On Enterprise Architecture Patterns: A Tool for Sustainable Transformation

Roberto García-Escallón(✉), Adina Aldea, and Marten van Sinderen

University of Twente, Enschede, The Netherlands

Abstract. Organizations across the world today face similar problems, thus, solutions to these problems could also be re-used across many organizations. Climate change is one such common problem to organizations, where any solution implemented by one could be re-used by many others. These re-usable solutions could be Enterprise Architecture Patterns, but there is a lack of guidance on how to use them in practice. This study proposes an extension to the commonly used TOGAF, to better leverage these reusable solutions. Thus, this enables organizations using this framework to enhance it with Enterprise Architecture Patterns. As part of the proposed methodology, re-usable patterns supporting sustainable characteristics are built. The resulting methodology is validated with an expert panel, gathering positive comments.

Keywords: Enterprise Architecture · Enterprise Architecture Patterns · Sustainability

1 Introduction

Today, climate change calls for a widespread transformation. A transformation for a sustainable society that is being demanded by millions around the globe [20]. Many projects are underway to make said change a reality, but time is running out, as the looming deadline of 2030 for reducing carbon emissions by 45% worldwide, to avoid warming higher than 1.5 °C, nears [2]. Although, the kind of changes required is 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. Because some of the changes needed to diminish emissions are common throughout organizations, solutions developed for one organization may apply to others. For these common challenges and repeatable solutions, the concept of patterns is of great value [1].

As Enterprise Architecture (EA) practitioners aim to steer changes in organizations, they are pushed to do so at an increasing pace. Besides climate change, the pace of technological change and the threat of being disrupted is driving organizations to change faster. To enable EA practitioners to bring about these transformations in organizations, this study proposes a methodology for the specification of EA for sustainable organizations using patterns. This study is a

J. Filipe et al. (Eds.): ICEIS 2020, LNBIP 417, pp. 858–882, 2021.
https://doi.org/10.1007/978-3-030-75418-1_39

followup of [7], and [6], and is organized as follows: First, a description of the background is provided; second, the research methodology is described; third, the results of a systematic literature review are reported; fourth, the methodology is proposed; fifth, a validation of the methodology is shown; finally, conclusions are drawn.

2 Background

Enterprise Architecture (EA) is a relatively new field of research that aims to steer the change in an organization [13]. 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 Framework (TOGAF), among others [21,27]. 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 [12]. 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.

2.1 Patterns

The organizations' EA is applied in, as well as all other organizations, have similarities in their structure and behaviour with other organizations, similarities that could be also called patterns. In the words of Alexander [1], 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" [1]. 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 [5]. 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.

2.2 Sustainability

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 [23]. The effects of climate change are clear: climate change, impacts to human health, mass extinction of species, among others [3,4,19].

Climate change calls for a transformation, one that is widespread and towards sustainability, which is being demanded by millions around the globe [20]. 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 °C, draws closer [2]. 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.

3 Research Methodology

The approach followed throughout this study is Design Science Methodology [25]. As a methodology, Design Science describes the designing and investigating of an artifact and its interaction with its context. These activities correspond with the research problems in design science, they are either Design Problems or Knowledge Questions. The former focuses on designing a solution that will act within a problem context, the latter focuses on knowledge without the influence of the context [25].

The implementation of this methodology is based on a cycle, the engineering cycle. It is composed of four steps, the investigation of the problem, the design of the solution, its validation and finally its implementation. Within the scope of this study, the solution in question was not implemented [25].

To achieve the study's goal, these steps are followed, starting with the definition of the design problem: the need for an increased pace of EA change projects, and the difficulty practitioners face when treating sustainability concerns in organizations. To solve the problem, an artifact designed to enable practitioners to prepare an EA specification for sustainable organizations using patterns is prepared.

In order to design this artifact, first, an investigation on the problem is performed, to which two knowledge questions were identified, *what EAPs are there in literature?* and *what characterizes a sustainable organization?*. These two questions are answered using the Systematic Literature Review (SLR) methodology shown below, and their results are shown in Sect. 4.

After gathering the required knowledge during the problem investigation step the artifact is designed. This design is described in Sect. 5. Finally, The artifact is then validated, using a case study and interviews with experts as shown in Sect. 6. A more detailed description of this step can be found in [7].

3.1 Systematic Literature Review

In order to answer the knowledge questions, two separate SLR are performed. The SLRs follow the methodology of Rouhani et al. [18], as it is a very thorough work in the EA field. This method outlines three stages to a SLR: a planning

phase, an execution phase and a result analysis phase. In order to enhance this method and arrive at a richer set of literature, the backwards and forwards citation techniques will be included, to include additional articles that might be relevant but were not present in the results of the initial query [26]. In order to execute this last step, Google Scholar was used, which shows both, backward and forward citations, easily. For all other steps leverage Scopus, ACM Digital Library, IEEE Xplore, Science Direct - Elsevier, Springer Link, Taylor and Francis and Web of Science. The process is shown in Fig. 1. For the first knowledge question, the keywords used *"enterprise architecture" AND "Pattern"*. While for the second knowledge question the steps were more relaxed as the time constraints on the study drew nearer. As such, the backward and forward citation techniques were not performed. Finally, the keywords used for the second review were *"characteristics of sustainability" or "characteristics of circular economy" or "characteristics of sustainable business" or "sustainability characteristics" or "circular economy characteristics" or "sustainable business characteristics"*.

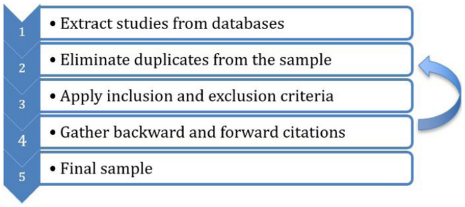

Fig. 1. Overall process of the SLR - adapted from [6].

4 Systematic Literature Reviews

In this section, the two SLR executed are described, first on EAPs in literature, second on Characteristics of sustainable organizations. The results of the former SLR was first published in [6], but the main findings are included here. The results of the latter SLR can be found in [7], but the results are included below.

4.1 EAPs in Literature

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 periods. 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 SBMs, 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 [16]. Although the

representation of the patterns may differ, their basic constructs are the same, which would make it possible to translate these patterns into an EA representation of them, based on the work of [10]. This method would pave the way to take these Business Model Patterns repositories into EAPs.

Being able to relate the patterns extracted from SBMs, and translating them to EA, 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 [23], 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.

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. This lack of information may be related to 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 of 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 of EAPs 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 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.

Fields Researching Patterns. On Fig. 2 we have classified the four main types of patterns found through the SLR in terms of the four main layers of the Archimate Language [13]. Based on [10] and the Archimate constructs they use to describe a Business Model [16] 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.

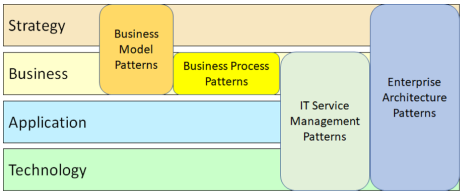

Fig. 2. Classification of fields - adapted from [6].

Enterprise Architecture Management Patterns are omitted from this graph. This is due to their focus on the practice of EA 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 an EA framework and methodology. Thus, although the focus of the EAM patterns is the EA practice itself, this is different to the EAPs, which is the enterprise.

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 the EA field are based on the 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 a repeating problem is also present in other works on patterns [1]. 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 an exhaustive work but do not explicitly show all possible combinations. Finally, P22 took current standards and made them into patterns.

The 50% of studies in the sample-based the patterns from the author's experience. When reviewing the definitions by [1] 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 the literature review and author's experience are P5 and P17 which base their patterns on standard practices. In the 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 [1]. 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.

4.2 Characteristics of Sustainable Organizations

In this section, the results of an SLR performed to find the characteristics of sustainability is described. 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.

Classification of Characteristics. 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 the capabilities of the organization. These, and all other classes, are explained in further detail below. In Tables 1 and 2 this classification is shown.

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.

4.3 Description

In Fig. 3 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 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

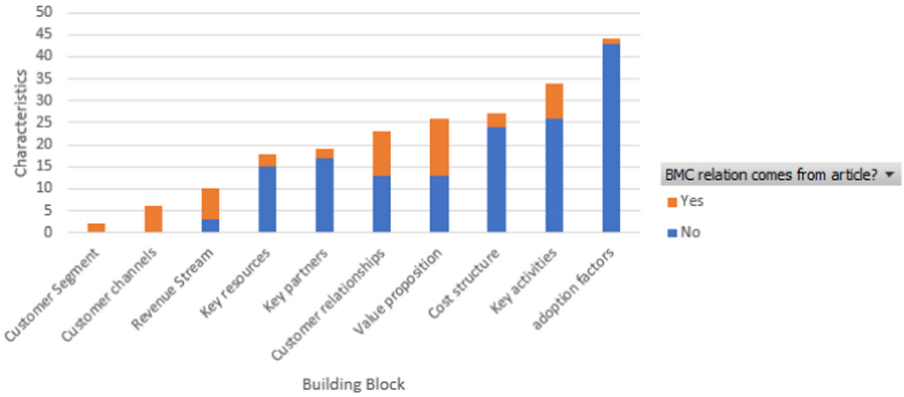

Fig. 3. Characteristics classified.

Table 1. Classification of characteristics.

Building block	Description of characteristics classified to this block
Customer segments	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 [17]
Customer relationships	Co-creation of the value proposition, community relationships
Channels	In this SLR the characteristics found to belong to this class all focus on the relationship between the organization and their customer. Among them some are 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) [9]. Also in this block are the characteristics related to take-back systems (C27,C49)
Value proposition	Those that 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)
Key activities	Varied, 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 rainwater, conserving natural resources, and avoiding using slave labour (C126, C128, C131, C204, C152, C151)
Key Resources	Varied, 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 bio-materials 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)

(*continued*)

Table 1. (*continued*)

Building block	Description of characteristics classified to this block
Key partnerships	Characteristics that 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)
Revenue stream	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 the supply chain, etc. (C18, C20, C17, C19)

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 wastewater, physical waste, emissions, and end of life of products of organizations.

Table 2. Classification of characteristics cont'd.

Building block	Description of characteristics classified to this block
Cost structure	Divided into 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	An example are the characteristics focusing on learning at an organizational level, as well as educating the community it is 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)

4.4 Applicable Characteristics

The following section relates the characteristics with Archimate concepts, mainly through the 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 [10]. 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 the lower layer's concepts, e.g. an application component. In Table 3 the BMC building blocks, including the two extensions mentioned above, are shown. With an X the relationship studied by [10] is shown and with a C the relationship proposed after reviewing the Sustainability Characteristics. The reasoning behind each assignment is explored below.

Table 3. Relation between extended BMC and Archimate. X means relationship is defined by [10], 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

The adoption factors building block, as it's a new concept being introduced in S2, is not present in the previous studies [10]. 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. leadership creating strategies for reducing waste (C62, C63, C64), that describe how the organization should act then it is closely to 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 no concept ties directly to it. The language specification mentions that object attributes could be used for costs [22]. [10] 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 previous studies [10]. 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 seen in 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 labour 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. This 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.

5 Methodology for the Specification of EA Using Patterns

Although the first two knowledge questions posed above were answered, there were still a few building blocks missing before a methodology could be designed. First, from the sample of EAPs gathered, a small subset of them were described using a common language. Second, besides the BMI patterns, no EAPs were focusing on sustainability. Third, any methodology would depend on the combination of multiple EAPs, alas no studies in the sample mentioned ways to do so. Thus, the following subsection focuses on these design problems and the solutions proposed.

5.1 Designing the Building Blocks

Translating the Subset of Patterns to Archimate. The EAPs found in the SLR were described in multiple ways, written and with diagrams, some were described using Archimate, while some others were already described using other modeling languages. A subset of the latter were translated by the author concentrating on being as aligned with the source as possible. All other patterns translated 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 the Appendix. There, both the source file and extracted images are present.

Proposing New Patterns. After performing the translation, some gaps were identified and in some of the EAPs, i.e. the applications are deployed to nodes in the internal facilities of the organization. However, as is found in the Characteristics found in the second knowledge question, sharing and virtualization is a characteristic of sustainable businesses, and currently, a popular 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 SaaS, PaaS, and IaaS service respectively. These were built using the guidelines established by [15]. In Fig. 4 the NewPattern001 is shown, the other two follow the same structure. Under the Appendix, the diagrams and source files of these EAPs can be found.

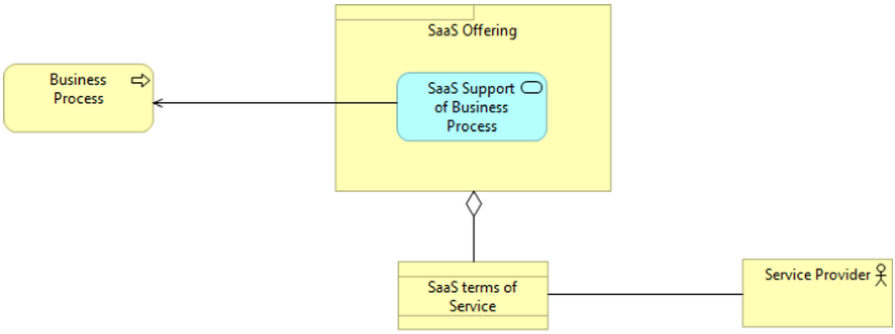

Fig. 4. NewPattern001.

Proposing Sustainable Patterns. Following this gap, 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, as they were compared to Archimate concepts in Table 3 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 cataloged in the Appendix.

The resulting patterns use Archimate concepts, except for Key partners which does not include application layer concepts. Instead, the characteristics describe business concepts with certain requirements, however, it's arguably impossible to fulfil 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 objects. 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 the 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 into 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 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 centres. Second, a group describing IT resources. Third, a group describing production processes and buildings.

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 Fig. 5, 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.

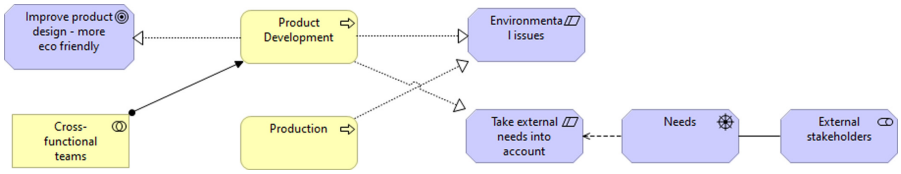

Fig. 5. Key activities - product.

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 Fig. 6. By describing the patterns that are derived from pattern X and the patterns Y that fulfil 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 between patterns documented previously would be automated.

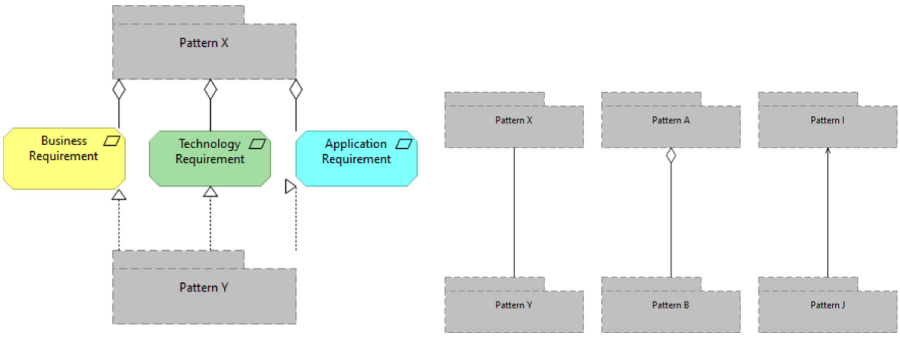

Fig. 6. Requirements and patterns & patterns combined.

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 Fig. 6. Here, a description of two patterns that are related to 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 Fig. 6 between pattern I and J. This combination happens mainly when pattern J is focused on 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 noticeable lack of patterns describing how one layer may serve the next.

The fourth way of combining patterns is through the aggregation relationship. This case is shown in Fig. 6, 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 Fig. 6. In some cases, EAPs describe multiple layers of EA, Business, Application, and even Technology. However, due to the ways patterns can be combined with each other, and especially 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 Fig. 6, where Pattern Q is decomposed in its layers, and its sub-patterns for application and technology layers are exchanged for Pattern R. An example of 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 (Fig. 7).

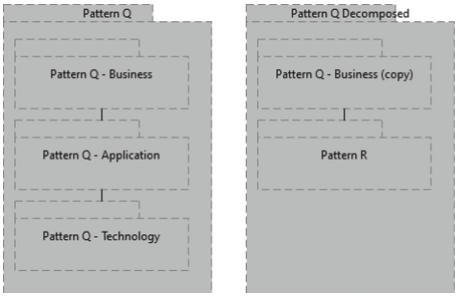

Fig. 7. Patterns decomposed.

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.

To avoid falling into the Yet Another Model trap, the proposed methodology is based on the ADM. 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.

5.2 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. 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.

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.

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.

In Fig. 8 a view into such a phase is given. This was taken from a case study performed using the methodology. In the figure, the guiding pattern can be found at the top left, from which a series of business layer requirements are detected and listed using the before mentioned notation. On the right side of the figure, the patterns found to fulfil the requirements are gathered. These patterns are linked using the Realization relationship as proposed in the notation above. Similar diagrams are prepared for each layer, Application and Technology.

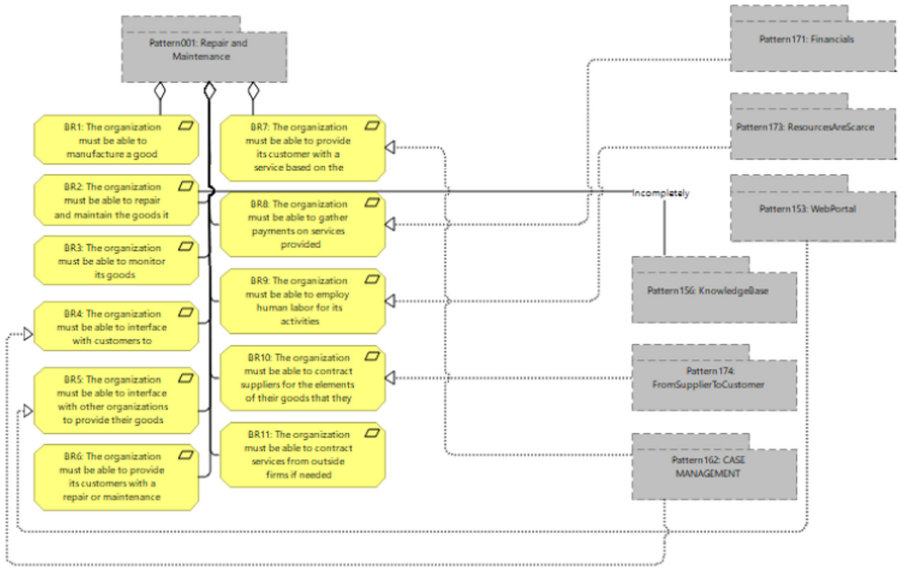

Fig. 8. Preliminary phase example.

5.3 Specification Phases

Following on comes the specification of the EA, through phases B, C, and D. 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.

In Fig. 9 the result of these phases can be seen. Using the proposed notation and methodology in a case study, a specification of EA was built [7]. With this single view, practitioners could have a simple way to communicate how an entire organization functions, by leveraging a shared understanding of the solutions being reused.

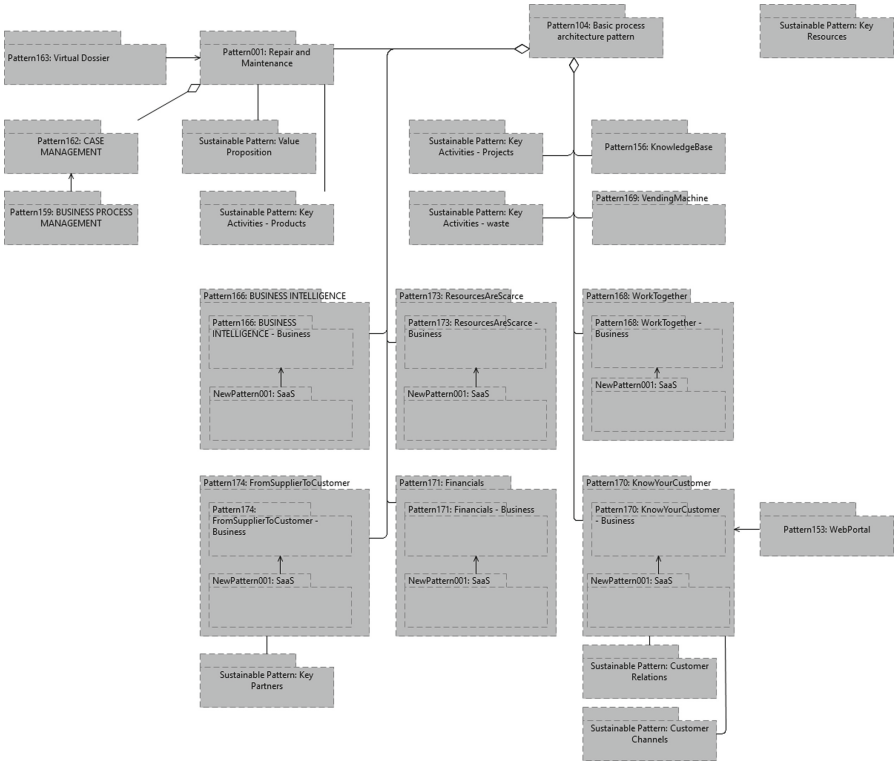

Fig. 9. EA specification using patterns.

6 Validation of the Methodology

Following the Design Science methodology, after developing a solution it must then be validated, prior to its implementation [25]. 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). This theory is selected as it has been proven to be effective in predicting the adoption of Information Systems, with an r-squared of 0.5 [24]. However, the sample size of this study means that the results are valid for qualitative analysis only. This questionnaire is present in the Appendix.

6.1 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 an architect (expert B)

3. An architect from a major cloud provider, with 2 years experience as an architect (expert C)
4. An architect working with a large consulting firm, mainly dealing with financial sector customers, with 8 years of experience as an architect (expert D)
5. An architect working with a large consulting firm, mainly dealing with financial sector customers, with 6 years of experience as an 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.

6.2 Experts Opinion

Overall the experts' opinions were positive. A 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 informally. 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 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 criterion in one of their customers. As for expert 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 implement them. Expert B even went as far as proposing that a possible next step to this study is the identification of implementation patterns that organizations could use depending on their own capabilities.

However, exceptions were experts D and E that mentioned their worry on

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 commented on 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 to the methodology's description are necessary to make this relationship more clear.

6.3 Questionnaire Results

Table 4. 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

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 (Table 4).

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. This corresponds with their 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. Inversely, 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. The **ATUT** construct had a similarly

positive result meaning that experts perceive the methodology interesting, fun, or a good idea.

The **BI** and **SI** constructs had a split score, half of the experts evaluated them positively and half as negative. For the former, representing that they are not certain they will use the methodology in the future. For the latter, it may be because this method was not shown to any of their superiors, as all items relate to external social influences.

7 Conclusions

The result of this study is a methodology for the specification of EA for sustainable organizations using patterns. 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 extending the ADM, building upon its same phases to make its adoption simpler to organizations already using the TOGAF. 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.

First, an SLR was performed to gather the state of the literature for EAPs. 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. However, the sources used were 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 were an obstacle. As these are usually limited to a relatively short number of pages, it is difficult to present all the information that 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.

Second, an SLR was performed to gather 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. This set is likely incomplete, as the literature on sustainability is increasingly wide and complex. For example, there are more than 100 different definitions on Circular Economy alone [8,11]. 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 of 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.

In the field of EA, the use of sustainability concepts is not common, and including them in 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 labour. However, a step further would be to design structural and behavioural components in an organization that implicitly implements the requirements used in this study. These newly designed components could then become patterns to be adopted widely.

7.1 Contributions

The contributions to academia are multiple. 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, including fields like BMI and BPM. 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 of 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.

As for practitioners, the methodology proposed can be applied together with the patterns found in scientific literature and industry standards, simplifying EA projects by using it as a common language describing solutions proven to work in other organizations. Second, the set of sustainability characteristics classified in terms of the building blocks of the BMC offer organizations today a classified list, based on scientific literature, of characteristics they can implement to be more sustainable. Third, a notation was proposed to describe the relationships of patterns used in an organization. This 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.

7.2 Limitations

The main limitation is the language used, where the concept of the *pattern* may not be used commonly, especially in other fields of research. An example is the Human Resource (HR) Architectures proposed by [14], which show patterns in HR management. This is present also with the sustainability keywords, where a more in-depth exploration of the terms used in the field may have gleaned more characteristics. However, 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.

7.3 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 organizations, either through literature or with the help of its members. This is similarly 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. Another way to extract them 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.

Finally, the implementation of this methodology into a traditional EA project using TOGAF is needed. Through its real-world usage, a more thorough validation would be achieved, allowing its improvement into a more valuable tool for the field.

Appendix

Under the git repository https://github.com/robertorgarcia/EAPatterns the appendices to this study can be found. Specifically the following:

- The study samples used in the SLRs
- The results of the SLRs (EAPs and Characteristics)
- The intermediary classifications of the results
- A subset of EAPs translated to Archimate
- A set of proposed EAPs
- A case study built using EAPs

References

1. Alexander, C., Ishikawa, S., Silverstein, M.: A Pattern Language: Towns, Buildings, Construction. Oxford University Press, New York (1977)
2. Allen, M., et al.: Technical summary: global warming of 1.5 c. An IPCC Special Report on the impacts of global warming of 1 (2019)
3. Braungart, M., McDonough, W., Bollinger, A.: Cradle-to-cradle design: creating healthy emissions - a strategy for eco-effective product and system design. J. Cleaner Prod. **15**(13–14), 1337–1348 (2007). https://doi.org/10.1016/j.jclepro.2006.08.003

4. Ceballos, G., Ehrlich, P.R., Dirzo, R.: Biological annihilation via the ongoing sixth mass extinction signaled by vertebrate population losses and declines. Proc. Natl. Acad. Sci. **114**(30), E6089–E6096 (2017). https://doi.org/10.1073/pnas.1704949114
5. Gamma, E., et al.: Design Patterns - Elements of Object Oriented Software Architecture (1995)
6. García-Escallón, R., Aldea, A.: On enterprise architecture patterns: a systematic literature review. In: Proceedings of the 22nd International Conference on Enterprise Information Systems, pp. 666–678. SCITEPRESS - Science and Technology Publications (2020). https://doi.org/10.5220/0009392306660678
7. Garcia-Escallon, R.: Enterprise architecture patterns: Supporting sustainable development. Ph.D. thesis, University of Twente, Enschede, The Netherlands (2020)
8. Geissdoerfer, M., Savaget, P., Bocken, N.M., Hultink, E.J.: The circular economy - a new sustainability paradigm? J. Cleaner Prod. **143**, 757–768 (2017). https://doi.org/10.1016/j.jclepro.2016.12.048
9. Geissdoerfer, M., Vladimirova, D., Evans, S.: Sustainable business model innovation: a review. J. Cleaner Prod. **198**, 401–416 (2018). https://doi.org/10.1016/j.jclepro.2018.06.240
10. Iacob, M.E., Meertens, L.O., Jonkers, H., Quartel, D.A.C., Nieuwenhuis, L.J.M., van Sinderen, M.J.: From enterprise architecture to business models and back. Softw. Syst. Model. **13**(3), 1059–1083 (2012). https://doi.org/10.1007/s10270-012-0304-6
11. Kirchherr, J., Reike, D., Hekkert, M.: Conceptualizing the circular economy: an analysis of 114 definitions. Resour. Conserv. Recycl. **127**(September), 221–232 (2017). https://doi.org/10.1016/j.resconrec.2017.09.005
12. Lankhorst, M.M., Proper, H.A., Jonkers, H.: The architecture of the archimate language. In: Halpin, T., Krogstie, J., Nurcan, S., Proper, E., Schmidt, R., Soffer, P., Ukor, R. (eds.) BPMDS/EMMSAD -2009. LNBIP, vol. 29, pp. 367–380. Springer, Heidelberg (2009). https://doi.org/10.1007/978-3-642-01862-6_30
13. Lankhorst, M.: Enterprise Architecture at Work. The Enterprise Engineering Series, 3rd edn. Springer, Heidelberg (2017). https://doi.org/10.1007/978-3-662-53933-0
14. Lepak, D.P., Snell, S.A.: Examining the human resource architecture: the relationships among human capital, employment, and human resource configurations. J. Manag. **28**(4), 517–543 (2002). https://doi.org/10.1177/014920630202800403
15. Nardi, J.C., et al.: 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. IEEE (2016). https://doi.org/10.1109/EDOCW.2016.7584386
16. Osterwalder, A., Pigneur, Y.: Business Model Generation: A Handbook for Visionaries, Game Changers, and Challengers. John Wiley & Sons, Inc., Hoboken (2010)
17. Rogers, E.M.: Diffusion of Innovations, 5th edn. Free Press, New York (2003)
18. Rouhani, B.D., Mahrin, M.N., Nikpay, F., Ahmad, R.B., Nikfard, P.: A systematic literature review on enterprise architecture implementation methodologies. Inf. Softw. Technol **62**, 1–20 (2015). https://doi.org/10.1016/j.infsof.2015.01.012
19. Stahel, W.R.: Circular economy. Nature **531**, 435–438 (2016)
20. Taylor, M., Watts, J., Bartlett, J.: Climate crisis: 6 million people join latest wave of global protests (2019). https://www.theguardian.com/environment/2019/sep/27/climate-crisis-6-million-people-join-latest-wave-of-worldwide-protests

21. The Open Group: The TOGAF® Standard, Version 9.2 (2018). https://www.vanharen.net/the-togaf-standard-version-9-2/
22. The Open Group: ArchiMate® 3.1 Specification: Chapter 3 Language Structure (2019). https://pubs.opengroup.org/architecture/archimate3-doc/chap03.html
23. United Nations: Transforming Our World: The 2030 Agenda for Sustainable Development. Technical report, United Nations Publishing, New York, New York, USA (2015). https://sustainabledevelopment.un.org/?menu=1300
24. Venkatesh, V., Morris, M.G., Davis, G.B., Davis, F.D.: User acceptance of information technology: toward a unified view. MIS Q. Manag. Inf. Syst. (2003). https://doi.org/10.2307/30036540
25. Wieringa, R.J.: Design Science Methodology: For Information Systems and Software engineering. Springer, Heidelberg (2014). https://doi.org/10.1007/978-3-662-43839-8
26. Wolfswinkel, J.F., Furtmueller, E., Wilderom, C.P.M.: Using grounded theory as a method for rigorously reviewing literature. Eur. J. Inf. Syst. **22**(1), 45–55 (2013). https://doi.org/10.1057/ejis.2011.51
27. Zachman, J.A.: A framework for information systems architecture. IBM Syst. J. **26**(3), 276–292 (1987)