Developing Cloud-based Enterprise Architectures Using Archetypes

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Abstract. The digital transformation of industries, which traditionally focused on physical products, towards integrated product-service offerings requires fundamental changes also on the level of information technology. In particular, these changes require the provision of flexible IT architectures that support fast adaptations for innovative combinations of physical products and IT-delivered services. In this context, multiple dimensions need to be taken into account. These range from performance and cost aspects to recent opportunities emerging from modern cloud-based approaches. In this paper we describe how the selection of an appropriate IT architecture can be supported using the concept of archetypes. Thereby different options for the design of the IT architecture are derived and compared to each other. The approach has been successfully applied in a feasibility study with Hilti Corporation where it supported the realization of the Hilti Cloud.

Keywords: Enterprise Architecture, Cloud Computing, Archetypes

1 Introduction

The digitization of industrial companies can today be witnessed in many sectors. This is accompanied by a number of research initiatives on a global and European level under terms like Factories of the Future, Industry 4.0, or Industrial Internet. The basis for these developments is on the one hand a change in business models where traditional product-focused business models are being transformed to such focusing on products and services [12,5]. Thereby, it is aimed for an increased value offering for the customer where the producers of products are also the providers of accompanying services. At the heart of these developments lies the support through information technology. IT enables not only the effective and efficient design of such product-services-systems (PSS) [3,13] but also fundamentally enables the realization of PSS themselves. In addition, recent developments such as internet-of-things technologies, cyber-physical and autonomous systems [9] contribute to additional challenges and opportunities for digital enterprises.

From the viewpoint of information technology it is therefore of primary importance to incorporate aspects of flexibility and adaptability in its strategic directions to cope with these developments. Due to the fast pace of emerging business requirements and technological changes, continuous adaptations of hardware and software infrastructures become necessary in order to provide optimal support for the realization of IT-based solutions. As a consequence, the underlying IT architecture needs to be aligned to these demands. Most recently, cloud-based solutions have been identified as a suitable way to meet these demands [11]. Cloud computing refers to the "ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (..) that can be rapidly provisioned and released with minimal management effort or service provider interaction" [14, p.2].

For introducing cloud-based architectures in organizations multiple dimensions need to be taken into account. This concerns different types of cloud architectures as well as possible individual cloud configurations. In addition, technical characteristics such as performance and capacity aspects have to be taken into account, as well as economic dimensions such as direct and indirect costs. The decision for or against a particular cloud architecture and potential individual configurations is thus characterized by considerable complexity. In order to support decision makers in selecting a suitable solution, we propose in the following a structured approach that is based on the concept of *archetypes*. For this purpose we first discuss in section 2 the foundations for the approach and related work. In the subsequent section 3 we will describe the concept of archetypes for initiating enterprise architecture management with a particular focus on cloud architectures. The application of the concept will be illustrated through a case study conducted with Hilti Global IT. The paper will be concluded by an outlook on the next steps.

2 Foundations and Related Approaches

As a foundation for decisions in architecture management a structured approach is essential to take into account all involved aspects. For this purpose it can be reverted to insights gained in the past as found in the academic literature as well as from industrial practice and standards [2,5]. Especially in the area of enterprise architecture design, a large variety of standards and reference models are today available that have been developed by international consortia [10, p.601ff.]. These range from frameworks for the governance of organizations and information technology such as COBIT (Control Objectives for Information and Related Technology), best practice reference models such as ITIL (IT Infrastructure Library) to frameworks for the design, planning, implementation, and maintenance of enterprise architectures such as TOGAF (Open Group Architecture Framework).

For our purposes we regarded TOGAF as one of the most prominent frameworks in enterprise architecture management. TOGAF is maintained by The Open Group, which is a global consortium of more than 500 members from major companies, government organizations, universities, and individuals[3]. The goal of TOGAF is to support the development of an enterprise architecture in terms of an alignment of business requirements and IT capabilities [15]. TOGAF originated in 1995 from the previous TAFIM (Technical Architecture Framework for Information Management) that had been developed by the US Department of Defense and has since then been continuously refined and extended.

Due to the complexity of enterprise architecture frameworks, often only a subset of them is actually used depending on the required purpose. In our case we focused on the first two phases of the so-called Architecture Development Method (ADM) cycle of TOGAF. In total, the TOGAF ADM cycle consists of one preliminary phase and the eight core phases: A. Architecture Vision, B. Business Architecture, C. Information Systems Architecture, D. Technology Architecture, E. Opportunities and Solutions, F. Migration Planning, G. Implementation Governance, H. Architecture Change Management [15, Section 5]. In the preliminary phase it is determined which architecture capability is required by the organization. This includes the reviewing of the organizational context and the identification of established frameworks, methods, and processes that are affected by the architecture capability. It also needs to be decided what organizational model shall be used for the enterprise architecture, which principles and requirements the architecture should follow and which tools shall be used or implemented that support the architecture capability [15, Section 6.1ff].

Subsequently, in the Architecture Vision phase the objectives are to develop the vision of what is to be achieved by the enterprise architecture and to obtain approval for realizing the architecture vision and deploy a concrete architecture in an organization. This includes in particular the identification of stakeholders and their requirements, the definition of the scope of the architecture, the elaboration of the details of the architecture's principles, the definition of the target architecture's value proposition and the identification of potential risks of the architecture [15]. Besides the different documents that describe the outcome of these activities, the TOGAF specification also suggests the use of solution concept diagrams [15, Section 7.5].

3 The Concept of Archetypes for Initiating Enterprise Architecture Management

Based on the considerations taken in the first phases of the TOGAF ADM, the concept of archetypes has been applied and further refined for the domain of enterprise architecture management. Archetypes are frequently used in the context of information systems. They are described by the following four characteristics according to [1]: first, they permit to let users formally express their concepts

[3] `http://www.opengroup.org/our-members` last accessed 19-02-2016

and the relationships between these concepts. Based on this formal definition, it is ensured that the input of users corresponds to the domain requirements through guiding and validating the user input using verification mechanisms. Third, they can be used to guarantee interoperability in terms of correctly interpreting the results. And fourth, they enable the efficient querying of complex data structures.

For a successful use of the archetype concept it is necessary to first establish a formal schema which is subsequently filled with detailed information. This can be accomplished by using different kinds of technologies. Possible options include the use of databases, enterprise modeling tools, spreadsheets, ontologies or rule-based systems. Depending on the capabilities of the used technology, the values that are inserted into the schema template can be more or less restricted and semantically described [4,7]. For example, a typical spreadsheet application permits to enter arbitrary data types in a specific cell. However, using constraint mechanisms, these entries may be constrained to certain types of values or even a pre-defined set of values from which a user needs to choose.

In the following we will describe how the concept of archetypes has been applied for supporting the initial phases of enterprise architecture management. For this purpose we set up a life-cycle model that contains six sequential steps for designing and evaluating archetypes in the context of enterprise architecture management - see figure 1. The life-cycle has been derived during intensive discussions with domain experts and by taking into account the steps of the TOGAF ADM [15].

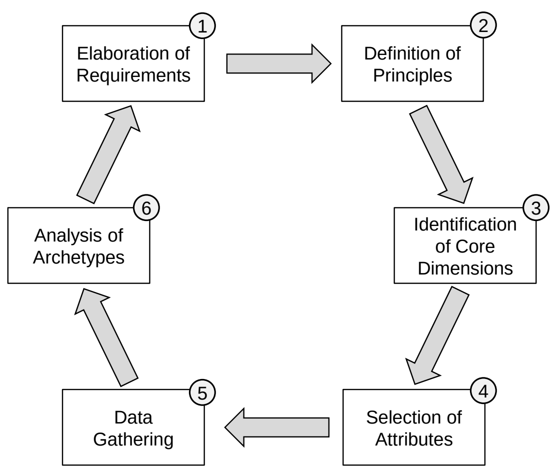

Fig. 1. Phases of the Archetype Life-Cycle

The particular goal of this procedure is to derive and analyze different options for the conceptual design of an enterprise architecture during the preliminary and architecture vision phase. The life-cycle starts with the elaboration of requirements and the definition of principles. Subsequently, the core dimensions of the archetypes are identified and according attributes are selected. Then, data is gathered which is finally used to analyze the different archetype instances. If necessary, the cycle can be repeated to refine the design of the archetypes.

In the context of the preliminary and architecture vision phases, the archetypes resulting from this lifecycle serve as direct input for the further development of the enterprise architecture. In particular, they give guidance on the different options for the fundamental design of the architecture. They can thus be used for illustrating the solution concepts in order to receive a sponsor's sign-off for proceeding with the realization of the enterprise architecture. In the next subsections we will describe in more detail the individual phases. The examples we will give to illustrate the steps thereby refer to the introduction of cloud-based enterprise architectures for an organization from the viewpoint of the IT department.

3.1 Elaboration of Requirements

At the start of the lifecycle the overall requirements for the future enterprise architecture have to be elicited. These can either be derived from general strategic IT goals or specifically elaborated. Typical categories that have to be taken into account comprise *internal customer*, *technical*, and *legal/economic requirements*. If necessary, further categories can be added, e.g. to account for *company-specific* requirements that depend on the industry or sector. With internal customers it is thereby referred to other organizational and in particular business units which consumer the services provided through the IT department.

Examples for internal customer requirements in the context of cloud-based architectures are for example the reliable delivery of services, the delivery of service enhancements without interruption or the provision of an excellent user experience. Examples for technical requirements are the use of standards wherever possible to ensure interoperability and maintainability, the use of loose coupling approaches, the use of continuous delivery and deployment or the ensuring of high reliability. Examples for legal and economic requirements are the provision of secure services for data protection and privacy, the minimization of liability threats or the adherence to cost and time constraints.

3.2 Definition of Principles

The second step is the definition of principles for the enterprise architecture. In this aspect we took up the proposal in the TOGAF specification that describes architecture principles as "the underlying general rules and guidelines for the use and deployment of all IT resources and assets across the enterprise" [15, Section 23.2]. They thus constitute the basis for decisions regarding the enterprise architecture. The TOGAF specification also lists the components for defining architecture principles. These include the *name*, *statement*, *rationale*, and *implications*. The architecture principles can be derived from the requirements defined in the first step as well as from external constraints, current technologies or recent trends in the industry or sector.

In the following we list two examples for architecture principles in the context of cloud architectures. The first principle is derived from the technical requirements and targets standardization and is shown in table 1. The second principle is derived from legal and economic requirements. It targets the compliance to legal requirements in terms of data privacy - see table 2.

Table 1. Example Architecture Principle: Standardization

Name:	Standardization
Statement:	The cloud architecture must not rely on proprietary standards that are only implemented by a single or few vendors. Open standards such as RESTful web services or OAuth2.0 shall be applied wherever possible.
Rationale:	As data needs to be exchanged with third parties a focus on the long-term interoperability perspective is important.
Implications:	If a standard exists, it should be used instead of proprietary solutions. Existing applications need to be adapted to standards. If several standards exist, a default internal standard needs to be defined. For external applications a reasonable amount of standards should be supported.

Table 2. Example Architecture Principle: Data Privacy Compliance

Name:	Data Privacy Compliance
Statement:	The cloud architecture shall comply with the data privacy regulations of the European Union. With this it must be assured that all personal-identifying data resides in the EU or countries that comply with European data privacy and other relevant regulations.
Rationale:	Compliance with European data privacy and other relevant regulations.
Implications:	Compliance has to be actively managed and knowledge about data protection needs to be shared within the organization.

3.3 Identification of Core Dimensions

In the third step the actual design of the archetypes is initiated. For this purpose the *core dimensions* of the archetypes have to be identified. A core dimension in this context stands for a characteristic of the future enterprise architecture that is applicable to all archetypes and differentiates between the archetypes. Core dimensions are thus used to derive the outlines of the archetypes. In figure 2 it is illustrated how the derivation of archetypes can be accomplished along two or three core dimensions. On the left side of figure 2 the two core dimensions $D1$ and $D2$ with their values $d11, d12$ and $d21, d22$ are depicted. Their combination leads to the outline of the four archetypes $AT1$, $AT2$, $AT3$, and $AT4$. Similarly, on the right side of figure 2 the derivation is shown for three core dimensions $D1$, $D2$, and $D3$ and two resulting archetypes $AT1$ and $AT2$. It has to be noted that not necessarily all combinations of the core dimensions correspond to suitable archetypes. It rather has to be decided which of the potential combinations make sense, especially in regard to the aforementioned requirements and principles. The chosen archetypes should then be described in detail, e.g. by stating the *rationale* for adding the archetype to the list of suitable archetypes and the *implications* that the particular archetype has on the design of the overall architecture.

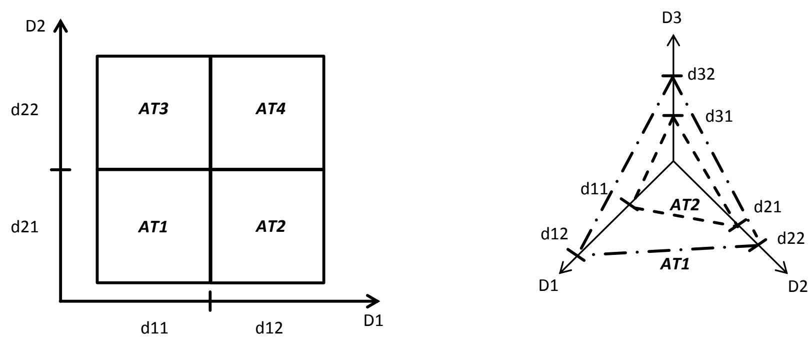

Fig. 2. Ilustration of the Derivation of Archetypes based on 2 and 3 Core Dimensions

As an example for possible core dimensions in the context of cloud-based enterprise architectures the well-known dimensions *deployment model* and *service model* could be used. Thereby, the dimension "deployment model" could have the values public cloud, private cloud or hybrid cloud and the service model the values IaaS (Infrastructure-as-a-Service), PaaS (Platform-as-a-Service), and SaaS (Software-as-a-Service). Resulting archetypes could then be a combination of the public cloud deployment model with the SaaS service model or a private cloud model with the IaaS service model. Based on the previously defined requirements and principles it has to be decided which of these combinations shall be further investigated and detailed with more information. The rationale for choosing an archetype combining public cloud deployment and the SaaS model could be to easily apply scalability to the architecture while taking a potential vendor-lock-in into account. The implication of this archetype would then be to use as many SaaS services as possible in the architecture and to conciously agree on the vendor-lock-in.

3.4 Selection of Attributes

In order to detail the characteristics of each archetype, attributes are chosen in the next step that are applicable to all investigated archetypes. This is illustrated in figure 3. For every archetype AT_i each of the attributes $Attr_j$ has to be applicable. In addition, it has to be specified of which type the attributes are. Possible types include standard data types such as integer, float or string as well as compositions of those. Also the level of measurement has to be defined for each attribute, i.e. nominal, ordinal, discrete, continuous etc.

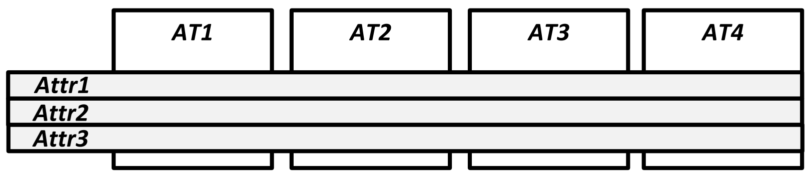

Fig. 3. Selection of Attributes for the Archetypes

Examples for attributes in the context of cloud-based enterprise architectures could be the following: expected technical complexity, scalability, migration and run efforts, or the amount of vendor-lock-in. For each of these attributes an integer value from 1-5 could be applied, indicating the range of *fully applies* to *does not apply*. In this way the different archetypes can be compared to each other in detail.

3.5 Data Gathering

Subsequently, data has to be gathered for the selected attributes. This involves the use of various techniques such as the conduction of vendor studies and the solitication of offers, prototype implementations for assessing technical attributes or investigations of academic and professional literature. Thereby the attributes that have been selected in the previous phase are now filled with concrete information. This step can also be used to highlight which vendor solutions correspond to which archetypes and how their characteristics manifest themselves in the attributes. This is illustrated in figure 4 where for each of the two archetypes vendor solutions $V1, V2$ and $V3, V4$ are shown. Thereby it is expressed that e.g. vendor solution $V1$ corresponds to the characteristics of archetype $AT1$ and the attribute values $a11, a21, a31$.

In the context of cloud-based enterprise architectures a large number of vendor offerings exist today. For filling the according attribute values it can therefore either reverted to the technical specifications of these offerings directly or to third-party evaluations, e.g. by market research companies.

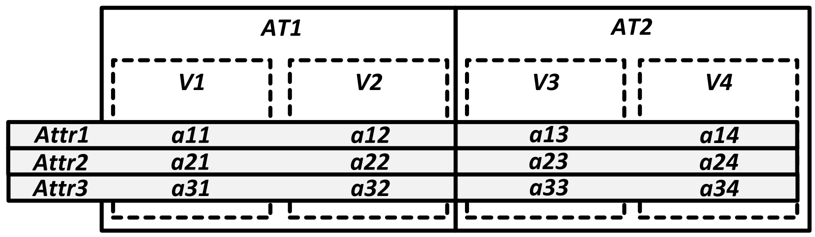

Fig. 4. Attributes for Archetypes filled with Information from Vendor Solutions

3.6 Analysis of Archetypes

Finally, the archetypes and the according vendor solutions can be analyzed and compared to each other. The analysis can be based on the formally assigned attribute values, e.g. by using as a score for a vendor solution v_i the sum or weighted sum over all attributes - see equation 1. Thereby, the weight w_j of an attribute a_{ji} can be adjusted in order to account for their importance in regard to the requirements and architecture principles.

$$v_i^{\text{score}} = \sum_{j=1}^{n} w_j \cdot a_{ji}, \text{ for } i = 1 \ldots m \tag{1}$$

Besides formal comparisons the characteristics of the archetypes also need to be reflected against the requirements and architecture principles. As these are stated in textual form this needs to be accomplished by the enterprise architecture experts of an organization. Again, this should be done in a structured way, e.g. using a SWOT analysis for each archetype that is conducted in a series of workshops.

For evaluating the practical feasibility and applicability of the archetypes in an organization, it also needs to be assessed how each archetype would affect the current application and service landscape. As an archetypes represents the future strategic orientation of the enterprise architecture, it is necessary to investigate for example how existing applications and services have to be changed if the archetype is to be realized. As a basis for this it can be reverted to existing enterprise architecture repositories. It then has to be analyzed for a suitable subset of the existing application and service landscape how its structure and behavior are affected. Based on the detailed description of each archetype this can be conducted down to the level of attributes.

For example, in the context of cloud-based enterprise architectures an archetype that relies on SaaS components from an external vendor has to be evaluated in terms of its compatibility with required or existing services. This compatibility can thereby be evaluated in terms of required functionality but also in terms of the attribute values that characterize a specific vendor solution, e.g. in terms of scalability and throughput performance.

4 Case Study: Hilti Cloud

The approach described above has been successfully applied in a case study with Hilti Global IT. Hilti is a Liechtenstein based company and the market leader for professional demolition and fastening technology in construction. It has a workforce of about 23,000 employees working in more than 120 countries. As many other companies in the area of manufacturing, Hilti has also adopted a strategy that is directed towards digitalization and the offering of product-service bundles. In order to meet future demands from its business units in terms of IT support for products and services, Hilti Global IT decided to incorporate cloud-based computing technologies. Thereby a set of core IT services shall be provided to other organizational units at Hilti, which can be used to compose new applications and offerings while at the same time maintaining compatibility and interoperability through common data and services.

For determining possible options for designing the future Hilti cloud architecture, the concept of archetypes was used as a foundation. Based on four categories of requirements - customer requirements, technical requirements, Hilti-specific requirements, and legal and economic requirements - 14 architecture principles were elaborated in a series of workshops with Hilti's IT experts. Subsequently, the core dimensions for the archetypes were identified. These comprised on one axis the deployment models and on the other the standard cloud service models IaaS, PaaS, and SaaS. The deployment dimension was thereby further detailed by the values one vendor, multiple vendors for public clouds, shift scenarios where resources can be shifted from vendor to another, and hybrid variants combining developments on the side of Hilti and on the side of cloud vendors. In total 11 archetypes were derived that warranted further investigation. Each of these archetypes was described in more detail using its rationale and implications.

For the selection of attributes, at first 13 attributes were chosen to analyze the archetypes in more detail. In doing so it was soon discovered that only four archetypes would comply fully with the previously defined requirements and architecture principles. Therefore only these four were further considered. Subsequently, further attributes were added to the analysis. In particular it had to be investigated how existing vendor solutions could meet the requirements of each archetype. This resulted in another 57 attributes that were added to the four archetypes. In the data gathering step 16 different kinds of vendor solutions were then regarded by Hilti's IT experts and their properties represented using the specified attributes.

With this information the analysis of the archetypes was conducted. This also involved the assessment of how a choice for an archetype would affect the future Hilti cloud service and application landscape. For this purpose a first draft of the future landscape was designed including all necessary components and their interfaces as well as in some cases also the required technologies. After another series of workshops with Hilti's IT experts where in-depth discussions and SWOT analyses were conducted for the archetypes, the most suitable archetypes as well as possible vendor solutions could be presented. Hilti's IT then decided for one archetype and an accompanying vendor solution.

From a technical point of view, the realization of the archetypes was done using at first spreadsheets and subsequently an enterprise architecture management platform. The platform we used was the freely available community edition of ADOit[4]. Spreadsheets had the advantage that most IT users are today familar with them and can thus easily contribute their knowledge. They can also be easily shared via out-of-the-box cloud storage service solutions. With the transition to the enterprise architecture management platform, more complex analyses could then be conducted, e.g. to assess the dependencies between future and existing services and how these would be affected through different archetypes – see the screenshot in figure 5.

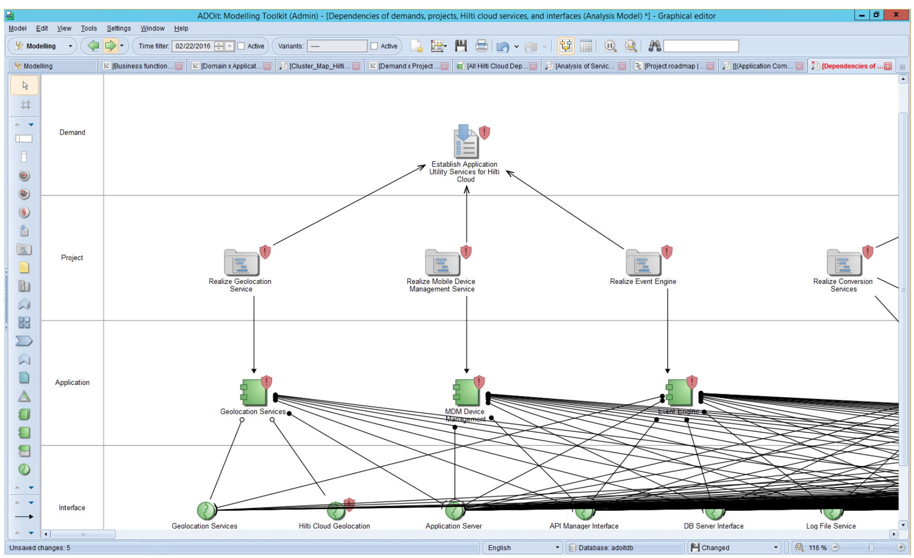

Fig. 5. Screenshot of an Analysis of the Application Landscape and Services in ADOit

5 Conclusion and Outlook

In this paper we described the concept of archetypes for supporting the initial phases of enteprise architecture design and development. The approach has been successfully applied in a case study with Hilti Global IT and enabled a decision for the future design of the Hilti cloud architecture. In conclusion, the concept of archetypes proved to be suitable for initating the first phases of enterprise architecture management. Although some existing tools in the form of spreadsheet applications and an enterprise architecture management platform have

[4] See `http://www.adoit-community.com/` last accessed 22-02-2016

been used, additional tool support would further ease the elaboration and handling of archetypes. In particular it could be reverted to approaches in the area of meta modeling and visualization [8,6] that would permit to design specific support for the concept of archetypes and establish according analysis methods.

References

1. Beale, T.: Archetypes: Constraint-based Domain Models for Future-proof Information Systems. In: Proceedings of the 11th OOPSLA Workshop on Behavioural Semantics. (2002)
2. Berzisa, S., Bravos, G., Gonzalez, T., Czubayko, U., Espana, S., Grabis, J., Henkel, M., Jokste, L., Kampars, J., Koc, H., Kuhr, J., Llorca, C., Loucopoulos, P., Pascual, R., Pastor, O., Sandkuhl, K., Simic, H., Stirna, S., Valverde, F., Zdravkovic, J.: Capability Driven Development: An Approach to Designing Digital Enterprises. Business & Information Systems Engineering 57(1), 15–25 (2015)
3. Boehm, M., Thomas, O.: Looking beyond the rim of ones teacup: a multidisciplinary literature review of Product-Service Systems in Information Systems, Business Management, and Engineering & Design. Journal of Cleaner Production 51, 245–260 (2013)
4. Bork, D. and Fill, H.-G.: Formal Aspects of Enterprise Modeling Methods: A Comparison Framework. In: 47th Hawaii International Conference on System Sciences. pp. 3400–3409. IEEE (2014), DOI: 10.1109/HICSS.2014.422
5. Demirkan, H., Kauffman, R.J., Vayghan, J.A., Fill, H.G., Karagiannis, D., Maglio, P.: Service-oriented technology and management: Perspectives on research and practice for the coming decade. Electronic Commerce Research and Applications 7(4), 356–376 (2008)
6. Fill, H.G.: Visualisation for Semantic Information Systems. Gabler (2009)
7. Fill, H.G., Burzynski, P.: Integrating Ontology Models and Conceptual Models using a Meta Modeling Approach. In: 11th International Protégé Conference (2009)
8. Fill, H.G., Karagiannis, D.: On the Conceptualisation of Modelling Methods Using the ADOxx Meta Modelling Platform. Enterprise Modelling and Information Systems Architecture 8(1), 4–25 (2013)
9. Hui, G.: How the Internet of Things Changes Business Models. Harvard Business Review July 29 (2014)
10. Krcmar, H.: Informationsmanagement. Springer (2015)
11. Liu, F., Tong, J., Mao, J., Bohn, R., Messina, J., Badger, L., Leaf, D.: NIST Cloud Computing Reference Architecture - Recommendations of the National Institute of Standards and Technology. NIST Special Publication 500-292 (2011)
12. Martinez, V., Bastl, M., Kingston, J., Evans, S.: Challenges in transforming manufacturing organisations into product service providers. Journal of Manufacturing Technology Management 21(4), 449–469 (2010)
13. Medini, K., Boucher, X., Peillon, S., Matos Da Silva, C.: Product Service Systems value chain configuration - A simulation based approach. Procedia CIRP 30, 421–426 (2015)
14. Mell, P., Grance, T.: The NIST Definition of Cloud Computing. Special Publication 800-145 (2011)
15. The Open Group: TOGAF Version 9.1 - Open Group Standard - Enterprise Edition. Document Number: G116, The Open Group (2011)