Strengthen the Architecture Principle Definition and Its Characteristics

A Survey Encompassing 27 Years of Architecture Principle Literature

Michiel Borgers and Frank Harmsen
School of Business and Economics, Maastricht University, Tongersestraat 53, Maastricht, The Netherlands

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Abstract: Although architecture principles are important in the implementation of information systems requirements, empirical evidence of the effect of architecture principles is lacking. Before actually conducting the empirical research, it is important to have a solid definition and description of the research object, i.e. the architecture principle. In this paper, we strengthen both the definition of the architecture principle and the description of its characteristics. With a model based analysis we investigated 27 years of literature on architecture principles and eliminated inaccuracies and incompleteness. This definition and description provides a basis for determining the impact of using architecture principles during the implementation of the information systems requirements in our next step of research.

1 INTRODUCTION

The implementation of information systems plays an important role in digital transformations. Architecture principles play a key role in guiding the design and the implementation of information system requirements. Architecture principles are "central elements of enterprise architecture frameworks" (Stelzer 2009) and architecture principles enable the regulative role of enterprise architecture (Greefhorst and Proper 2011). Furthermore architects have a positive attitude towards architecture principles (Greefhorst et al. 2013). But so far, there is no empirical evidence of any contribution architecture principles have to the success of information system implementation (Borgers 2016; Haki and Legner 2012, 2013), notwithstanding the fact, that in practice the implementation of information system requirements is not straightforward (Elias 2014; Flyvbjerg and Budzier 2011). So, are architecture principles effective?

To be able to determine the impact of applying architecture principles on the successful implementation of the requirements, we have to identify and describe them first. We need to identify architecture principles, in order to distinguish them from general design principles, guidelines, or technology standards. To this end, a good definition is necessary but currently lacking. Subsequently we need a way to describe the architecture principles distinctively, in order to compare them. For example, what are the differences between the principles "good is good enough" and "business data have to be used throughout the application"? Which of those architecture principles is formulated well, are they linked to requirements, and are there prerequisites to be fulfilled? A description of the characteristics of the architecture principles will help in answering these questions.

Based on a limited literature review, we conducted a case study research at the Dutch Tax Agency (Borgers and Harmsen 2016) to identify and measure architecture principles. We concluded that the definition of 'architecture principle' we used in the case study was not distinctive enough to uniquely identify architecture principles in relation to other kind of statements. Secondly, the descriptions of the characteristics were not distinctive enough as well, because they contained subjective terms like "enough", "easy" and "obvious". Moreover, the coherence between the used characteristics was not explicit, causing that some characteristics were more highlighted than others.

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To strengthen both the definition and description of the architecture principles, we have conducted an elaborate literature review. Our aim is to consolidate all known relevant literature into a comprehensive and consistent definition and set of characteristics captured in a model. This result will help us in our empirical research of comparing architecture principles. Moreover, a good definition and description of architecture principles will help in drawing up and using architecture principles in practice as well.

Given the analysis described above, we answer in this paper the following research question:

"How are, according to literature, architecture principles comprehensively and consistently defined and described?"

The *definition* should provide an exact statement of the meaning of an architecture principle. The definition describes the essence of the term 'architecture principle' without additional elements. The *description* is a listing of all characteristics of an architecture principle. It describes the architecture principle in his exhaustiveness by his characteristics and their interrelationships. The distinction between these two concepts are in accordance with both the Oxford dictionary and Lyons (1977).

We start this paper with the research methodology in section two. In the third section we provide the results of the literature review. Next, in section four, we discuss the results and give limitations to those results. We finish this article with conclusions and further research.

2 RESEARCH METHODOLOGY

To answer the research question we started refining the research question into two sub questions. Based on those two research questions we defined our research process, including scope definition, models for analysis, and selection criteria for selecting the right literature.

2.1 Research Question

To be able to find the right results, we refined our general research question into two sub questions. The first sub question should focus on the identification of architecture principles: what kinds of statement are in scope as architecture principles? The second sub question should help in getting a model to describe an architecture principle in a manner as exhaustive as possible. As a result, we used the following two research questions in our research:

1. What are definitions of architecture principles in literature and what are the similarities and differences between those definitions?
2. With which characteristics are architecture principles described and how are architecture principles related to their environment?

2.2 Research Process

We used a six-step approach for this literature review, based on the literature review method of Webster and Watson (2002). This method was also used by Stelzer (2009) and Haki (2012) and with that, we have equivocality of the research process in this area of research. The six steps were:

1. Defining the boundaries of the literature review;
2. Compiling two models (one for each research question) needed for analysing the results of the literature review;
3. Identifying and selecting relevant literature;
4. Reviewing the results of the literature review using our models
5. Answering the sub research questions based on the results of the analysis.
6. Addressing the limitations, discussing the results and presenting implications for further research

2.3 Boundaries of Research

Our research is focusing on architecture principles to be used for implementing information system (IS) requirements. In the initiation of this literature review, however, we found out that there is a lack of architecture principle literature related to the scope of IS specifically. There is, however, literature on enterprise architecture principles and software architecture principles. IS architecture is part of enterprise architecture (Land et al. 2008), and therefore it is possible to confine the literature review to the enterprise, which we did. Therefore, all conclusions related to principles used in enterprise architecture can be applied to principles for the IS architecture as well. As a consequence, we scoped our literature search on architecture principles related to Enterprise, Information System, or IT.

2.4 Models Used for Analysis

We used two models to help us analysing the results that we found in the selected publications. For the first research question our aim is to have an instrument helping to decompose the definitions found. This decomposition helps to identify all elements relevant for describing the essence of the term 'architecture principle' and also to determine which additional elements are not distinctive.

To experience the essence of a subject, the interrogative WH-questions (Wikipedia 2017) are helpful. We used the 7 most-used interrogative WH questions (what, why, how, with which, who, when, and where) to decompose the definitions. Each element of a definition is attached to one of the questions. After the decomposition of all definitions, we analysed per question the similarities and differences in phrasing. Based on the analysis we formulated a new phrasing for a strengthened definition (see table 5).

Figure 1: Decomposing architecture principle definitions with WH-questions.

In answering the second research question we used a framework to model the architecture principle. In this framework (see fig 2) we distinguish the relevant entities in our research, like architecture principle, design, and strategy. Most of them are artefacts of the development process.

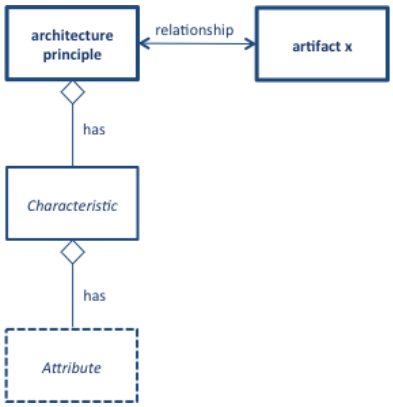

Figure 2: Framework for modelling the characteristics of an architecture principle.

An entity has characteristics, defined as "a feature belonging typically to an architecture principle and serving to identify it." A characteristic, in its turn, has one or more attributes, as "an inherent part of the characteristic". We also address the relationships between the entities and between the entity and its characteristics. In designing the model we used the UML in accordance with (Fischer et al. 2010; Aier et al. 2011).

During the literature review we listed each new characteristic or entity we found in a table, including the definition, attributes and relationship. When we did find a synonym, we added that one to the one found earlier. In the end this resulted in a list of unique characteristics, entities and relationships to each other. As a final step, we designed the model describing the architecture principle using the framework.

2.5 Search & Selection of Literature

We used the various well-known databases, journals, and search mechanisms (for instance, EBSCO, Google Scholar, AISeL and Research Gate), to find relevant literature. In selecting the right publications, we used the following inclusion and exclusion criteria. First criterion is the selection of English publications only. Secondly, the title or abstract has to contain at least the combination of terms <architecture principle> AND (<Enterprise> OR <IS> OR <IT>). Based on those criteria we obtained a list of publications (see table III).

We analysed the abstracts of those publications and selected those ones addressing the definition or description of architecture principles in general. We excluded all other literature covering the application of architecture principles. Each of the selected publications was read and analysed extensively and all relevant information in the publication was structured for analysis.

In some publications we did find citations to prior literature as well. When those publications were addressing specific elements of architecture principles, we added them to our list of publications. In most cases those publications did not satisfy all selection criteria, because they were addressing another (related) subjects.

3 RESULTS

In this section we describe the results of our research and we answer the two sub research questions defined. We start with the general research results, and in the two following sub-sections we provide the

definition and description of the architecture principles respectively.

3.1 General Research Results

After the search and selection of publications we found 28 publications we rated as most relevant in defining and describing architecture principles (see table 3). Those publications are covering a time span between 1990 and 2017. Some of those publications introduce new definitions and descriptions, while others strengthen existing ones. Many publications confirm and use the conclusions of previous publications.

All authors confirm the importance of architecture principles for the architecture and design of systems. Not only from a theoretical perspective, but also in practice architects state that architecture principles have added value, according to different surveys (Greefhorst et al. 2013; Winter and Aier 2011; Haki and Legner 2013).

Of all publications found, most of them are describing architecture principles in general, calling it Enterprise Architecture (EA) principles. Only a few are related to a specific layer of the architecture, such as business, information system, application, or technical infrastructure (The Open Group 2011a; Greefhorst and Proper 2011; Hoogervorst 2004). Specific publications related to architecture principles are difficult to find. Therefore, as discussed in section 2, we used the more general yet still applicable literature on EA principles instead.

Our research shows, generally speaking, consensus about architecture principle definitions and its characteristics over the previous 27 years. In 2013 Haki already mentioned the increasing consensus on what he was calling "the nature and definition of EA principles" (Haki and Legner 2013). Since Haki's paper, there were only a few new publications with similar ideas. Nevertheless, between the 28 publications we did find some inaccuracy or incompleteness, which we will elaborate in the next two sections to strengthen both the definition and description of an architecture principle.

3.2 Definition of an Architecture Principle

In answering the first sub research question we first listed all found definitions in literature in a table (see table 4 for an overview of all definitions). In this overview it is interesting to see that the definitions in later publications are a consolidation of previous definitions and are evolving to more comprehensive ones. In (Fischer et al. 2010; Haki and Legner 2013) the elaboration of the definitions is quite detailed, which would make it in our terms more a description than a definition. It is noteworthy to see there were no really deviating definition or remarks on prior publications whatsoever.

To give insight in the similarities and differences between those definitions, we decomposed the definition with the WH-questions. During the analysis we were, in accordance with the Oxford definition, focussing on the essence of an architecture principle, while the definition should be comprehensive and consistent as well. Here we will address the similarities and differences per WH-question as also summarised table 5 in the appendix.

In describing the determining elements of an architecture principle most authors do agree that an architecture principle is a statement, as a type of design principle. In accordance with Haki et al. (2013), and Fischer et al. (2010) we state that the architecture principle should be "based on business and IT strategy", because with architecture we want to focus on the essential requirements. Although many authors do agree that an architecture principle is a type of design principle, we omit this because we address the design-element later in the definition.

Although defined in many different ways, the purpose of the architecture principle can be summarised as describing restriction to the design. This is consistently formulated by Greefhorst and Proper (2011) with "normatively describes a property of the design of an artefact". In our case the artefact is the Information System.

In many definitions the objective of the architecture principle is described as "should be met by the architecture" or "justification for decision making throughout an EA". But an architecture in itself has the objective that a system meets its essential requirements. And because architecture is focusing on the 'essential' requirements, we would like to address this in the definition. With that, it is the distinguishing element between design and architecture principles.

Looking for additional elements in describing the essence of an architecture principle, we do not see real distinctive parts. In our analysis of the remaining WH-questions, we only identify elements, which we can link to elements in our definition. E.g., "*a rationale is formulated*" can be linked to the elements "*is based on business and IT strategy*" and "*its essential requirements*". That does not mean that those elements are irrelevant: those elements have to be part of the description of the architecture

principle, as we already indicated above. This hypothesis is strengthened by the fact that only four authors are addressing one or more remaining WH-questions in their definition.

By combining these findings, we define an architecture principle for information systems as:

" An architecture principle is a declarative statement, based on, at least, business and IT strategy. It normatively describes a property of the design of an information system, which is necessary to ensure that the information system meets its essential requirements."

With this analysis we conclude that there is consensus in literature about the definition of an architecture principle. The differences in the definitions found are related to the use of undefined terms or the use of synonyms. Furthermore, we found incomplete or copious definitions, without catching the essence of an architecture principle.

3.3 Description of Architecture Principles

Although we now have defined the essentials of an architecture principle, we still have to describe it. As a consequence, we answer the question "With which characteristics are architecture principles described and how are architecture principles related to its environment?".

In answering this question, we started investigating the different types of principles. For many years, there were, in general, two types of architecture principle: *design principles* and *representation principles* (Stelzer 2009; Winter and Aier 2011; Haki and Legner 2012). The latter type refers to the way architectures should be represented, while the first directs the design of a system itself. In literature they were described as having different characteristics and serving different objectives.

Recently Lumor, et al. (2016) introduced a third type of principle, namely *architecture management principles*. Those architecture management principles are reflecting the process nature of EA. The idea behind this third type of principles is the fact that in general architecture and its principles might be a product, process, result, etc. (Slot 2010; Lumor et al. 2016; Greefhorst and Proper 2011; Sandkuhl et al. 2015), and an architecture principle should address the process view as well.

In this literature review we take the view that these different types are different perspectives on the same kind of architecture principles. This is in accordance with Lindström (2006), who distinguishes syntactic and semantic characteristics. Syntactic characteristics are describing the elements and their interrelationships of a principle. Semantic characteristics describe the quality elements of the principle. Haki posed in (Haki and Legner 2012) that this differentiation is the same kind of subdivision as the differentiation of design and representation principles. So, depending on perspective, the architecture principle has more or less specific characteristics.

We do understand that, with this choice, we will collect all kinds of characteristics, which also might be related to each other. We encountered this consequence already in our case study research (Borgers and Harmsen 2016). To address this consequence, we will, in the next step of our research project, classify all the characteristics found.

Next, we distinguished the characteristics of the architecture principle itself on the one hand and the relationship with entities in its environment on the other. This breakdown is comparable with the definition of Richardson and Aier et al. (Fischer et al. 2010; Winter and Aier 2011), (Richardson et al. 1990) in a core definition and basic extensions, and helpful to get more transparency in the description of the architecture principle. In literature we found all kinds of characteristics and entities described. Using our framework we listed all these characteristics (see table 1 and fig 3).

3.3.1 Characteristics

We start with the 'specification' characteristic. There is consensus on the specification of an architecture principle by the attributes "statement", "rationale", and "implications". All authors naming these three attributes as an inherent part of an architecture principle. We group these three attributes together in one characteristic, because together they specify the architecture principle.

The second characteristic of an architecture principle is called 'measure'. This characteristic describes the level of fulfilment of the principle. To some authors, e.g. Aier, Haki and Lindström (Haki and Legner 2013; Fischer et al. 2010; Lindström 2006), this is a typical characteristic for an architecture principle, because of an architecture principle should be respected to some extent.

Hoogervorst (2004; 2009), endorsed by (Aier et al. 2011; Winter and Aier 2011), and Greefhorst and Proper (2011), introduced the characteristic "Key action" as guidelines for implementing the principle.

Recently Marosin (2016) added the characteristic "Precondition", which has to be fulfilled by key actions before a principle can be applied. Because both elements are strongly related to each other, we consider them as attributes of one characteristic called 'Prerequisites' of which the principles depends on.

We also introduce the 'meta data' characteristic. This characteristic typifies the architecture principle so it can be managed. Attributes like name, assurance, visualisation and generic information are in scope of this characteristic. Many of such attributes are defined by Greefhorst and Proper (2011) and till now there is no exhaustive overview of this kind of attributes.

Finally, there are all kinds of quality, or semantic, attributes defined in literature, which the architecture principle should meet. TOGAF (The Open Group 2011a), Van Bommel (2006), Lindström (2006), Marosin (2016) and Greefhorst (2011) all have their own list of quality attributes. A more detailed comparison shows that they only use different terms for the same type of attributes or use a slightly different definition of the quality attribute. Therefore we choose the quality attributes used by Van Bommel (2006) and Greefhorst (2011): Specific, Measurable, Achievable, Relevant and Time-framed (SMART). The reason to choose this list of quality attributes, is the fact that they are defined quite detailed in (Greefhorst and Proper 2011) and that they are easy to remember because of the re-use of the SMART criteria for objectives.

Table 1: Characteristics for Architecture principles.

Characteristic	Attribute	Definition
Specification		
	Statement	Succinctly and unambiguously communicates the fundamental rule to the user of the principle
	Rationale	Highlights the business benefits of adhering to the principle
	Implications	Highlights the requirements for carrying out the principle
Measure		Level of the fulfilment of the statement
Prerequisites		
	Precondition	Preconditions and requirements to be fulfilled before the principle can be applied
	Key action	Guidelines for implementing the principle, giving the preconditions
Meta data	Several	Specifications to be able to govern the principle
Quality		
	Specific	The user can understand its intention and its effects to use it in his work
	Measurable	Possible to determine whether or not a given behaviour is in line with architecture principle
	Achievable	The implications of it can all be performed by or adhered to by all those affected
	Relevant	The principle should lead to a improvement of the system meeting the essential requirement
	Time framed	Principe should be stable in context and time

3.3.2 Entities in Its Environment

Next to their characteristics listed above, the context in which the architecture principles are used, is important as well (Stelzer 2009; Fischer et al. 2010; Aier et al. 2011; Proper and Greefhorst 2010; Greefhorst and Proper 2011), in particular for the effect of a principle. The key context of an architecture principle, according to literature, consists of the 'design', 'requirements', 'the architecture', 'the strategy', and 'the architecture principle set'. We describe those relationships one by one and are visualised in figure 3.

The most direct relationship an architecture principle has, is with the 'design'. Architecture and therefore also architecture principles restricts the design freedom of a system, according to (Hoogervorst 2009; Hoogervorst 2004; Dietz 2008; Greefhorst and Proper 2011). As we already have seen in the definition of the architecture principle, that restriction is necessary "to ensure the information system meeting its essential

requirements". So via the design the architecture principle should ensure the Information System satisfies the 'requirements'.

Besides, an architecture principle is, most of the time, part of a set of principles. Although in most literature the focus is on individual architecture principles, a principle is only effective if it is part of a set (Lindström 2006; Greefhorst and Proper 2011; Stelzer 2009), (Marosin and Ghanavati 2015), (Marosin et al. 2016). Because we are interested in the contribution of architecture principles, we have to describe 'the architecture principle set' as well. We define an architecture principle set as a group of architecture principles defined and presented as a collection. Because a set of principles is an entity in itself, it has characteristics and attributes as well. Based on Greefhorst and Proper (2011) we define three types of characteristic: 'classification', 'meta data' and 'quality of the set'. See table 2 for a definition of the characteristic types.

First, architecture principles are grouped together based on a 'classification'. This 'classification' is based on the type and scope of the architecture principles. The type is related to the architecture layers of an architecture model. There are many definitions of architecture layers in use like TOGAF (The Open Group 2011b), Zachmann (1987), and IAF (Van 't Wout et al. 2010). In our scope we consider the Information System layer and within this layer the subdivisions Application and Infrastructure. Architecture principles can also be classified based on the (organisational) level of use: for a specific solution, a division, for an entire organisation, etc.

Secondly, an architecture principle set can be typified by 'meta data' to manage the principle set, such as name, release number, amount of architecture principles in the set, etc. Some authors do address the point that the amount of principles in the set should be as small as possible (Land and Proper 2007; Lindström 2006; van Bommel et al. 2006). Many attributes may be added to the characteristic 'meta data', and for now there is no complete list available.

And lastly, similar to the individual architecture principle, an architecture principle set meets quality standards: 'quality of the set'. In the case of a set of principles we distinguish the attributes 'representative', 'accessible' and 'consistent'.

Looking at the entities related to an architecture principle we have two left. In the architecture principle definition we also have described the statement "…based on business and IT strategy". In our literature review we did not see a sharp clarification of the relationship between 'business and IT strategy' and an architecture principle. We see the architecture principle set as part of the 'architecture' and the 'strategy' guides this architecture. Because an architecture principle is part of the architecture, it is based on the strategy as well.

Table 2: Characteristics for architecture principle set.

Characteristic	Attribute	Definition
Classification		
	Type	The principles in the set are related to one of the architecture layers.
	Scope	Level of use of the principle.
Meta Data	Several	Specifications to be able to govern the principle set.
Quality of the set		
	Representative	The set covers all relevant requirements in a specific problem domain.
	Accessible	Users can find and retrieve the set of principles and they can comprehend the principles.
	Consistent	No contradictions between the architecture principles in the set.

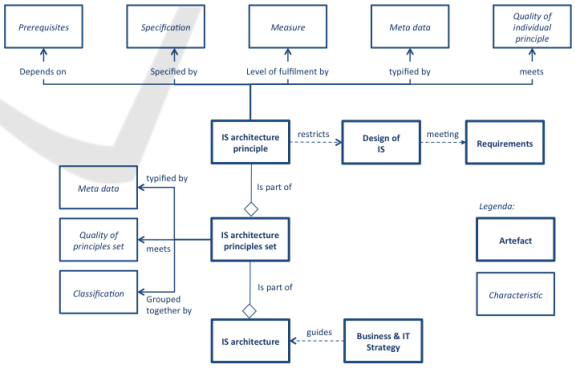

Figure 3: Framework of Architecture principles and its environment.

Based on our analysis and the framework in section II, we built up the final model of describing the architecture principle including his environment (see figure 3). As discussed in our analysis above, this model is diverging slightly from the meta-model of Aier, et al. (Fischer et al. 2010; Aier et al. 2011).

In our literature review we determined consensus on the characteristics as well. Although we are of the

opinion that the different types of architecture principles are perspectives on the same kind of principles, we did not find any contradictions. We added and reorganised some characteristic and attributes. As already addressed in our case study research (Borgers and Harmsen 2016), some characteristics were defined relatively subjective in literature, using terms like “significant”, “easy”, or “obvious”. We have strengthened the definitions where possible (see table 1 and 2), while we are aware of the fact that architecture principles are semi structured, informal and written in natural language (Land et al. 2008; Marosin and Ghanavati 2015; Marosin et al. 2016; Marosin et al. 2014; Buckl et al. 2010). Furthermore, we have described the architecture principle set with characteristics and attributes as well, because the contribution of architecture principle is only effective in a set.

4 LIMITATIONS, CONCLUSIONS & FURTHER RESEARCH

With the results of section 3 we may conclude that we are able to define and describe architecture principles comprehensively en consistently. In this section, we address the limitations of our research methodology. Secondly we discuss the results of our literature review and end up with implications for further research to consolidate this area of research.

4.1 Limitations

There are two threats to the validity of our results. The first limitation we have identified is the interpretation of the words that have been used in the definitions and the characteristics. Although semantics of natural language is always an issue in literature study, we encountered in several papers descriptions that were rather vague, and therefore subject to (personal) interpretation and possible wrong conclusions. Because many publications confirm and use the conclusions of previous publications, we judge the risk of misinterpretation low.

The other limitation is the rather broad scope of the literature search by considering architecture principles in the enterprise domain instead of architecture principles in the IS domain. In certain cases, we translated architecture principle characteristics to specific IS ones without knowing whether that would be valid in practice. This is a topic for further research. Because architecture principles can affect multiple architecture domains (Greefhorst and Proper 2011), we consider this as low risk.

To discuss the results of our literature review we also sent our draft paper to a small group of senior experts in this research area. We used their response to eliminate indistinctness in the draft paper. Besides that, the experts addressed some specific remarks related to the paper.

Several experts mentioned that formulating architecture principles is important, but that the use of architecture principle is the real issue in practice. The description of the architecture principle is a precondition, necessary to determine the use and the effectiveness of architecture principles.

The second remark is related to the ordering of the characteristics. As addressed in section 3 we have chosen not to order the characteristics in this part of our research, although there are different perspectives on architecture principles. Two experts suggest to order the characteristics using some framework, for example the dimensions framework defined in Greeforst and Proper (2011). Such frameworks will help in evaluating the relationships between the different characteristics as well.

The last remark was related to the definition of the architecture principle. The original definition suggests that architecture principles are based on business and IT strategy only. We do agree with the experts that business and IT strategy are just two, be it important, sources to formulate architecture principles. So we reframed the definition by adding ‘at least’ in the phrasing.

4.2 Final Conclusions

In most relevant publications we found 15 different definitions of architecture principles and a large set of characteristics. In a period of 27 years the definition of an architecture principle has been consolidated. Besides, there is consensus about many characteristics. Nevertheless we did find some inaccuracy or incompleteness in definitions and descriptions, as we addressed in this paper.

First, we found all kinds of definitions in literature, with most of them incomplete or just not striking the essentials of an architecture principle. By decomposing and rephrasing the elements of those definitions we ended up with a more comprehensive and consistent definition.

In describing the architecture principles with characteristics we defined all types of principles as different perspectives on the same kind of principles. We grouped together the rationale, statement and

implication into one characteristic ‘specification’. Besides we distinguished ‘key action’ and ‘preconditions’ as two separate attributes, combined in the characteristic ‘Prerequisites’. We also considered ‘Meta data’ and ‘Quality’ as explicit characteristics of an architecture principle, which has not been done in all past literature. Where possible we tried to define the characteristics more objectively – despite the fact that in natural language, interpretations of words is always possible. Altogether, there were no contradictions found in past literature, but we have extended the description of the Architecture principle with new characteristics.

Analysing the contribution of individual architecture principles without looking at the set of principles is of no use. An architecture principle is only effective in combination with other architecture principles. We therefore also described the characteristics of the architecture principle set: ‘Classification’, ‘Quality’ and ‘Meta data’. We described the characteristics of both an architecture principle and the architecture principle set into a framework also related to entities in its environment.

4.3 Further Research

The results of this literature study are interesting in itself, but are the definition and description still valid in practice? Is the assumption that the characteristics of an enterprise architecture principle can be applied to an architecture principle in all cases? And are the definition and description of the architecture principles suitable for comparing principles with each other? To answer these questions, the next step in this research is to examine the definition and description in real life cases.

Using the results of this literature study we will initiate new case studies, focusing on the question: “To what extent is there a fit between the definition and description of architecture principles from the literature review and the appearance of architecture principles in practice?”. The results of these case studies will help to improve and further refine the definition and description of architecture principles. And more importantly, it is the next step in determining their contribution to the success of IS requirements implementation.

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APPENDIX

Table 3: Most relevant publications related to defining and describing architecture principles.

Nr.	Title of publication	Author	Year of Publication	Reference
1	A Principles-Based Enterprise Architecture: Lessons from Texaco and Star Enterprise	G.L. Richardson, et al.	1990	(Richardson et al. 1990)
2	A Big-Picture Look at Enterprise Architectures	F.J. Armour, et al.	1999	(Armour et al. 1999)
3	Enterprise Architecture: Enabling Integration, Agility and Change	J. Hoogervorst	2004	(Hoogervorst 2004)
4	Enterprise Architectures – Review on Concepts, Principles and Approaches	D. Chen, et al.	2004	(Chen & Lillehagen 2004)
5	Giving Meaning to Enterprise Architectures – Architecture Principles with ORM and ORC	P. van Bommel, et al.	2006	(van Bommel et al. 2006)
6	On the Syntax and Semantics of Architectural Principles	Ä. Lindström	2006	(Lindström 2006)
7	Impact of principles on Enterprise Engineering	Martin Op 't Land, Erik Proper	2007	(Land & Proper 2007)
8	Architecture principles – A regulative perspective on enterprise architecture	Van Bommel, et al.	2007	(van Bommel et al. 2007)
9,10	The Open Group Architecture Framework TOGAF™	The Open Group	2007, 2011	(The Open Group 2007) (The Open Group 2011b)
11	Enterprise Architecture Principles: Literature Review and Research Directions	Dirk Stelzer	2009	(Stelzer 2009)
12	The Roles of Principles in Enterprise Architecture	Erik Proper, Danny Greefhorst	2010	(Proper & Greefhorst 2010)
13	What Is an Enterprise Architecture Principle?	Christian Fischer, Robert Winter, Stephan Aier	2010	(Fischer et al. 2010)
14	A Conceptual Framework for Enterprise Architecture Design	Sabine Buckl	2010	(Buckl et al. 2010)
15	Enterprise Architecture Principles and their impact on the Management of IT Investments	Kalevi Pessi, et al.	2011	(Pessi et al. 2010)
16	How are Enterprise Architecture Design Principles Used?	Robert Winter, Stephan Aier	2011	(Winter & Aier 2011)
17	Construction and Evaluation of a Meta-Model for Enterprise Architecture Design Principles	Stephan Aier, Christian Fischer, Robert Winter	2011	(Aier et al. 2011)
18	Architecture Principles – The Cornerstones of Enterprise Architecture	Danny Greefhorst, Erik Proper	2011	(Greefhorst & Proper 2011)
19	New Avenues for Theoretical Contributions in Enterprise Architecture Principles – a Literature Review	Mohammad Kazem Haki, Christine Legner	2012	(Haki & Legner 2012)
20	The Dutch State of the Practice of Architecture Principles	Danny Greefhorst, Hendrik Proper, Georgios Plataniotis	2013	(Greefhorst et al. 2013)
21	Enterprise Architecture Principles In Research And Practice: Insights From An Exploratory Analysis	Mohammad Kazem Haki, Christine Legner	2013	(Haki & Legner 2013)
22	A Principle-based Goal-oriented Requirements Language (GRL) for Enterprise Architecture	Diana Marosin, Sepideh Ghanavati, Dirk van der Linden	2014	(Marosin et al. 2014)
23	Alignment of Enterprise Architecture Principles: A Case Study	Christer Tallberg, Kalevi Pessi, et al.	2015	(Tallberg & Pessi 2015)
24	Measuring and Managing the Design Restriction of Enterprise Architecture (EA) Principles on EA Models	Diana Marosin, Sepideh Ghanavati	2015	(Marosin & Ghanavati 2015)
25	The nature and a Process for Development of Enterprise Architecture Principles	Kurt Sandkuhl, Daniel Simon, Matthias Wissotzki, Christoph Starke	2015	(Sandkuhl et al. 2015)
26	Do IT architecture principles contribute to IT system's requirements realisation?	Michiel Borgers	2016	(Borgers 2016)
27	Case report of identifying and measuring IT architecture principles in the Dutch Tax Agency	Michiel Borgers, Frank Harmsen	2016	(Borgers & Harmsen 2016)
28	Formalizing and Modeling Enterprise Architecture (EA) Principles with Goal-oriented Requirements Language (GRL)	Diana Marosin, Marc van Zee, Sepideh Ghanavati	2016	(Marosin et al. 2016)

Table 4: Overview of architecture principle definitions by different authors.

Nr.	Definition of architecture principle	Author	Year of Publication	Reference
1	"Principles are an organization's basic philosophies that guide the development of the architecture… Principles provide guidelines and rationales for the constant examination and re-evaluation of technology plans."	G.L. Richardson, et al.	1990	(Richardson et al. 1990)
2	"… simple, direct statements of how an enterprise wants to use IT. These statements establish a context for architecture design decisions by translating business criteria into language and specifications that technology managers can understand and use. Architecture principles put boundaries around decisions about system architecture."	F.J. Armour, et al.	1999	(Armour et al. 1999)
3	" … collectively the design principles are identified as enterprise architecture."	J. Hoogervorst	2004	(Hoogervorst 2004)
4	"Architecture principles are rules to use when elaborating enterprise architectures."	D. Chen, et al.	2004	(Chen & Lillehagen 2004)
5	"Architecture principles define the underlying general rules and guidelines for the use and deployment of all IT resources and assets across the enterprise…."	Ä. Lindström	2006	(Lindström 2006)
6	"Principles are general rules and guidelines, intended to be enduring and seldom amended, that inform and support the way in which an organization sets about fulfilling its mission"	TOGAF	2007	(The Open Group 2007)
7	"Enterprise architecture principles are fundamental propositions that guide the description, construction, and evaluation of enterprise architectures."	Dirk Stelzer	2009	(Stelzer 2009)
8	"An EA principle constrains and guides the design of the EA and may in turn provide justification for decision-making throughout an EA. In general, principles are self-restraint and not externally obliged, …. by law in terms of compliances."	Sabine Buckl	2010	(Buckl et al. 2010)
9	" An EA principle is based on business strategy and IT strategy. Principles can be attributed to different layers. An EA principle is described in a principle statement saying what to improve. For each principle, a rationale is formulated explaining why the principle is meant to help reaching a predefined goal. For each principle, concrete implications or key actions are described explaining how to implement the principle. Measurement is a key issue of EA principles. For every principle, it should be defined how to determine its fulfilment."	Aier, et al.	2010	(Fischer et al. 2010)
10	"Architectural principles are statements that express how your enterprise needs to design and deploy information systems across the enterprise to connect, share and structure information."	Pessi, et al.	2010	(Pessi et al. 2010)
11	"A qualitative statement of intent that should be met by the architecture. Has at least a supporting rationale and a measure of importance."	The Open Group	2011	(The Open Group 2011b)
12	"a declarative statement that normatively prescribes a property of the design of an artifact, which is necessary to ensure the artifact meets its essential requirements."	Danny Greefhorst, Erik Proper,	2011	(Greefhorst & Proper 2011)
13	"EA principles can be attributed to *different architectural layers*, should be based on *business and IT strategies*, and refer to the *construction of an organization*. Each EA principle should be described in a principle *statement* along with a *rationale* that explains why this principle is helpful in attaining a predetermined goal, as well as *implications* that describe how to implement this principle. Finally, *metrics* could be identified for each principle to measure its fulfilment."	Mohammad Kazem Haki, Christine Legner	2013	(Haki & Legner 2013)
14	"an enterprise-specific and abstract, yet simple collection of statements, which generally provide a framework for decision making and thus support the transformation process of an enterprise from a current to a target EA."	Kurt Sandkuhl, Daniel Simon, Matthias Wissotzki, Christoph Starke	2015	(Sandkuhl et al. 2015)
15	"In EA, principles have been defined as guidelines and rationales for the design and evolution of technology plans. In other words, EA principles can be seen as "rules of conduct" and can be made more precise and operational by formalization."	Diana Marosin	2016	(Marosin et al. 2016)

Table 5: Decomposition and consolidation of an architecture principle definition.

Interrogative question	Explanation	Definitions in literature	Consolidated description for Architecture principle
What	What is an architecture principle? Describing the determining elements.	are organisation's basic philosophies [23], are simple, direct statements [20], are design principles [17], are rules [21], defines the underlying general rules and guidelines [24], are general rules and guidelines, intended to be enduring and seldom amended [39], are fundamental propositions [1], are self-restraint and not externally obliged [31], is based on business and IT strategy [18], are statements [40], a qualitative statement of intent [33], a declarative statement [2], should be based on business and IT strategies [15], have been defined as guideliness and rationales [28], can be seen as 'rules of conduct' [28], is described in a principal statement [18], an enterprise-specific and abstract, yet simple collection of statements [25], which generally provide a framework [25]	is a declarative statement, as a specific type of design principle, based on business and IT strategy.
How	How does the principle work? Describing the manner of the principle.	establish a context for architecture design decisions by translating business criteria into language and specifications [20], put boundaries around decisions about system architecture [20], can be attributed to different layers [18], that normatively prescribes a property of the design of an artifact [2], can be attributed to different architectural layers [15], refer to the construction of an organization [15], can be made more precise and operational by formalization [28]	It normatively describes a property of the design of an IS,

Table 5: Decomposition and consolidation of an architecture principle definition (cont.).

Interrogative question	Explanation	Definitions in literature	Consolidated description for Architecture principle
Why	Why is the architecture principle described? Describing the reason(s) or objectives to achieve.	that guide the development of the architecture [23], for the constant examination and re-evaluation of technology plans [23], how an enterprise wants to use IT [20], for the use and deployment of all IT resources and assets across the enterprise [24], that inform and support the way in which an organization sets about fulfilling its mission [39], that guide the description, construction, and evaluation of enterprise architectures [1], constrains and guides the design of the EA and may in turn provide justification, for decision making throughout an EA [31], saying what to improve [18], reaching a predefined goal [18], that express how your enterprise needs to design and deploy information systems across the enterprise to connect, share and structure information [40], that should be met by the architecture [33], to ensure the artifact meets its essential requirements [2], why this principle is helpful in attaining a predetermined goal [15], for the design and evolution of technolgy plans [27], for decision making and thus support of the transformation process of an enterprise from a current to a target EA [25]	which is necessary to ensure the IS meeting its essential requirements. ,
Which	With which elements is an architecture principle included? Describing the elementary components of an architecture principle.	provide guideliness and rationales [23], a rationale is formulated explaining why the principle is meant to help [18], concrete implications or key actions are described [18], measurement is a key issue of EA principles..it should be defined how to determine its fulfillment [18], has at least a supporting rationale and a measure of importance [33], should be described in a principle statement, along with a rationale...., as well as implications [15], metrics should be identified for each principle to measure its fulfilment [15]	[Not relevant]
Who	Who is using the architecture principle? Describing the personal related to the architecture principle.	that technology managers can understand and use [20]	[Not relevant]

Table 5: Decomposition and consolidation of an architecture principle definition (cont.).

Interrogative question	Explanation	Definitions in literature	Consolidated description for Architecture principle
When	When are architecture principles used? Describing the timing of the use.	constant [23], when elaborating enterprise architectures [24]	[Not relevant]
Where	Where is the architecture principle located? An architecture principle should be accessible for people.	-	[Not relevant]