

Enterprise Architecture Principles: Literature Review and Research Directions

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Abstract. This paper presents a literature review on enterprise architecture principles. The results show that there are various gaps in the research literature: No accepted definition of enterprise architecture principles has emerged yet. A detailed conceptual framework is still lacking. Business principles, IT principles and enterprise architecture principles are often mixed up. Research into generic design principles is still in its infancy. Our review illustrates the necessity to conduct more research on enterprise architecture principles. We describe conceptual foundations and provide guidance for further research in this field.

Keywords: enterprise architecture, architecture principles, design principles, representation principles, design rules, literature review.

1 Introduction

The term architecture is defined as the “fundamental organization of a system embodied in its components, their relationships to each other, and to the environment, and the principles guiding its design and evolution” [1], [2]. Accordingly, we define enterprise architecture as the fundamental organization of an enterprise embodied in its components, their relationships to each other, and to the environment, and the principles guiding its design and evolution.

According to the Oxford Dictionary of English a principle – among other explanations – is (1) a fundamental truth or proposition serving as the foundation for belief or action, (2) a rule or belief governing one’s personal behaviour, (3) a general scientific theorem or natural law, (4) a fundamental source or basis of something.

In the context of enterprise architecture, however, “a precise definition of the concept of principles as well as the mechanisms and procedures needed to turn them into an effective regulatory means still lacks” (p. 49) as van Bommel et al. point out [3]. As a matter of fact, when conducting an initial examination of publications on enterprise architecture principles we found various interpretations of the concept. Some authors take individual views leading to inconsistencies in research findings.

Compared to the literature on enterprise architecture in general, the number of publications on enterprise architecture principles is limited. This is surprising as various authors [4], [5], [6], [7], [8], [9] reckon architecture principles as pivotal elements of enterprise architectures. Hoogervorst actually equates architecture with principles.

He defines architecture “as a consistent set of design principles and standards that guide design” (p. 215) [10]. Richardson, Jackson, and Dickson call principles “the most stable element of an architecture” (p. 389) [6]. Aside from that, architecture principles are central elements of enterprise architecture frameworks such as TOGAF [7].

The aim of this paper is to conceptualize the research area of enterprise architecture principles, to examine prior research, and to identify research options.

The remainder of the paper is organized as follows. Section 2 contains conceptual foundations of enterprise architecture principles. Section 3 describes results of our literature review. In section 4 we summarize our findings and provide directions for further research.

2 Conceptual Foundations

In the following sections we describe conceptual foundations of enterprise architecture principles.

2.1 Architectural Triangle

In the architecture framework proposed by The Open Group [7] architecture “has two meanings depending upon the context: 1. A formal description of a system, or a detailed plan of the system at component level to guide its implementation [and] 2. The structure of components, their inter-relationships, and the principles and guidelines governing their design and evolution over time.” [7] In other words, the term architecture may denote both, the inherent structure of a system and its representation. Hence, architecture and architectural representation should be distinguished. The architecture is a conceptual model of the system of interest. The architectural representation is a more or less formal description of the architecture. Figure 1 illustrates the associations of a system, its architecture, and architectural representation arranged parallel to the so-called semiotic triangle [11], [12].

Architecture principles may refer either to the design or to the representation of architectures. We label the first as design principles and the latter as representation principles. Design principles are fundamental propositions guiding the construction and

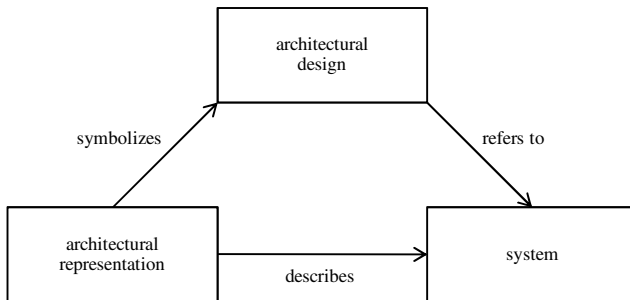


Fig. 1. Architectural Triangle

evaluation of architectures, e.g. separation of concerns, modularity, or loose coupling. Representation principles are fundamental propositions for describing and modeling architectures, as well as for evaluating architectural representations. Examples for representation principles are understandability, consistency, and completeness.

2.2 Context of Architecture Principles

Principles are means to achieve certain ends. When designing enterprise architectures principles serve to accomplish business, IT, or architecture goals. Constraints (e.g. strategic, financial or technological limitations) may restrict the applicability or validity of architecture principles.

Since principles are usually abstract, high-level propositions they need to be specified in order to guide the development or evaluation of a system. This is often realized by providing rules or guidelines for the development of architectures and evaluation criteria for quality assessment. Schekkerman defines a rule as “a prescription on how something has to be done” (p. 34) [5]. Guidelines are less rigorous. They provide guidance for behavior but do not call for strict obedience. Evaluation criteria are quality characteristics for the assessment of architectural designs or representations. Figure 2 shows the context of architecture principles.

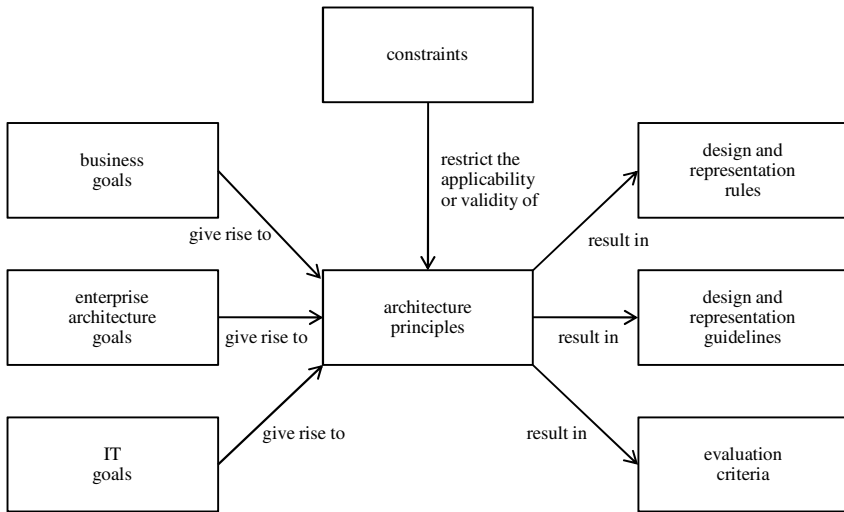


Fig. 2. Context of Architecture Principles

Rules, guidelines, and criteria for designing or evaluating architectures should be derived from architecture principles, which in turn should be derived from relevant goals [13].

2.3 Network of Principles

Architecture principles are usually embedded in a network of associated principles, for example, business and IT principles as well as principles that refer to elements of

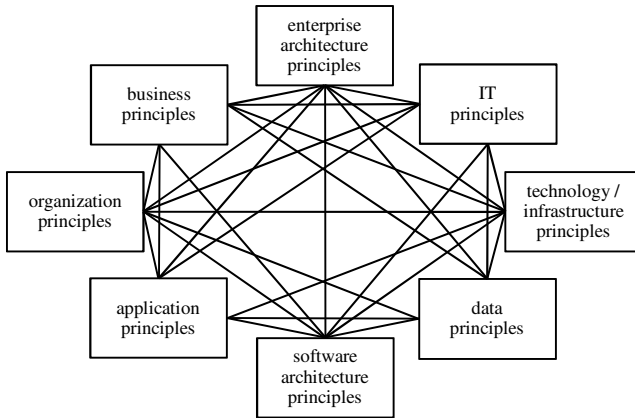


Fig. 3. Network of Principles

enterprise architectures such as organization, application, software architecture, data, or infrastructure principles. Figure 3 exemplifies a network of principles.

2.4 Level of Universality of Architecture Principles

Architecture principles in related arenas, such as software engineering or organizational design, are generic propositions that are largely independent from mission, strategy, objectives, constraints, or conditions of a particular enterprise, organizational unit, or project. Examples for software architecture principles are separation of concerns, modularity, loose coupling, and tight cohesion [14].

Principles described in the literature on enterprise architecture are often enterprise-specific, i.e. tailored to the needs of the enterprise. For example: “Star Enterprise IT areas will need to collaborate to provide the best service in application development and support, and to eliminate artificial internal competition” (p. 389) [6].

3 Literature Review

3.1 Method

We used a structured approach recommended by Webster and Watson [15] to identify relevant publications for the review. As a first step, we examined IS journals and IS conference proceedings using the EBSCO database and the Web of Science. We conducted electronic searches in titles and abstracts on the following keywords: “enterprise architecture” and “principle” or “design” or “rule” or “guideline”.

In a second step, we extended our search to IS journals and conference proceedings that were not covered by our original search. These searches identified a total of 42 articles. After analyzing each article’s abstract, keywords, or the full article when necessary, we excluded 27 articles that did not appear to be concerned with or relevant to enterprise architecture principles. This process provided 15 articles for in-depth review.

In a third step we reviewed the citations in the articles identified in the previous steps to determine prior articles on enterprise architecture principles. A further set of four articles from journals and conference proceedings other than those formally searched was collected and a subset of 19 articles was read in full and coded.

We did not include articles on architecture principles from related research areas such as software engineering or organizational design and engineering. We limited our review to articles focusing on enterprise architecture principles. We also did not include articles discussing principles for designing or evaluating enterprise architecture frameworks or principles for service oriented architectures [16], [17]. We excluded all publications that only mentioned the terms architecture principles, design rules, or guidelines without elaborating on these concepts. Out of the 19 coded articles, eleven include passages of interest. They are compiled in the analysis.

3.2 Overview of the Literature

Compared to the considerable amount of publications on enterprise architecture in general, the number of articles presenting research findings on enterprise architecture principles is rather low. This is surprising because architecture principles are considered to be essential elements of architectures [1], [2], [7]. We identified no more than eleven publications that analyze enterprise architecture principles [3], [4], [6], [8], [9], [10], [13], [18], [19], [20], and [21]. Only four of these articles [3], [6], [9], and [13] have their main emphasis on principles. The other seven articles discuss principles among other topics.

Prevalent methodologies used are case studies [4], [6], [21], [13] and conceptual descriptions [3], [8], [9], [10], [19], and [20]. One article [18] uses mathematical representation. We did not find any survey that explores development, use, or evaluation of architecture principles in multiple enterprises.

3.3 Definitions of Enterprise Architecture Principles

No accepted definition of the term enterprise architecture principles has emerged yet. Table 1 presents definitions of architecture principles covered by our review. Authors of articles [4], [18], [20], and [21] do not define the term.

It is remarkable that the term architecture principle is defined in six articles only. One article [10] equates a collection of design principles with enterprise architecture. It is also interesting that only one definition [6] emphasizes that principles may guide design *and* evaluation of architectures. The other definitions focus on the design purpose of principles.

Furthermore, some definitions focus on selected layers of enterprise architectures. They do not seem to consider all layers of enterprise architectures. Some definitions focus on IT (“simple, direct statements of how an enterprise wants to use IT” [8]; “rules and guidelines for the use and deployment of all IT resources and assets” [13]), others on business (“rules and guidelines ... that inform and support the way in which an organization sets about fulfilling its mission” [3] and [9]). Only two definitions [6] and [19] comprise enterprise architecture in its entirety.

Table 1. Definitions of Enterprise Architecture Principles

References	Definitions
[3] referring to [7]	“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.” (p. 49)
[6]	“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.” (p. 389)
[8]	“... 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.” (p. 38)
[9] referring to [7]	“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.” (p. 1139)
[10]	(no explicit definition); “collectively the design principles are identified as enterprise architecture” (p. 217)
[13]	“Architectural principles define the underlying general rules and guidelines for the use and deployment of all IT resources and assets across the enterprise ...” (p. 2)
[19]	“Architecting principles are rules to use when elaborating enterprise architectures.” (p. 1214)

3.4 Context of Architecture Principles

The context of architecture principles as outlined in section 2.2 is often structured in rationales and implications [6], [8] or in goals and rules [9], [13], [20], [21]. A rationale gives an explanation for the principle. It states underlying reasons, in most cases by explaining the principle’s contribution to achieving architectural or business goals. Implications describe potential consequences for those in charge of developing, evaluating or deploying the architecture or elements of the architecture [6]. Accordingly, Hoogervorst claims: “All principles should have a three-fold context: the rationale of the principle, (2) the implications, and (3) key actions necessary for making the principle operational” (p. 229) [10]. Richardson, Jackson, and Dickson propose the following structure for describing enterprise architecture principles: (1) principle statement, (2) rationale, and (3) implications [6].

Constraints are neglected by nine articles included in our review. This is astonishing because constraints may help researchers and practitioners to correctly assess the principle’s scope and validity. Van Bommel et al. [9] suggest using constraints when formalizing architecture principles. Chen and Lillehagen [19] point out that architecture principles should be embedded in goals and objectives, constraints, conditions, and challenges.

Similar to the situation in service design [16] there is no empirical validation of successful architecture principles. We did not find any publication that explores the

relationship between deploying architecture principles and attaining architecture goals. Lessons learned when deploying enterprise architecture principles [6], [8], [13], [21] provide anecdotal evidence at best. Tested knowledge on which architecture principles facilitate the achievement of specific architecture goals would be highly beneficial for the enterprise architecture community.

3.5 Network of Principles

Interdependencies of enterprise architecture principles and other principles, e.g. IT principles or business principles, are not mentioned in ten of the articles included in our review [3], [4], [6], [8], [9], [10], [18], [19], [20], and [21].

Lindström [13] points out, that architectural principles should be derived from business principles which in turn should be derived from business strategy. IT governance and IT strategy principles should be derived from architectural principles. However, the distinction of architecture principles and other principles remains ambiguous. Lindström [13] cites the following architectural principles of Vattenfall, a major European energy provider: “IS/IT Strategy development shall be an integral part of business strategy development.” “Control of development and implementation of IS/IT projects must comply with a corporate common project management model.” Most of the so-called enterprise architecture principles reported in her article resemble IT principles. Lindström does neither distinguish IT principles from enterprise architecture principles nor does she explain criteria of how to tell between IT and architecture principles. The same is true for principles compiled by Richardson, Jackson, and Dickson [6].

3.6 Level of Universality of Architecture Principles

In our review we found articles that examine generic principles and other articles that report about enterprise specific principles. In a second step we analyzed which level of universality is addressed by the articles focusing on design principles and on representation principles respectively. Table 2 shows the level of universality and the nature of the architecture principles discussed in the articles included in our review.

Table 2. Level of Universality and Nature of Architecture Principles

	design principles	representation principles
generic	[19], [21]	[3], [4], [9], [18], [20]
enterprise-specific	[6], [8], [10], [13]	

The majority of the articles focus either on enterprise-specific design principles or on generic representation principles. Only two articles elaborate on generic design principles. No article describes enterprise-specific representation principles.

We were astonished about the fact that only two article describe generic design principles for enterprise architectures. We had expected that two decades of research on enterprise architectures would have yielded more knowledge on design principles that are independent of the specific circumstances of a particular enterprise.

4 Summary and Research Directions

The results of our review show that there are various gaps in the research literature: No accepted definition of enterprise architecture principles has emerged yet. Design and representation principles often are not explicitly distinguished. A detailed conceptual framework that could serve as a basis for conducting quantitative research is still lacking. Business principles, IT principles and enterprise architecture principles are often mixed up. Research into generic design principles is still in its infancy.

Our literature review illustrates the necessity to conduct more in-depth research on enterprise architecture principles. We suggest the following options for future research:

1. Identifying an appropriate definition of enterprise architecture principles. An acceptable definition should cover all layers of enterprise architecture and should not be restricted to particular layers. It should also account for the three major purposes of architecture principles: design, description, and evaluation of systems. We propose the following definition: Enterprise architecture principles are fundamental propositions that guide the description, construction, and evaluation of enterprise architectures. Enterprise architecture principles fall into two classes: Design principles guide the construction and evaluation of architectures. Representation principles guide the description and modeling of architectures, as well as the evaluation of architectural representations.
2. Obviously it is difficult to clearly distinguish enterprise architecture principles from IT principles or business principles. We do not know whether and how companies distinguish these categories of principles. More research is needed to answer the question whether this distinction is helpful and how it can be achieved.
3. Exploring the issues of enterprise architecture principles from more theoretical perspectives. Adjacent research areas may provide helpful insights to answer this question. Research into software engineering and software architecture has yielded considerable findings on architecture principles [14], [22]. Organizational design and engineering explore principles of how to design and to describe enterprises [23], [24]. Research on service oriented architectures has produced valuable knowledge on architecture principles [16], [17]. Systems architecting [25] may also provide helpful insights of how to design architecture principles.
4. Investigating generic enterprise architecture design principles. Findings on generic design principles are meager in the field of enterprise architecture. Adjacent research areas, such as software architecture or organizational design and engineering, have produced valuable knowledge on generic design principles. It would be highly interesting to explore whether there are generic design principles that are applicable to all layers of enterprise architectures. In a second step, scholars could address the question under which circumstances specific principles may contribute to the achievement of particular enterprise architecture goals.
5. Extending the basis of case studies. There are only few publications that describe practical experience with enterprise architecture principles. Since this research field has not yet been explored in detail and theoretical foundations are meager we need more explorative research. More case studies might help to shed light on key issues and success factors when formulating and deploying architecture principles.

6. Conducting quantitative research. When a detailed conceptual framework for exploring enterprise architecture principles is elaborated quantitative research should be conducted. Surveys covering multiple enterprises in various industries could help to assess whether enterprise architecture principles converge to a coherent set of generic principles or whether these principles need to be tailored to the specific needs of the particular enterprise.

References

1. IEEE 1471-2000 IEEE Recommended Practice for Architectural Description of Software-Intensive Systems – Description (2000)
2. ISO/IEC 42010:2007 Systems and software engineering – Recommended practice for architectural description of software-intensive systems (2007)
3. van Bommel, P., Buitenhuis, P.G., Stijn, J.B., Hoppenbrouwers, A., Proper, E.H.A.: Architecture Principles – A Regulative Perspective on Enterprise Architecture. In: Reichert, M., Strecker, S., Turowski, K. (eds.) EMISA 2007, pp. 47–60. Gesellschaft fuer Informatik, Bonn (2007)
4. Winter, R., Fischer, R.: Essential Layers, Artifacts, and Dependencies of Enterprise Architecture. JEA 3(2), 7–18 (2007)
5. Schekkerman, J.: Enterprise Architecture Good Practices Guide: How to Manage the Enterprise Architecture Practice, Trafford, Victoria (2008)
6. Richardson, G.L., Jackson, B.M., Dickson, G.W.: A Principles-Based Enterprise Architecture: Lessons from Texaco and Star Enterprise. MISQ 14(4), 385–403 (1990)
7. The Open Group: TOGAF Version 9. The Open Group Architecture Framework (TOGAF) (2009), <http://www.opengroup.org>
8. Armour, F.J., Kaisler, S.H., Liu, S.Y.: A Big-Picture Look at Enterprise Architectures. IEEE IT Professional 1(1/2), 35–42 (1999)
9. van Bommel, P., Hoppenbrouwers, S.J.B.A., Proper, E.H.A., van der Weide, T.P.: Giving Meaning to Enterprise Architectures - Architecture Principles with ORM and ORC. In: Meersman, R., Tari, Z., Herrero, P. (eds.) OTM 2006 Workshops. LNCS, vol. 4278, pp. 1138–1147. Springer, Heidelberg (2006)
10. Hoogervorst, J.: Enterprise Architecture: Enabling Integration, Agility and Change. IJCIS 13(3), 213–233 (2004)
11. Lyons, J.: Semantics. University Press, Cambridge (1977)
12. Ogden, C.K., Richards, I.A.: The Meaning of Meaning: A Study of the Influence of Language Upon Thought and of the Science of Symbolism. Harcourt & Brace, New York (1923)
13. Lindström, Å.: On the Syntax and Semantics of Architectural Principles. In: Proceedings of the 39th Annual Hawaii International Conference on System Sciences, p. 10. Computer Society Press, Washington (2006)
14. Witt, B.I., Baker, F.T., Merritt, E.W.: Software Architecture and Design. Principles, Models, and Methods. Van Nostrand Reinhold, New York (1994)
15. Webster, J., Watson, R.T.: Analyzing the Past to Prepare for the Future: Writing a Literature Review. MISQ 26(2), xiii–xxiii (2002)
16. Aier, S., Gleichauf, B.: Towards a Sophisticated Understanding of Service Design for Enterprise Architecture. In: Feuerlicht, G., Lamersdorf, W. (eds.) ICSSOC 2008. LNCS, vol. 5472, pp. 316–326. Springer, Berlin (2009)
17. Erl, T.: SOA: Principles of Service Design. Prentice Hall, Upper Saddle River (2008)

18. Goikoetxea, A.: A Mathematical Framework for Enterprise Architecture Representation and Design. *IJITDM* 3(1), 5–32 (2004)
19. Chen, D., Lillehagen, F.: Enterprise Architectures - Review on Concepts, Principles and Approaches. In: Sobolewski, M.W., Cha, J. (eds.) *Proceedings of the 10th International Conference on Concurrent Engineering (ISPE CE 2004)*, pp. 1211–1216. Tsinghua University Press, Beijing (2004)
20. Balabko, P., Wegmann, A.: Systemic Classification of Concern-Based Design Methods in the Context of Enterprise Architecture. *ISF* 8(2), 115–131 (2006)
21. Wilkinson, M.: Designing an ‘Adaptive’ Enterprise Architecture. *BT Technology Journal* 24(4), 81–92 (2006)
22. Bass, L., Clements, P., Kazman, R.: *Software Architecture in Practice*, 2nd edn. Addison-Wesley Longman, Reading (2003)
23. Romme, A.G.L., Endenburg, G.: Construction Principles and Design Rules in the Case of Circular Design. *Organization Science* 17(2), 287–297 (2006)
24. Goold, M., Campbell, A.: *Designing Effective Organizations. How to Create Structured Networks*. Jossey-Bass, San Francisco (2002)
25. Rechtin, E.: The Art of Systems Architecting. *IEEE Spectrum* 29(10), 66–69 (1992)