Framework and Reference for Architecture Design

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Recommended Citation
http://aisel.aisnet.org/amcis2008/118
ABSTRACT
The paper outlines the design of enterprise architectures. The architecture design is based on a comprehensive architecture framework which classifies the basic domains of enterprise architecture and lays the ground for architecture description. The description of enterprise architecture is based on three basic views. The component view describes the elements of architecture and their relationships. The communication view shows how the elements interact with one another. The distribution view describes how the elements are distributed in terms of location or organisational assignment.

Key element of architecture design is to account for interdependencies among the building blocks of architecture. Blueprints are introduced as a means in planning the deployment of architecture on a large scale. Blueprints give a comprehensive view on the building blocks and how they interact. They show the effects of architecture design between business, application, and infrastructure architecture. The main stakeholders and their respective usage of the design techniques are explained.

Keywords
enterprise architecture framework, architecture description, views, blueprints, architecture management, stakeholders

ENTERPRISE ARCHITECTURES
Principles and overview

Architectures are a commonly used term in the design of information systems. However understanding and structuring of enterprise architecture and their basic elements differs (see the discussion in Buhl/ Heinrich 2004). IEEE Standard 1471-2000 defines architecture as “... fundamental organization of a system, embodied in its components, their relationships to each other and the environment, and the principles governing its design and evolution” (IEEE 2000).

Enterprise Architecture comprises the entire business with all its constituents. The alignment of the business and organizational design of the enterprise (business architecture) with the IT architecture is fundamental. The wide range of different domains and scope of enterprise architecture and its high complexity are characteristics of enterprise architectures. The following sketches some objectives to be pursued with enterprise architecture management (Aranow 2002, p. 9f., Dietzsch 2005, p. 36f, Masak 2005, p. 9f., Meta Group 2002, p. 6f., 49f., Günzel/ Rohloff 2003, p. 424, TOGAF 2006, Umek/ Tannhäuser 2004, p. 55f.):

- Strategy and business orientation
- enabling, leverage of IT, new business models
- Planning and controlling
- target oriented, steering of I&C program with strong impact and to secure compliance to standards
Adaptability and continuity
- dynamic markets, business, and technology, provide for scalability and growth,
  adapt to organisational change
- provide for continuity by lasting architecture principles and structure

Effectiveness and efficiency
- success oriented, strategy based architecture
- to develop & implement the I&C landscape in a systematic and efficient manner
  and to utilize synergies

Transparency and communication
- complexity and dependencies of architecture building blocks
- heterogeneous composition of people involved (from management to IT experts)

Enterprise Architecture is a means to support business and IT alignment. Architecture planning is the ground for the
development of the IT landscape and at the same time provides the agility to react fast to market requirements.

Approach and research results
The enterprise architecture approach presented in this paper was developed in a number of architecture projects within
Siemens at corporate and business unit level (Siemens 2005, 2000, IT Scope 2003a/b) based on design science. Architecture
description and procedures were tested and advanced in iterative steps. However, this paper tries to highlight the principal
features and findings and refrains from project or company specifics.

The paper shows how an architecture framework and three distinct views on architecture support the reduction to core entities
and construction principles. Blueprints give overview on the IT landscape and show interdependencies between the building
blocks of architecture. Views and blueprints can be combined for large and small scale architecture development. The main
stakeholders of enterprise architecture from the business as well as IT side and their respective usage of the design techniques
are explained.

REFERENCE FOR ARCHITECTURE DESIGN
Requirements for Architectures in the Large and Architecture Description

In contrast to information systems architecture, which is widely discussed under the aspect of a single information system
being integrated in an organization and aligned with business processes, enterprise architecture takes the entire IT landscape
into focus. In comparison architecture is understood as city planning and not only as planning the architecture of a house
(Gartner Group 2002, Burke 2003). It requires the definition of development plans for an entire area and not only the
construction plan for a building. The development of the IT landscape in contrast to the information system architecture of a
single system is architecture design on a large scale. It requires adequate features for architecture description. The following
summarizes essential requirements of “architectures in the large” and challenges the development of an enterprise
architecture method (compare Dern 2006, p. 81-83):

- Reduction to core entities and construction principles
- Balance of abstraction and specialization
- Representation of mutual dependencies
- Integration of architecture in the large and in the small

An architecture description is a formal description of a system, organized in a way that supports reasoning about the
structural properties of the system. It defines the building blocks and components that make up the overall system, and
provides a plan from which products can be procured, and systems developed, that will work together to implement the
overall system.

The IEEE-Standard “Recommended Practice for Architectural Description of Software Intensive Systems” (IEEE 2000) can
be used as a basis for an architecture description. Figure 1 shows the basic understanding described in this standard: every
system has an architecture, which can be recorded by an architectural description. The architectural description is organized
into one or more constituents called (architectural) views. Each view addresses one or more of the concerns of the system
stakeholders. The term view is used to refer to the expression of a system’s architecture with respect to a particular viewpoint (Bachmann 2000, Clements et al. 2003). Each view addresses one or more of the concerns of the system stakeholders. Basically, a system has one or more stakeholders. Each stakeholder typically has interests in, or concerns relative to, that system. We will address the stakeholders in the last section.

Concerns are those interests which pertain to the system’s development, its operation or any other aspects that are critical or otherwise important to one or more stakeholders. Concerns include system considerations such as performance, reliability, security, distribution, and ability to evolve. A system exists to fulfill one or more missions in its environment. A mission is a use or operation for which a system is intended by one or more stakeholders to meet some set of objectives.

![Diagram of architectural description](image)

**Figure 1:** The conceptual model of an architectural description (IEEE 2000)

The principle of views is the basis of every reasonable architecture description and the need for multiple views in architecture descriptions is widely recognized in the literature. The IEEE standard 1471 (IEEE 2000), however, describes only the concept of views, stakeholders and concerns. Because of the wide range of opinions on selecting appropriate views, the standard does not make any statements on selecting views, the notation or name of views.

In contrast to the diversity of existing views for architecture description (e.g. see examples of architecture descriptions and views in Bernus et al. 1998, Clements et al. 2003, Österle 1995, Österle/ Winter 2003, Scheer 1999, Zachman 1987) we propose a consolidation of views to a manageable set but which describes all relevant properties of architecture.

**Enterprise Architecture Framework**

In this section a framework is introduced which structures enterprise architecture in key domains and building blocks in order to give a comprehensive view on all relevant aspects of enterprise architecture (for an overview on enterprise architecture frameworks see Schekkermann 2006, p. 85f., James 2004, Lapkin 2004a, 2004b, Schulman 2004). Examples for frameworks are: The Open Group Architecture framework (TOGAF 2006), Federal Enterprise Architecture Framework (FEAF), Generic Reference Enterprise Architecture Methodology (GERAM), Gartner and META Group Enterprise Architecture Frameworks (Gartner, META Group 2002), and Zachman Framework (Zachman 1987, Sowa/ Zachman 1992). Regardless which one to choose, it is important to base architecture development on a framework, it is essential for transparency, communication, and a systematic approach.

The Open Group Architecture framework (TOGAF 2006, Version 8.1.1) is widely recognized and plays a prominent role. It consists of four domains: The business (or business process) architecture defines the business strategy, governance, organization, and key business processes. The data architecture describes the structure of an organization's logical and physical data assets and data management resources. The applications architecture provides a blueprint for the individual application systems to be deployed. Finally the technology architecture describes the logical software and hardware capabilities that are required to support the deployment of business, data, and application services.
However, since the data architecture is defined as the 'logical and physical data assets of an organization it mixes business requirements with technical implementation. In difference to TOGAF the architecture framework introduced in this paper clearly separates the domains of business and IT architecture. This provides for a clear distinction of the business oriented description of the enterprise architecture and the derived technological implementation. Hence, in the proposed framework the information architecture is not described as a separate architecture domain but split in a building block of the business architecture in terms of logical information structures and a building block of applications architecture in terms of implementation of data repositories. Furthermore, the framework details the domains in architecture building blocks to give a comprehensive overview of all constituents of enterprise architecture.

The framework is composed of three basic domains each with distinct architecture building blocks.

The business architecture describes the fundamental organisation and requirements of the business based on business strategy and objectives. It is composed of the four building blocks business model, organizational architecture, process architecture, and information architecture.

- The business model gives a high level view on the nature of the business in terms of products & services offered in the market, the value chain, business partners, market channels utilized, and the combination of resources and information for generating value add.
- The organizational architecture describes the organizational design of the enterprise and the principal cooperation with customers and suppliers.
- The process architecture classifies and describes all processes of the business and their respective value adds. It is the core building block of the business architecture. The process architecture can be classified in the core business processes customer relationship management, supply chain management, product life cycle management and the management and support processes.
- The information architecture shows the logical structure of all information entities like products, business partners, logistic information etc.

![Figure 2: Enterprise architecture framework](image)

The application architecture gives an overview on all applications supporting the processes of the business with the building blocks enterprise applications, portal & information management platform, data repositories, and EAI Services.

- Enterprise applications are supporting the automation of business processes and can be assigned to the respective process in terms of their functional support.
The portal and information management platform is the universal access to all company information and knowledge. Portals are designed to specific user groups like customer, business partner, and employees.

Data repositories are the physical storage of all relevant company data and provide an integrated view on product -, customer and business partner -, logistic -, or financial data.

Enterprise application integration services provide the integration of applications and data across the company. Integration technology spans from message exchange, data exchange to process integration.

The infrastructure architecture, also referred to as technology architecture, comprises the software, hardware and network infrastructure required for operations of all applications. Infrastructure building blocks are basic services, workplace services, server systems & storage, and the network.

- Basic services are essential applications providing a specific functional support which are independent from business processes. Examples are communication services like Email or Telco, directory or search services, and administration services like single sign on or PKI. Web Services are emerging services which transfer the concept of basic service to the internet. Basic services are modules to be used in different applications.
- Workplace services provide for presentation and work with information and for productivity support at the work place (office desk, shop floor etc.). They comprise fixed and mobile devices at the client site and include basic office applications and browser.
- Server systems support all back end resources like applications, data repositories, integration services etc. Storage provides all memory capacity for running the applications on the server.
- Networks provide the communication links in the LAN and WAN, within the company, between companies and in the Internet.

Security is integral part of all architecture building blocks and described in an overlaying structure.

With this architecture definition in mind, it should be obvious that enterprise architecture is more than the collection of the constituent architectures. The interrelationships among these architectures, and their joint properties, are essential to the enterprise architecture.

This paper can only give an outline on the domains of the enterprise architecture framework and sketch the main building blocks at a high level. All building blocks of the framework are detailed down to the level of modules, systems and components. The framework gives a comprehensive description of all relevant elements of enterprise architecture providing a principal structure and classification schema used as a reference for architecture development.

Reference for Enterprise Architecture Design

The projected method for architecture design consolidates the modeling of enterprise architectures to a few essential and ample techniques. They were developed and tested in a number of projects at Siemens AG (IT SCOPE 2003, Siemens 2000). In order to generate different views of architecture all architecture documentation is stored in a repository. The Corporate modeler (Casewise 2006) is used and enhanced with additional features for architecture description. The IT Navigator (Siemens 2005) was developed for analysis and assessment of architecture.

The following figure depicts the architecture framework introduced and the corresponding techniques for architecture description. It is based on the principal elements of the architecture framework for information systems described by Sinz (Sinz 1997, p. 3, Sinz 2002).

Views: Each enterprise architecture domain can be described taking a specific view, which looks at the architecture, its structure and elements from a specific perspective. Three basic views were identified which are sufficient to describe all relevant aspects of enterprise architectures:

Component view: The view describes the logical and functional structure of the architecture in scope. All building blocks and their systems and components are described in terms of composition, structure and relationships among one another. The component view allows for different level of detail of the architecture. Components, systems, subsystems, building blocks can be grouped or decomposed. The segmentation of the diagram is in building blocks based on the respective architecture in scope.
Communication view: The view describes the communication (interaction) between systems and components. The relationship among the systems is decomposed in the interaction of components within a system and to other systems. Different types of communication can be described with distinct notation for communication lines. The segmentation of the diagram is in communication areas based on the respective architecture in scope.

Distribution view: The view describes the allocation of systems or components in terms of geographical or organizational distribution. The diagram is segmented in organization or location based on the respective architecture in scope.

These three views can be applied to all domains of enterprise architecture. However, the segmentation of the diagram is selected according to the appropriate context of the domain and chosen level of detail. The high complexity of enterprise architectures can be reduced by taking particular views which focus on specific aspects of architecture. The three views facilitate the reduction to core entities and construction principles and the understanding of their behavior.

The reference for architectural description is based on the following features:

Relationship/dependencies between the enterprise architecture domains can be described using the concept of blueprints. A blueprint is a plan which describes the deployment of an architecture building block across the enterprise. It pictures the landscape of this building block in a matrix of two business dimensions (see next section for details).

Standards are an essential element being used for all architecture building blocks which provide for interchangeability, ease of across system communication etc. Besides the use of standards identification and usage of commonly recognized pattern is also an important objective for architecture design. In the following we focus on examples for the three views and blueprints in order to illustrate the proposed techniques.

In the following section we use selected examples to outline the advancement to enterprise architecture description, layout and use of the proposed techniques. It should illustrate the principal approach without focus on the specific company’s architecture.

**DESCRIPTION OF ENTERPRISE ARCHITECTURES**

**Architecture views**

For the design of architecture a “Service Oriented Architecture” (SOA) approach is followed (for SOA principle e.g. Allen 2006, Bieberstein et al. 2006, Durst/ Daun 2007, Dietzsch/ Götz 2005, Marks/ Bell 2006, Pulier/ Taylor 2005, Schönherr 2004). Basically, IT-architecture can be always seen as providing services to the business e.g. an application supporting a business process, office and communication services at the workplace supporting each individual employee. Taking these perspective puts the value adds of IT in the focus. Consequently the building blocks of the architecture framework are structured in service groups, core services, and service modules.
For the design of architectures in the large an aggregated view on architecture is required which goes beyond the semantics of modeling techniques like UML, thus a notation specific for the purpose of architecture design has been developed. Furthermore, different architecture domains are to be integrated and the models are to be understood by various stakeholders with diversified background (see the ArchiMate approach for integration of models in Arbab et al. 2007). Figure 4 gives an extract of the notation of the essential elements.

**A Service Module** is the smallest service offering unit. It is defined by price, quality and functionality. Several Service Modules may be bundled and offered as a Shared Service.

**A System and Sub-System** is the functional grouping of components into a hierarchical structure. The highest level of the structure is always a System.

**Components** are the building blocks of a Service Module. A Component is a logical unit described with a defined distinct set of functions. Several Components can appear as one physical unit (e.g. web application, database and storage on one server).

**An Organizational Component** defines Governance, Responsible and Operator of a Site. Governance is defining the rules, Responsible has to ensure adherence to the rules and the Operator is implementing the rules.

**Element for grouping Systems for two purposes:**
- Systems to be assigned an Organizational Component
- Systems at a specific geographic location

**Figure 4: Notation for architecture views (extract)**

In the following we use the example of an Email Service to demonstrate the description of this service using the three views. It is not only to show how these views describe the Email Service in all its aspects but also to outline the features of these views in light of architecture description. An Email Service is a basic service (see framework definition in section 1). It is composed of client -, server -, and storage components, like the Email client system; internet mail server, internet ip-addressing (DNS), Siemens corporate directory (SCD), Virus competence center (VCC), public key infrastructure (PKI), security, local mail service, mail transfer server (MTA proxy and firewall), and the lifetime email system (LTE) at the server and with the LTE repository at the storage side. All are constituents of the Email Service. The three views describe all relevant properties of that Service, each with a specific viewpoint.

**Figure 5: Component view (example Email Service)**
The communication view describes the interaction between the service modules, systems, and components of the Email Service. The diagram is segmented in the communication areas Internet, Extranet, Intranet, Campus and Data Center LAN.

The distribution view describes the allocation of service modules, systems, or components in terms of geographical or organizational distribution. Like the component view, the distribution view is divided into three major parts. However, the distribution view is divided horizontally rather than vertically. The segmentation of the diagram follows the company’s organization in corporate, group, and region. In addition organizational responsibility of a site is assigned in the categories Governance (defining the rules), Responsible (to ensure adherence to the rules), and Operator (implementing the rules). Note that the horizontal distribution in the example diagram is due the organization set up in focus, it would look different for any other organization. However, the principal layout of the proposed distribution diagram is similar.
The Email Service example illustrated the use of the three views for infrastructure architecture. The same principles for the design of the views are applied for applications architecture using the respective building blocks for the segmentation of diagrams. The views can be used at any level of detail for the decomposition of the chosen part of architecture (building block, service module, system). The combination of the architecture descriptions derived can be used for an integration of architecture in the large and in the small. Furthermore, since the views for components, communication or distribution highlight the key architecture elements, their relationship and interfaces they facilitate the identification of pattern in order to establish standards for the design of architecture.

Dependencies of architecture building blocks

Enterprise Architecture is more than the collection of the constituent architectures. The inter-relationships among these architectures, and their joint properties, are essential to the enterprise architecture. Thus, the architecture domains should not be approached in isolation. Key element of architecture design is to account for interdependencies among the building blocks of architecture. Blueprints are introduced as a means in planning the deployment of architecture on a large scale. Blueprints give a comprehensive view on the building blocks and how the interact. They show the effects of architecture design between business, application, and infrastructure architecture.

In the focus of enterprise architectures is the alignment of business and IT. In other words, the design of the business architecture determines the IT architecture which has to support and enable business. The building blocks of business architecture with the process architecture as the core define the frame for the design of the IT landscape. The dependencies between the different architectures can be described in blueprints. A blueprint is a plan which describes the deployment of an architecture building block across the enterprise. It pictures the landscape of this building block in a matrix of two business dimensions. The Figure 8 illustrates the derivation of main IT blueprints from the organization and process architecture.

The application landscape describes for each business process how it is supported by applications. The second dimension shows the deployment in organizational units, like divisions, business segment etc. The data repository landscape describes the deployment with databases and how the support defined information clusters of the information architecture. The second dimension shows the deployment of the databases in organizational units. The service landscape shows the deployment of infrastructure services and the support of applications. The second dimension shows the deployment in organizational units.

Figure 8: Main blueprints for IT architecture development
In general, different types of blueprints can be generated depending which dependency of business -, applications -, and IT infrastructure architecture or building block is in focus. Also, the matrix dimensions can be chosen in different level of detail, although the experience in architecture projects shows that a high level is sufficient in order to derive decisions for architecture development. Generating to detailed blueprints involves a lot of resources and time without enriching the decision base in the same degree. The three blueprints introduced provide a good information base for management decisions. Figure 9 gives an example of an application landscape.

A blueprint describes the deployment of an architecture building block across the enterprise (for alternative layout, e.g. Arbab 2007 et al., p. 49f., Dern 2006, p. 71f., Krcmar 2005, p. 197, Lankes et al. 2005 or the Business Systems Planning, IBM 1982). Lankes et al. take a comparable approach in applying the discipline of cartography to the description and design of application landscapes in order to picture a number of information systems.

Application blueprints are in the main focus in order to show IT support for business. It pictures the application landscape in a matrix of two business dimensions. The application blueprint describes for each business process how it is supported by applications. The figure 9 gives a simplified, illustrative example. The applications in use are mapped to the company’s business processes. The second dimension shows the deployment in organizational units, like divisions, business segments etc.

![Figure 9: Principal layout of an application blueprint](image)

In a number of projects blueprints have been proven to give a transparent overview on the application landscape and are a sound basis to derive architecture decisions. At a glance one can see processes not supported by applications or redundancies where more than one application is in place for a process. Blue prints are used for presentation of “as is” as well as target architecture.

**Organisation and Stakeholders in Architecture Management**

The development of architectures is complex and extensive. It involves a number of participants with different professional background. Figure 10 outlines the main stakeholders involved in an enterprise architecture management. It shows their basic roles and usage of architecture design techniques (see Dern 2006, p. 108f., Meta Group 2002, p. 69f., 205f., 333f., TOGAF 2006).
An anchor point on the line of a particular role shows the usage of the marked technique. The size of the technique outlines the use across the three architecture domains. In addition to the techniques discussed in the prior chapter, methods for IT strategy definition and implementation are included in this overview due to the fact that this is the major reference for architecture development.

The stakeholders like CEO/CFO; CIO, IT strategy planer, and program manager are involved in the business/IT strategy and decisions for direction, objectives of architecture, and IT program. They merely use methods of business IT alignment, IT impact, portfolio techniques and blueprints. Architecture principle and pattern are partly used.

The core is the architecture team led by an architect at enterprise level. The team is composed of architects of all architecture domains (Meta Group 2002, p. 69f., recommends not to exceed 8 persons TOGAF 2006 recommends about 5-10 max.). Additional teams are set up for diverse architecture domains. These teams drive the overall process, create and maintain deliverables and oversee all infrastructure projects. They develop an architecture requirements definition and other key artefacts and present it to the steering committee and architecture review board for approval.

The central role plays the enterprise architect who leads the architecture development and coordinates all respective activities. He is responsible for as is/ target-architectures and dependencies among architectures. In addition, there are other domain related architects involved. Responsibility of architects can be on diverse domains ranging from system to enterprise architecture. Architects use the entire range of techniques with different levels of detail depending on their respective domain.

Process owners focus on blueprints which show how processes are supported by applications and services. Principles and patterns for business architecture are also used.
System owners and system developers use component-, communication-, and distribution diagrams with focus at system level. Defined principles and pattern are basis for their work.

The respective techniques are used differently by the stakeholders depending on the respective scope of work. The alternate ways of architecture description are an important means of communication among the stakeholders involved in the architecture development process and the alignment of business and IT.

**SUMMARY AND OUTLOOK**

This paper addressed the design of enterprise architectures. The first section introduced a comprehensive architecture framework which classifies the basic domains and building blocks of enterprise architecture. It is used as reference for the constituents of enterprise architecture. Furthermore the principal techniques for architecture design were outlined using views and blueprints to show the interdependencies of architecture. The projected method for architecture design consolidates the modeling of enterprise architectures to a few essential and ample techniques. They provide adequate means for architecture description and a sound basis for communication and decision making.

However, architecture development is very much management and communication among the different parties involved and not only technical construction. Based on the projected method for architecture design the main stakeholders from the business as well as IT side and their respective usage of the design techniques are explained. The enterprise architecture approach aligns business and IT. In a number of projects the design techniques presented proved to be capable to advance the communication and architecture design of the different parties involved in architecture development.

The techniques introduced are embedded in a well defined architecture development process. Architecture management and process are fundamental for a business oriented, sustainable development of enterprise architecture. Project experiences in this area will be addressed in a separate paper. Future work will enhance the project experiences and findings to a set of guidelines for architecture management and governance. This will be added with methods to measure enterprise architecture success and an architecture management maturity model.

**REFERENCES**


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