%7Dsingle%7B%5C_%7Dpages%7B%5C_%7Dfinal%7B%5C_%7D120516.pdf

Zachman, J. A. (1987). A framework for information systems architecture. *IBM systems journal*, *26*(3), 276–292.

Appendix A

Enterprise Architecture Patterns - Systematic Literature Review sample

What follows are the sources for Chapter 2 SLR. It can also be found in https://github.com/robertorgarcia/EAPatterns/blob/master/Appendix%20A%20-%20Sources.csv

- P1: Weking, J., Hein, A., Böhm, M., & Krcmar, H. (2018). A hierarchical taxonomy of business model patterns. Electronic Markets, 9(1), 97–104. https://doi.org/10.1007/s12525-018-0322-5

- P2: Lüdeke-Freund, F., Gold, S., & Bocken, N. M. P. (2019). A Review and Typology of Circular Economy Business Model Patterns. Journal of Industrial Ecology, 23(1), 36–61. https://doi.org/10.1111/jiec.12763

- P3: Da Silva, L. F., & E Abreu, F. B. (2010). An IT Infrastructure patterns approach to improve IT service management quality. Proceedings - 7th International Conference on the Quality of Information and Communications Technology, QUATIC 2010, 171–176. https://doi.org/10.1109/QUATIC.2010.34

- P4: Yamamoto, S., & Zhi, Q. (2019). ArchiMate Business Model Patterns to e-Healthcare. In Y.-W. Chen, A. Zimmermann, R. J. Howlett, & L. C. Jain (Eds.), Smart Innovation, Systems and Technologies (Vol. 145, pp. 11–20). https://doi.org/10.1007/978-981-13-8566-7_2

- P5: Betz, C. T. (2011). Architecture and Patterns for IT Service Management, Resource Planning, and Governance: Making Shoes for the Cobbler's Children. In Architecture and Patterns for IT Service Management, Resource Planning, and Governance: Making Shoes for the Cobbler's Children. https://doi.org/10.1016/C2010-0-65839-1

- P6: Amshoff, B., Dülme, C., Echterfeld, J., & Gausemeier, J. (2015). Business model patterns for disruptive technologies. International Journal of Innovation Management, 19(3), 1540002. https://doi.org/10.1142/S1363919615400022
- P7: Zufall, J., Norris, S., Schaltegger, S., Revellio, F., & Hansen, E. G. (2019). Business model patterns of sustainability pioneers - Analyzing cases across the smartphone life cycle. Journal of Cleaner Production, 118651. https://doi.org/10.1016/j.jclepro.2019.118651
- P8: Remane, G., Hildebrandt, B., Hanelt, A., & Kolbe, L. M. (2016). Discovering new digital business model types - A study of technology startups from the mobility sector. Pacific Asia Conference on Information Systems, PACIS 2016 - Proceedings.
- P9: Buckl, S., Ernst, A., Kopper, H., Marliani, R., Matthes, F., Petschownik, P., & Schweda, C. (2009). EA Management Patterns for Consolidations after Mergers. SE 2009 – Workshopband, Workshop on Patterns in Enterprise Architecture Management (PEAM 2009), 19, 67–78. https://doi.org/10.1016/j.cell.2008.01.015
- P10: Khosroshahi, P. A., Hauder, M., Schneider, A. W., & Matthes, F. (2015). EAM Pattern Catalog Version 2.0. In Faculty for Informatics, TU München.
- P11: Barros, O., & Julio, C. (2011). Enterprise and process architecture patterns. Business Process Management Journal, 17(4), 598–618. https://doi.org/10.1108/14637151111149447
- P12: Šaša, A., & Krisper, M. (2011). Enterprise architecture patterns for business process support analysis. Journal of Systems and Software, 84(9), 1480–1506. https://doi.org/10.1016/j.jss.2011.02.043
- P13: Lankhorst, M. M., & Luttighuis, P. H. W. M. O. (2009). Enterprise architecture patterns for multichannel management. Software Engineering (Workshops), 150(March), 31–42. Retrieved from https://dl.gi.de/handle/20.500.12116/20378
- P14: Perroud, T., & Inversini, R. (2014). Enterprise architecture patterns: Practical solutions for recurring IT-architecture problems. In Enterprise Architecture Patterns: Practical Solutions for Recurring IT-Architecture Problems (Vol. 9783642375). https://doi.org/10.1007/978-3-642-37561-3
- P15: Schneider, A. W., & Matthes, F. (2015). Evolving the EAM pattern language. The 20th European Conference, 1–11. https://doi.org/10.1145/2855321.2855367

- P16: Alamro, S., Dogan, H., & Phalp, K. (2015). Forming Enterprise Recruitment Pattern Based on Problem-Oriented Conceptual Model. Procedia Computer Science, 64, 298–305. https://doi.org/10.1016/j.procs.2015.08.493
- P17: da Silva, L. F., & e Abreu, F. B. (2010). Patterns for IT Infrastructure Design. Proceedings of the 15th European Conference on Pattern Languages of Programs (EuroPLoP'2010), 1–8.
- P18: Makna, J., & Kirikova, M. (2011). Patterns-based is change management in smes. In W. W. Song, S. Xu, C. Wan, Y. Zhong, W. Wojtkowski, G. Wojtkowski, & H. Linger (Eds.), Information Systems Development: Asian Experiences (pp. 55–66). https://doi.org/10.1007/978-1-4419-7355-9_5
- P19: Moser, C., Junginger, S., Brückmann, M., & Schöne, K.-M. (2009). Some Process Patterns for Enterprise Architecture Management. Software Engineering 2009 – Workshopband, 19–30.
- P20: Remane, G., Hanelt, A., Tesch, J. F., & Kolbe, L. M. (2017). The Business Model Pattern Database-A Tool For Systematic Business Model Innovation. International Journal of Innovation Management, 21(1). https://doi.org/10.1142/S1363919617500049
- P21: Lüdeke-Freund, F., Carroux, S., Joyce, A., Massa, L., & Breuer, H. (2018). The sustainable business model pattern taxonomy—45 patterns to support sustainability-oriented business model innovation. Sustainable Production and Consumption. https://doi.org/10.1016/j.spc.2018.06.004
- P22: Vicente, M., Gama, N., & Silva, M. M. Da. (2013). Using archimate to represent ITIL metamodel. Proceedings - 2013 IEEE International Conference on Business Informatics, IEEE CBI 2013, 270–275. https://doi.org/10.1109/CBI.2013.45
- P23: Buckl, S., Ernst, A. M., Matthes, F., Ramacher, R., & Schweda, C. M. (2009). Using enterprise architecture management patterns to complement TOGAF. Proceedings - 13th IEEE International Enterprise Distributed Object Computing Conference, EDOC 2009, 34–41. https://doi.org/10.1109/EDOC.2009.30
- P24: van der Aalst, W. M. P., & Hofstede, A. ter. (2011). Workflow patterns. Retrieved October 21, 2019, from http://www.workflowpatterns.com/

Appendix B

Enterprise Architecture Patterns

Due to the size of the resulting patterns, they have been published under the following address: https://github.com/robertorgarcia/EAPatterns/blob/master/Appendix%20B%20-%20Patterns.csv

Appendix C

Sustainable Development Characteristics - Systematic Literature Review sample

The sources used for the Systematic Literature Review performed in Chapter 3 is shown below. It can also be found in https://github.com/robertorgarcia/EAPatterns/blob/master/Appendix%20C%20-%20Sustainable%20Development%20Characteristics%20-%20Systematic%20Literature%20Review%20sample.csv

- S1: Duarte, S., Cabrita, M. do R., & Cruz-Machado, V. (2020). Business Model, Lean and Green Management and Industry 4.0: A Conceptual Relationship. In J. Xu, S. E. Ahmed, F. L. Cooke, & G. Duca (Eds.), Proceedings of the Thirteenth International Conference on Management Science and Engineering Management (Vol. 1001, pp. 359–372). https://doi.org/10.1007/978-3-030-21248-3_27
- S2: Lewandowski, M. (2016). Designing the Business Models for Circular Economy—Towards the Conceptual Framework. Sustainability, 8(1), 43. https://doi.org/10.3390/su8010043
- S3: Caldera, H. T. S., Desha, C., & Dawes, L. (2018). Exploring the characteristics of sustainable business practice in small and medium-sized enterprises: Experiences from the Australian manufacturing industry. Journal of Cleaner Production, 177, 338–349. https://doi.org/10.1016/j.jclepro.2017.12.265
- S4: Singh, A. K., & Vinodh, S. (2017). Modeling and performance evaluation of agility coupled with sustainability for business planning. Journal of Management Development, 36(1), 109–128. https://doi.org/10.1108/JMD-10-2014-0140
- S5: Jones, P., Comfort, D., & Hillier, D. (2015). Sustainability and the UK'S leading retailers. Trziste, 27(1), 93–111.

- S6: Garbie, I. (2016). Sustainability Practicing. In Sustainability in Manufacturing Enterprises (pp. 151–167). https://doi.org/10.1007/978-3-319-29306-6_13
- S7: de Pádua Pieroni, M., Pigosso, D. C. A., & McAloone, T. C. (2018). Sustainable Qualifying Criteria for Designing Circular Business Models. Procedia CIRP, 69, 799–804. https://doi.org/10.1016/j.procir.2017.11.014
- S8: Smith, P. A. C., & Sharicz, C. (2011). The shift needed for sustainability. The Learning Organization, 18(1), 73–86. https://doi.org/10.1108/09696471111096019
- S9: Caldera, H. T. S., Desha, C., & Dawes, L. (2019). Transforming manufacturing to be 'good for planet and people', through enabling lean and green thinking in small and medium-sized enterprises. Sustainable Earth, 2(1), 4. https://doi.org/10.1186/s42055-019-0011-z

Appendix D

Sustainable Development Characteristics and Classes

Due to the size of the resulting characteristics, they have been published under the following address: https://github.com/robertorgarcia/EAPatterns/blob/master/Appendix%20D%20-%20Sustainable%20Development%20Characteristics%20and%20Classes.csv

Appendix E

Enterprise Architecture Patterns and the Sustainable Development Characteristics they support

The set of patterns supporting sustainability can be found in: https://github.com/robertorgarcia/EAPatterns/blob/master/Appendix%20E%20-%20Sustainable%20Patterns%20.csv

Appendix F

Translated Enterprise Architecture Patterns

The set of Patterns translated to the Archimate language can be found in https://github.com/robertorgarcia/EAPatterns

Appendix G

New Patterns Proposed

The set of Patterns proposed can be found in https://github.com/robertorgarcia/EAPatterns

Appendix H

Enterprise Architecture Specification

The entire Enterprise Architecture Specification can be found in https://github.com/robertorgarcia/EAPatterns

Appendix I

Questionnaire

The questionnaire used for the validation of the method is shown below. As presented by Venkatesh et al. (2003).

Performance Expectancy (PE):

- U6: I would find the method useful in my job
- RA1: Using the method enables me to accomplish tasks more quickly
- RA5: Using the method increases my productivity
- OE7: If I use the method, I will increase my chances of getting a raise

Effort Expectancy (EE):

- EOU3: My interaction with the method would be clear and understandable
- EOU5: It would be easy for me to become skillful at using the method
- EOU6: I would find the method easy to use
- EU4: Learning to operate the method is easy for me

Attitude towards the system (ATUT):

- A1: Using the method is a bad/good idea
- AF1: The method makes work more interesting
- AF2: Working with the method is fun
- Affect1: I like working with the method

Social influence (SI):

- SN1: People who influence my behavior think that I should use the method

- SN2: People who are important to me think that I should use the method
- SF2: The senior management of this business has been helpful in the use of the method
- SF4: In general, the organization has supported the use of the method

Facilitating conditions (FC):

- PBC2: I have the resources necessary to use the method
- PBC3: I have the knowledge necessary to use the method
- PBC5: The method is not compatible with other systems I use
- FC3: A specific person (or group) is available for assistance with method difficulties

Self-efficacy (SE):

- SE1: I could complete a job or task using the method If there was no one around to tell me what to do as I go
- SE4: I could complete a job or task using the method If I could call someone for help if I got stuck
- SE6: I could complete a job or task using the method If I had a lot of time to complete the job for which it was provided
- SE7: I could complete a job or task using the method If I had just the built-in help facility for assistance

Anxiety (ANX):

- ANX1: I feel apprehensive about using the method
- ANX2: It scares me to think that I could lose a lot of information using the method by hitting the wrong key
- ANX3: I hesitate to use the method for fear of making mistakes I cannot correct
- ANX4: The method is somewhat intimidating to me

Behavioral intention to use the system (BI):

- BI1: I intend to use the method in the next ¡n¿ months
- BI2: I predict I would use the method in the next ¡n¿ months
- BI3: I plan to use the method in the next ¡n¿ months